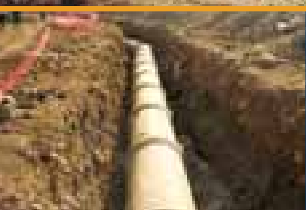
Water in the Arab World

Management Perspectives and Innovations



N. VIJAY JAGANNATHAN

AHMED SHAWKY MOHAMED

ALEXANDER KREMER

Editors

MIDDLE EAST AND NORTH AFRICA REGION

THE WORLD BANK

Water in the Arab World:

MANAGEMENT PERSPECTIVES AND INNOVATIONS

N. Vijay Jagannathan
Ahmed Shawky Mohamed
Alexander Kremer

Editors

MIDDLE EAST AND NORTH AFRICA REGION
THE WORLD BANK

Middle East and North Africa (MNA) Region
1818 H St., NW
Washington, DC 20433

Cover photographs: World Bank MNSSD staff, clients, and consultants.

Book design and typesetting: The Word Express.

Contents

Boxes

Figures

Tables

Preface

This volume is intended to serve as a water handbook. It represents the collective knowledge about water resources management acquired over recent years, both within the World Bank water team and with counterparts working in the Arab countries of North Africa and the Middle East (MNA).

The chapters offer a cornucopia of ideas and themes. Some chapters are based on background papers prepared for the 2007 "MNA Development Report on Water." Others draw on sector work prepared at the request of client countries. Yet others summarize observations based on study tours or other learning events sponsored by the World Bank.

Upon reviewing this lodestone of embedded knowledge, we realized that bringing together our observations and analyses could serve a useful purpose for public officials, other practitioners, academics, and students who are interested in learning more about the complexities of managing water resources management in one of the driest parts of the world.

N. Vijay Jagannathan
Ahmed Shawky Mohamed
Alexander Kremer

Acknowledgments

This book is the collective effort of the water team of the Middle East and North Africa (MNA) Region of the World Bank, which consists of staff members and consultants working on water issues in most countries of the Arab world and the Islamic Republic of Iran. The core team consisted of the three editors, N. Vijay Jagannathan (Sector Manager, Water), Ahmed Shawky Mohamed (Senior Water Resources Specialist), and Alexander Kremer (Senior Sector Economist), as well as Alicia Hetzner (Language Editor), and Georgine Seydi (Program Assistant).

Our debt of gratitude extends to a long list of colleagues in the MNA water team who have contributed chapters, often toiling long beyond their working hours and facing impossible deadlines imposed by the substance editors. Among the several consultants who have contributed, Chris Perry—who came up with the ABCDE approach, the organizing framework for the book's chapters—is gratefully acknowledged.

The team would like to express appreciation for the guidance and support received from three colleagues in the World Bank: Nadereh Chamlou and Omer Karasapan, who gave us helpful advice; and Juan Diego Rodriguez, whose support made the production of this book possible. In addition, the two peer reviewers, Shawki Barghouti (Director General of the International Center for Biosaline Agriculture, Dubai) and Rory O'Sullivan (Consultant to the Bank's working group on Embedded Knowledge), spent hours plowing through hundreds of pages of the various papers and giving very insightful comments and guidance to the team.

Finally, the team would like to thank Laszlo Lovei, Director of the Middle East and North Africa Sustainable Development Department, for his unwavering support and confidence, without which this enterprise could never have been completed in the timeframe required; and Nadir Mohammed, Operations Director of the MNA Region, for his encouragement to include this volume as a contribution to the region's Arab World Initiative.

The MNA Region gratefully acknowledges the generous cofinancing of this work by the Dutch government via the Bank-Netherlands Water Partnership Program (BNWPP).

Acronyms and Abbreviations

AA	Administrative Agencies
ABCDE	Assessment, Bargaining, Codification, Delegation, and Engineering
ABR	Anaerobic baffled reactors
ACAP	Anti-Corruption Action Plan
AFD	Agence Française de Développement
AGOSD	Alexandria General Organization for Sanitary Drainage
AM0020	Approved Monitoring Methodology, "Monitoring Methodology for Water Pumping Efficiency Improvements"
APFAMGS	Andhra Pradesh Farmer-Managed Groundwater Systems Project (FAO-India)
APWELL	Andhra Pradesh Ground Water Irrigation Schemes (FAO-India)
ASCE	American Society of Civil Engineers
AUEA	Associations des Usagers des Eaux Agricoles (WUA)
AWC	Arab Water Council
AWGA	Alexandria Water General Authority
AWI	Arab World Initiative
BAU	Business as usual
BC	Branch canal
BCM	Billion cubic meters
BCWUA	Branch canal water user association
BIA	Benefit Incidence Assessment
BOD	Biological oxygen demand
BOO	Build-Operate-Own

BOT	Build-Operate-Transfer
C/D	Codification and delegation
CAP	Compliance Action Plan
CAS	Country assistance strategy
CBA	Cost-benefit analysis
CBA	Catch Basin Authority (Morocco); cost-benefit analysis
CBO	Community-based organization
CDA	Community development association
CER	Certified Emissions Reduction (CDM)
CF	Conversion factor
CLEQM	Central Laboratory for Environment Quality Monitoring (Egypt)
CMD	Clean development mechanism
COCA	Central Organization for Control and Auditing
CPA	CDM Program Activity Design Document
CPA	Coalition Provisional Authority
CRDA	Regional Center for Agriculture Development (Tunisia)
CSO	Civil society organization
CWMP	Community Water Management Project (Yemen)
DBL	Design-Build-Lease
DBO	Design-Build-Operate
DEM	Digital elevation maps
DEP	Department of Environmental Protection (New York City)
DG GREE	General Department of Agricultural Engineering and Water/*Direction Générale du Génie Rural et de l'Exploitation des Eaux*
DGRE	Director General of Water Resources (Tunisia)
DH	Dirham
DIR	Detailed Implementation Review (WB INT)
DNA	Designated Operational Entity
DO	Dissolved oxygen
DWB	District Water Board
EC	Electrical conductivity
ED	Electrodialysis
EEAA	Egyptian Environmental Affairs Agency
EMWIS	Euro-Mediterranean Information System on Know-How in the Water Sector (EU)
EPA	US Environmental Protection Agency

EPADP	Egyptian Public Authority for Drainage Projects
EQO	Environmental Quality Objective
ER	Emissions reduction
ERR	Economic rate of return
ESRI	Environmental Services Research Institute
ET	Evapotranspiration
FARMOD	Software developed by FAO and WB to evaluate agricultural projects
FAS	Foreign Agricultural Service (USDA)
FDC	Farmer Design Committee
FO	Farmer Organization
G.E.O.R.E.	Optimal Water Resource Management Project (Tunisia)
GAC	Governance and corruption
GAFRD	General Authority of Fish Resources Development (Egypt)
GAP	Good Agricultural Practices (certificate)
GAPWSD	General Authority for Potable Water and Sanitary Drainage (Egypt)
GARPAD	General Authority for Rehabilitation Projects and Agricultural Development (Egypt)
GARWSP	General Authority for Rural Water Supply Projects (Yemen)
GDA	Agricultural development group
GFI	Government financial institution
GHG	Greenhouse gas
GIC	Communal interest groups (Tunisia)
GIS	Geographic information system
GLDAS	Global Land Data Assimilation System
GOE	Government of Egypt
GOFI	General Organization for Industrialization (Egypt)
GOGCWS	General Organization for Greater Cairo Water Supply
GOI	Government of Indonesia
GOSDC	General Organization for Sanitary Drainage in Cairo
GOY	Government of Yemen
GPOBA	Global Partnership on Output-Based Aid
GSCP	Groundwater and Soil Conservation Project (Yemen)
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit
GWh	Gigawatt hour

GW-MATE	Groundwater Management Advisory Team
ha	Hectare(s)
HMSO	Her Majesty's Stationery Office
HRU	Hydrologic response unit
IC	Irrigation Council
ICID	International Commission on Irrigation and Drainage
ID	Irrigation Department (Egypt)
IDRA	Institute for Development Research and Alternatives
IFI	International financial institution
IIIMP	Integrated Irrigation Improvement and Management Project
IIP	Irrigation Improvement Project
IIS	Irrigation Improvement Sector
IMT	Irrigation Management Transfer (Egypt)
INDH	National Initiative for Human Development/*Initiative Nationale de Développement Humain*
INS	National Statistical Institute/*Institut National de la Statistique* (Tunisia)
INT	Department of Institutional Integrity (WB)
IPCC	International Panel on Climate Change
IPTRID	International Programme for Technology and Research in Irrigation and Drainage
IRR	Internal rate of return
IWMD	Integrated Water Resources Management District
IWMI	International Water Management Institute
IWRM	Integrated Water Resources Management
KfW	Kreditanstalt für Wiederaufbau Entwicklungsbank (German development bank)
KRG	Ministry of Municipalities of the Kurdistan Regional Government
KWH or Kw/h	Kilowatt hour
l/s	Liter/second
LE	Egyptian pound/*livre égyptienne*
LGU	Local Government Unit
LLL	Laser land-leveling
LWCP	Land and Water Conservation Project (Yemen)
LWUA	Local Water Utilities Administration
M&E	Monitoring and evaluation
m^3	Cubic meter

m^3/s	Cubic meters per second
MAD	Moroccan currency
MAI	Ministry of Agriculture and Irrigation (Yemen)
MALR	Ministry of Agriculture and Land Reclamation (Egypt)
MAR	Managed Aquifer Recharge
MARH	Ministry of Agriculture and Water Resources/*Ministère de l'Agriculture et des Ressources Hydrauliques* (Tunisia)
MDG	Millennium Development Goal
MEB	Multi-effect boiling
MED	Multi-effect distillation; Mechanical and Electrical Department (Egypt)
METRIC	Mapping Evapo-Transpiration with High Resolution and Internalized Calibration
MEW	Ministry of Electricity and Water (Yemen)
MHUNC	Ministry of Housing, Utilities and New Communities (Egypt)
MIAC	Ministry of Internal Affairs and Communication
MIS	Management Information System
Mm^3	Million cubic meters
MMPW	Ministry of Municipalities and Public Works (Iraq)
MNA	Middle East and North Africa Region
MNSRE	Middle East and North Africa Rural Development, Water and Environment
MOB	Mayoralty of Baghdad
MoEE	Ministry of Electricity and Energy (Egypt)
MoHP	Ministry of Health and Population (Egypt)
MoI	Ministry of Industry (Egypt)
MoLD	Ministry of Local Development (Egypt)
MoSEA	Ministry of State for Environmental Affairs (Egypt)
MoT	Ministry of Transport (Egypt)
MPN	Most probable number
MSF	Multi-Stage Flash
MTEF	Medium-term expenditure framework
Mw	Megawatt
MWE	Ministry of Water and Environment (Yemen)
MWRI	Ministry of Water Resources and Irrigation (Egypt)
NASA	National Aeronautics and Space Administration (US)
NDS	National Development Strategy
NIA	National Irrigation Administration (Egypt)
NIB	National Investment Bank

NOPWASD	National Organization for Potable Water and Sanitary Drainage (Egypt)
NRW	Nonrevenue water
NWRA	National Water Resources Authority (Yemen)
NWRC	National Water Research Center (Egypt)
NWSSIP	National Water Sector Strategy and Investment Program (Yemen)
O&M	Operation and maintenance
OBA	Output-based aid
ONAS	National Sanitation Agency
ONEP	National Water Supply Company/*Office National de l'Eau Potable* (Morocco)
ORMVA	Regional irrigation and agricultural development agencies/*Offices régionaux de mise en valeur agricole (du Maroc)*
PAD	Project appraisal document
PAGER	National Program for Rural Water Supply and Sanitation (Morocco)
PDO	Project development objective
PER	Public expenditure review
PERSIANN	Precipitation Estimation for Remotely Sensed Information Using Artificial Neural Networks
PES	Payment for environmental services
PIM	Participatory Irrigation Management
PISEAU	Water Investment Program (Tunisia)
PIU	Project implementation unit
PMU	Project management unit
PNEEI	National Program of Irrigation Water Conservation
PoA DD	Program of Activities Design Document (CDM)
PPE	*Participation au Premier Etablissement*
PPI	Public irrigation scheme
PPIAF	Public-Private Infrastructure Advisory Facility
PPIIGB	[public land irrigated by large dams] (Tunisia)
Ppm	Parts per million
PPP	Public-private partnership
PSIA	Poverty and Social Impact Assessment
PVC	Polyvinyl chloride
PWP	Public Works Project (Yemen)
RES	Renewable energy source
Rg	Overall network yield

RO	Reverse osmosis; Regulatory Office (West Delta Project, Egypt)
RS	Remote sensing
RSU	Rural Sanitation Unit
RTA	River Transport Authority (Egypt)
RWS	Rural water supply
SA	Services Agencies
SAD	Decision support system (Spain)
SAIH	*Sistema Automatico de Informacion Hidrologica*
SBWMP	Sana'a Basin Water Management Project
SCADA	Supervisory Control and Data Acquisition (Spain)
SCRB	Separable Costs Remaining Benefits
SEBAL	Surface Energy Balance Algorithm of Land
SEI	Stockholm Environment Institute
SEMIDE	See EMWIS
SFD	Social Fund for Development (Yemen)
SINEAU	*Système d'Information National des Ressources en Eau* (Tunisia)
SME	Small and medium enterprise
SNACC	Supreme National Agency for the Control of Corruption
SOAS	School of Oriental and African Studies
SONODE	National Authority for Water Exploitation and Distribution
SRU	Strategic Research Unit (Egypt)
SS	Suspended solid
SWAT	Soil and Water Assessment Tool
SWCC	Saline Water Conversion Corporation (Saudi Arabia)
SWERI	Soils, Water and Environment Research Institute (MALR, Egypt)
TA	Technical assistance
TAP	Transparency, Accountability, and Participation Framework
TDS	Total dissolved solids
TTL	Task team leader
UFW	Unaccounted-for-water
UNEP	United Nations Environment Programme
USDA	US Department of Agriculture
VC	Vapor compression
VES	Plant entry volume

VSA	Conveyance plant volume
VSB	Cities Without Slums/*Ville Sans Bidonville*
VSM	Volume of briny water
VSS	Service plant volume
w.r.t.	With respect to
WAJ	Water Authority of Jordan
WASAMED	Water Saving in Mediterranean Agriculture
WB	World Bank
WBI	World Bank Institute
WEAP	Water Evaluation and Planning System
WES	Water and Environmental Sanitation Program (UNICEF)
WQM	Water quality management
WRM	Water resource management
WSS	Water supply and sanitation
WSSP	Water Sector Support Programme (Yemen)
WTP	Willingness to pay
WUA	Water user association
WUG	Water user group

1

Introduction: Beyond WRM—Unbundling Water Management in MNA Countries

N. Vijay Jagannathan, Ahmed Shawky Mohamed, and Christopher J. Perry

Over the past two decades, water management in the MNA countries has been strongly influenced by the idea of integrated water resource management (IWRM). This process advocated new approaches for the assessment, management, and development of freshwater resources.

IWRM processes attempt to provide holistic solutions to water issues. They depend on the commitment of governments and communities to adopt new approaches and back them by "substantial and immediate investments, public awareness campaigns, technology development, capacity building programs, and legislative and institutional changes" (Salman 2006).

In the MNA context, IWRM is particularly vital because hydraulic infrastructure plays such a critical economic role. These countries are in either the arid or hyper-arid zone, depend on seasonal rainfall, have very few rivers—some of which carry runoff from other countries—and often rely on fragile (and sometimes nonrenewable) aquifers. Consequently, their economies are much more sensitive to the way that water is extracted, conveyed, and consumed than are the economies of other regions.

Frederiksen (2005) distinguishes between *resource stewardship* (which is always a function of government, exercised on behalf of the nation) and *service provision* (which may be public, private, or cooperative). Once water resources are scarce and the possibility arises that one use affects another, the stewardship function must set some of the boundaries for service provision to protect the interests of *all* users.[1] If

[1] The same point, although described for just the water supply and sanitation sector, is made by World Bank 2004.

these institutional processes are inadequate or arbitrary, the outcome will not be optimal; but rather, one of wasted public finances, conflicts, and unproductive water use.

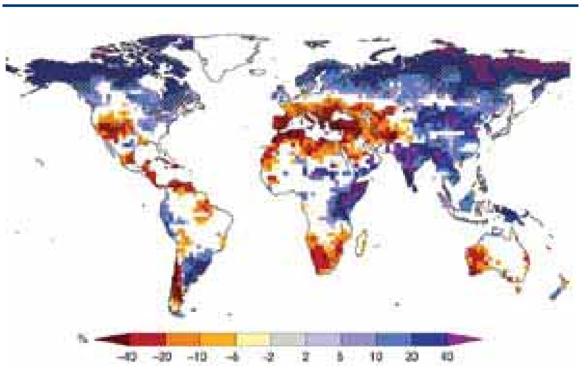
New Concern: Climate Change

Looking ahead, climate change poses additional challenges for IWRM:

> "Water managers have long dealt with changing demands for water resources. To date, water managers have typically assumed that the natural resource base is reasonably constant over the medium term and, therefore, that past hydrological experience provides a good guide to future conditions. Climate change challenges these conventional assumptions and may alter the reliability of water management systems."
>
> —*Bates and others, Intergovernmental Panel on Climate Change, 2008, 48*

This stark statement applies nowhere more forcefully than in the MNA countries. While average rainfall worldwide is anticipated to increase marginally, for the MNA region, the picture is quite different. For North Africa and the Middle East region over the next century, the 2008 IPCC report anticipates declining rainfall (–10 percent to –25 percent); declining soils moisture (–5 percent to –10 percent), declining runoff (–10 percent to –40 percent), and increasing evaporation (+5 percent to +20 percent) (IPCC, figure 2.8; ranges are indicative, interpreted from figures in text).

Figure 1.1 Large-Scale Relative Changes in Annual Runoff for 2090–99, Relative to 1980–99



Sources: Milly and others 2005; IPCC 2008.
Notes: White areas: Less than 66% of the ensemble of 12 models agree on the sign of change. Hatched areas: More than 90% of models agree on the sign of change .

Figure 1.1 reproduces figure 2.10 of the IPCC report, showing the details for runoff.

The key IPCC messages for MNA are the high incidence of reduced flows; severity of the projected declines in rainfall; higher temperatures; and agreement (indicated by hatching in figure 1.1) of the vast majority of models on the negative direction of change. These changes will create a new and more difficult context for water management. They further elevate the significance of the stewardship function of current generations of water managers for the future generations of water users for two reasons:

1. The future is likely to experience more competition and conflict among countries, sectors, communities, and individuals over water. The farmer lobby likely will demand more water, arguing that crop needs increase with temperature and rainfall variability. Urban water utilities will demand more water to meet the needs of growing, more prosperous populations. Finally, increased environmental flows will continue to be necessary for rivers and streams to maintain and regenerate themselves. At either the subregional or regional level, finding solutions to move water from one location to another (as from sparsely populated irrigated areas to growing cities, or from a municipal treatment plant to a water-stressed agricultural region for reuse) will meet stiff political and social resistance.[2] At the macro and international levels, crafting politically acceptable policies that set in motion the required adjustments among all the affected stakeholders will require institutional mechanisms that mitigate conflicts and enhance a culture of benefit-sharing.[3] Under these circumstances, policymakers are faced with the challenge to craft policy instruments that balance sustainable water management against the various political and social conflicts, while learning what is working and what is not working in existing programs and policies.
2. Agriculture (which utilizes 80 percent–90 percent of water in most MNA countries)[4] will not enjoy guaranteed water supply at past historical quantities. If there is increased variability in rainfall (as has been experienced in southeast Australia in the Murray-Darling Basin), increased requirements for municipal and industrial use will cut into agriculture's water share.[5] Farmers perforce will have to change water usage patterns at a time when plant water requirements

[2] "Subregional level" refers to aquifers and river basins within a country. "Regional level" refers to watercourses that are shared between two or more countries.

[3] See Sadoff and others (2008) for a description of how benefit-sharing concepts have led to greater cooperation among Nile riparian countries.

[4] Share of different subsectors' water consumption in the MNA countries is available in the "MNA Development Report on Water" (World Bank 2007).

[5] Personal communication from Professor Michael Young, who has been advising the water regulators of the Murray Darling Basin on how to regulate and manage these difficult trade-offs.

are increasing. For areas that already are operating with far less water than is required, changing water use patterns will make management more difficult. For areas whose supplies currently are adequate (most of Egypt, for example), the entirely new challenge of managing alternating abundance and scarcity will arise.[6] Country- or region-specific strategies for agricultural water management will need to be developed that focus on agricultural income productivity per unit of water, rather than per unit of land.[7]

In brief, IWRM approaches so far have advocated a holistic "think integrated," but "act disintegrated" approach to water management. In contrast, the forthcoming challenge—due to climate change—will be to also manage the social, political, and institutional processes of balancing the water use interests of present generations vs. future generations.[8]

What do these trends imply for IWRM programs in MNA countries? This volume argues that one needs to look beyond IWRM processes to learn more about the key actions that need to be taken on the institutional, economic, and technological fronts.

Are the Arab Countries Well-Positioned to Face These New Challenges?

Most countries in the MNA region face challenges on both fronts, with regard to both managing water resources in a sustainable manner and ensuring affordable and reliable water service delivery to farmers, households, and industries.

- In the case of water resource management, mechanisms for allocating water among countries and among sectors within countries need to focus on generating sustainable outcomes. The outcomes

[6] IPCC estimates suggest that, with higher rainfall in the catchment areas of the Nile River, the inflows into Lake Nasser-Nubia are likely to increase, leading to larger spillovers into the Toshka depression because of capacity constraints in this massive reservoir. Meanwhile, downstream in lower Egypt, municipal and industrial uses will continue to cut into the agricultural water share. The abundance of water is in an area of hyperaridity and very low population density (Toshka), whereas the scarcity of water is in the area of very high population density (Nile Delta).

[7] The good news is that recent developments in technology have the potential to enable this shift in measurement. See chapters by Bekele and others and Perry and Bucknall.

[8] See Briscoe and Malik 2007.

must be sustainable in both their social/political aspects (that is, minimizing prolonged conflicts among competing users), and the environmental aspect (that is, soundly managing aquifers to avoid groundwater depletion, and maintaining instream water quality in rivers and lakes).

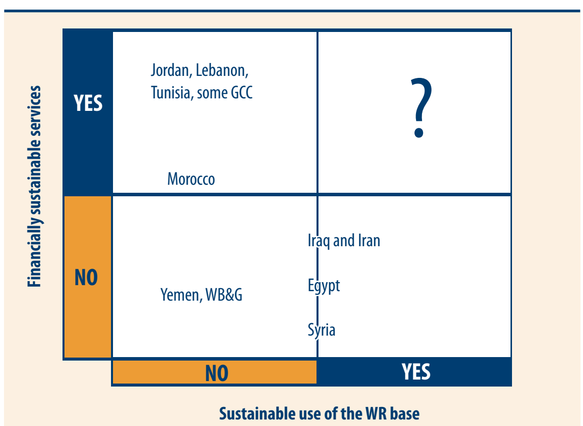
- Regarding water service delivery, responding to user demand is a continuous challenge that will be exacerbated by climate change. In addition, several countries in the region have a vicious circle of poor service delivery exacerbated by high operations and maintenance (O&M) costs, low end-user tariffs, the resultant tendency to "back-load" or defer maintenance, and, consequently, poor services.

In summary, water management in general has suffered from poor accountability (both external to service users and internal within resource management and service delivery organizations). More and more investments are being required to remedy the deferred maintenance of already installed hydraulic infrastructure in the region (World Bank 2007).

Figure 1.2 represents four possible outcomes. The vertical axis classifies two situations: (1) one in which the financial sustainability of irrigation and water supply services has been achieved by recovering O&M costs from service users, and (2) the other in which there is inadequate cost recovery. The horizontal axis classifies countries in two categories: according to whether they have or have not been able to sustainably manage the water resource base. It describes their success in achieving the stewardship function. Predictably, countries with sources of renewable surface water (such as large rivers) do relatively better in water resource management compared to countries that depend wholly on groundwater, which is easier to over-exploit, and more difficult to control.

Of the four possible outcomes, conceptually only one (the upper right box) will lead to sustainable outcomes, or the IWRM ideals. In the other three boxes, failures in policy, or in the

Figure 1.2 Conceptual Framework to Explain Ideal IWRM Outcomes



Box 1.1 What a Water Steward Should Monitor

To avoid the obvious confusion that arises when improved efficiency in one sector *increases* the water available for other uses, while improved efficiency in another sector *decreases* the availability for other uses, the following terminology was recently adopted by the International Commission on Irrigation and Drainage (Perry 2007):

Consumed fraction (evaporation and transpiration) comprising

- Beneficial consumption, consisting of water evaporated or transpired for the intended purpose—for example, evaporation from a cooling tower, transpiration from an irrigated crop.
- Nonbeneficial consumption, consisting of water evaporated or transpired for purposes other than the intended use—for example, evaporation from water surfaces, weeds, moist or waterlogged land.

Nonconsumed fraction, comprising

- Recoverable fraction, consisting of water that can be captured and reused—for example, flows to drains that return to the river system and percolation from irrigated fields to aquifers; return flows from sewage systems.
- Nonrecoverable fraction, consisting of water that is lost to further use—for example, flows of brine from a desalination plant.

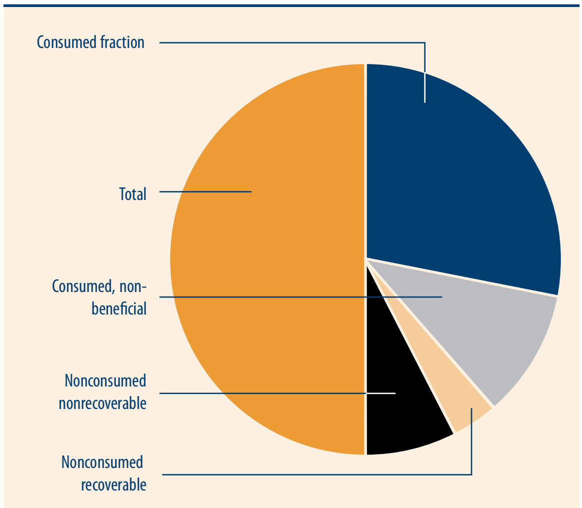
implementation of policy, result in countries falling short of the IWRM ideals.

The two axes of this diagram (finance, and water) present the two key facets of IWRM. The vertical axis describes to what degree a country is managing its water in a financially sustainable manner. The rules for financial accounting are known and proven—there is no debate about what constitutes a payment, a receipt, a stock, and a flow. There is an economic and political trade-off between spending $1 toward construction of an urban water supply system vs. spending $1 on an irrigation system. Once the system is constructed, unless costs of investments, operations, and maintenance can be recovered from the users, the contingent liability in the Ministry of Finance will increase rapidly.[9]

[9] Countries have major variations in cost recovery policies, with consequences for benefit incidence. See Shawky chapter on "Benefit Incidence Analysis in Egypt's Water Resources and Irrigation Sector."

The horizontal axis describes how far a country is managing its water in an environmentally sustainable manner. This aspect is more complex in terms of monitoring and building up remedial actions. For example, when a cubic meter of water allocated to an urban water supply system goes to a household, most of this water is released back to the water system as wastewater. If the latter is collected and treated (requiring capital-intensive investments, of course), the receiving water body is able to regenerate itself in both quantity and quality. In contrast, a cubic meter of water delivered to an irrigation project will largely be consumed— through transpiration by crops and evaporation. The remaining part of the original diverted water is returned to the hydrological system.

Figure 1.3 Water Consumptive Uses and Losses



Urban water supply systems serve primarily *nonconsumptive* users, while the whole purpose of an irrigation system is to increase crop water *consumption*. "Using" water is thus not as unambiguous as "spending" money, because agriculture has both consumptive and nonconsumptive uses of water. The proportions of the two categories vary from region to region. Depending on agro-climatic conditions, the sustainability of the water resource base could be severely jeopardized by unproductive consumption by agriculture and by inadequate policy attention being paid to managing the recoverable, nonconsumed fraction.[10] Figure 1.3 shows these distinctions with illustrative data. In a dry region such as MNA, minimizing nonbeneficial consumption (such as evaporation from reservoirs, open canals) and optimizing the extraction

[10] Definitions: (a) *Water use* is water made available deliberately by rainfall or other natural means for an identified activity. The term does not distinguish between uses that remove water from further use (evaporation from wet soil or wetlands; transpiration from irrigated crops, forests) and uses that have little quantitative impact on water availability (navigation, hydropower, most domestic uses).

(b) *Withdrawal* is water abstracted from streams, groundwater, or storage for any use, comprising (1) groundwater sinks, deep aquifers that are not economically exploitable, or (2) flows to the sea.

of recoverable fractions (such as sewage flows and farm runoffs) clearly become key policy priorities of future stewardship.

Organizational Framework for the Contributions to This Volume

The volume is organized around the observation by Perry (2003, 2008, and forthcoming) that water management at a time of societal competition for the resource could be viewed in terms of five elements:[11]

1. That the water supply is known and accessible to the user groups—not necessarily precisely, but at least based on experience. Over time, and with experience, the users are able to *ASSESS the availability* of water and what institutional measures it would take to keep this availability in future years.
2. The users at each level have agreed on the principles for sharing water (for example, prioritized by use or shared in accordance with land-holding or contribution to the original development). This is a *BARGAINING* process.
3. The agreed principles for sharing are translated into operational rules that govern day-to-day distribution of water. This is a process of *CODIFICATION*.
4. Where necessary—particularly for larger schemes in which a number of farmer groups exist—intermediate responsibilities and arrangements for implementation are defined. This is *DELEGATION*.
5. Finally, delivering the service requires infrastructure—*ENGINEERING*.

Taking a historical example, the Egyptian irrigation system evolved over several millennia as riverine communities learned how to harness the annual floods to develop irrigated agriculture in an arid climate. Through collective action that involved defining individual and group roles and responsibilities, these communities constructed inundation canals, and later devised the *sakia*, or Persian wheel, to lift water to their fields. Similarly, in the coastal areas of Yemen, communities harnessed flash floods or spate flows from the highlands through an elaborate system of earthen dikes and irrigation structures to grow food and cash crops. Developing complex institutional rules that created

[11] The framework was adopted during a meeting in Abu Dhabi in July 2008 to consider the proposed Arab Water Academy as a hub for organizing research and training.

incentives to collaborate and constructing physical structures that provided irrigation water to groups and to farmers within groups were the two key features of Yemen's process. Obviously, another key element was the learning and feedback loop, through which institutions evolve and more hydraulic infrastructure gets augmented.

Where there was more than one level of management (as in Egypt's inundation systems, or among the spate structures of Yemen), the framework can be applied at both levels—first allocating the main supply among user-groups, then allocating the group supply among individuals.

Organizing this book around the ABCDE framework enables the reader to appreciate the *multifaceted nature of water management*. In other words, public, private, and individual actors all contribute to successful water resource management; a variety of technologies are useful; both written laws and customary practice are effective; and facilities may be collectively owned, or constructed and operated by government. Successful water resource management requires that all the ABCDE elements are in place and are mutually compatible. The key is not particular patterns of ownership, types of water rights, or irrigation technology, but rather that each component is compatible with the other parts. Because they are integrated, when any of these components is changed, there will be significant implications for other components.

Compatibility among the ABCDE components is a feature of traditional water management systems that are based on limited information but extensive experience, simple technologies, and predictability of natural events (floods, droughts, seasonal rainfalls). For example, the organization of spate irrigation in Yemen, *aflaj* in Oman, *qanat* in Iran, and *mesqas* in the Nile delta was based on the knowledge passed down from one generation to another of water stocks, flows, and seasonal variability. Bargaining within groups led to the internalization and institutionalization of behaviors within and among groups. Codification took place either informally through norms and conventions, or formally through Islamic jurisprudence. Certain rights and responsibilities were delegated among farmers, while others devolved to village leaders and sheikhs. Decisions on when and what to construct were based on a long process of community engagement that was fairly well grounded in terms of (1) awareness of water availability and constraints, (2) institutional rules that were accepted by community members, and (3) construction technologies familiar to communities.

Much of traditional water management has changed in the past 50 years. New technologies arrived that short-circuited traditional procedures for accessing and utilizing water. Financing options for lumpy investments changed relationships within communities and, more importantly, between communities and the state. In the latter situation, state agencies assumed the full responsibility for the assessment phase, as well as for codifying rules to access investment finances. In practical terms, the state appropriated the right to decide where and when to invest in hydraulic infrastructure and to whom to provide the resultant water services. Under these circumstances, bargaining processes that had centered on local, well-understood norms and conventions were supplanted by communities "receiving" irrigation and water supply services from large government-sponsored programs. The decline of informal norms and conventions led to examples of water capture by elites, particularly when energy subsidies gave wealthy landowners privileged access to powerful pumpsets. Overall, these capital-intensive investments substantially impacted delicate water balances, altered the flow of rivers, increased the pace of groundwater extraction, and aggravated competition among water users.

Observed Variants of the ABCDE Model

In this section, some observed "unbundled" practices are described in terms of the ABCDE framework.

Moving Straight from A to C

In this variant, assessment of water availability is based on historical data and onsite technical investigations by a state agency. Little attention is paid to water accounting (box 1.1). The state agencies usually assume that, because water is available at the proposed investment location, the water "surplus" can be used either without detriment, or with suitable compensation, to existing users. The state agency also makes no attempt to define a formal specification of a water entitlement. Under these circumstances, not enough attention gets paid to assessing what worked and what did not work in existing informal institutional arrangements. Codification is focused around financing rules, because the state typically finances the capital investments. However, it imposes weak conditionalities for cost recovery from users. Once funds are made available, engineering solutions are implemented.

Moving Straight from A to C and Then to D

In response to the weaknesses of the earlier approach, the codification process recognizes the need to delegate responsibilities with a modified set of rules that separates the public and private good aspects. The former are paid by the state; the latter are paid by water users who benefit from using the service. Concerning water resources, in the absence of a basin- (or aquifer-) level accounting framework, there is no certainty that water entitlements are consistent with overall availability.

Introducing B in the Process

Given today's climate change concerns, assessments of water availability based on past data are no longer reliable. For example, in Morocco's river basins, recent precipitation has been 30 percent–40 percent lower than the historical trends (although 2009 rainfall has been adequate). Irrigation infrastructure in the large-scale irrigation perimeters (ORMVAs, or regional irrigation and agricultural development agencies) was designed based on rainfall data of past decades. Thus, this infrastructure over-designed water conveyance networks and under-served the beneficiary farmers. Farmers respond to the lack of reliable surface water by investing in pumping groundwater, often in excess of safe yields. Under these uncertainties, A and B become immediate priorities. Assessments and feedback of the risks to water resources from accelerating climate change, financing constraints, and population shifts to cities require information and knowledge-sharing among all water stakeholders in the country. Different forms of bargaining and institutional arrangements ranging from informal contracts to tradable water rights become relevant policy options that need to be debated.

Organization of Chapters

The chapters of this book are organized to present MNA staff observations and analyses of various aspects of IWRM through 3 types of activities commissioned over the past 3 years:

1. First and most significant, the MNA Sustainable Development Department's economic and sector work (ESW) in Arab countries. This work was summarized in the 2007 "MNA Development Report on Water" and in other initiatives of individual team members.

2. Insights and analyses by the MNA water unit staff on specific country-oriented topics that could be of general interest in Arab countries.
3. Observations from study tours and project-level engagements by MNSSD staff.

The organizing principle for these chapters has been the ABCDE. Predictably, the *assessment* section has the largest and most diverse selection of chapters. They range from general themes such as governance and climate change to specific assessments of topics that offer useful learning and knowledge-sharing to the reader. The second (B) section illustrates the importance of *bargaining* among water stakeholders to reach sustainable solutions. The third section reviews the various "rules of the game"—both formal *codification* experiences in the region vis-à-vis water laws and specific financing rules that alter incentives for water service delivery. The fourth (D) section reports on specific country-level initiatives that have *delegated* water service responsibilities to the lowest appropriate level. The final section evaluates the emerging opportunities offered by innovative technologies that could be harnessed to meet the emerging water challenges.

Assessments of Water Availability and Water Management

A1. Bridging the Practice Gap in Water Management: Lessons from the "MNA Development Report on Water"	N. Vijay Jagannathan
A2. Egypt: Water Sector Public Expenditure Review	Ahmed Shawky Mohamed and N. Vijay Jagannathan
A3. Assessing the Efficiency and Equity of Water Subsidies: Spending Less for Better Services	Ahmed Shawky Mohamed, Alexander Kremer, and Manish Kumar
A4. Applications of Latest Technologies and Hydrological Models in Water Resource Management and Planning in MNA Region	Bekele Debele Negewo, Julia Bucknall, and Ahmed Shawky Mohamed
A5. Water Resource Assessment in the Arab World: New Analytical Tools for New Challenges	Christopher J. Perry and Julia Bucknall
A6. Egypt Case Study: Energy Efficiency CDM Program: Irrigation and Drainage Pumping Sector	Abdulhamid Azad
A7. Accountable Water and Sanitation Governance: Japan's Experience	Satoru Ueda and Mohammed Benouahi
A8. Tunisia's Experience in Water Resource Mobilization and Management	Mohamed El Hedi Louati and Julia Bucknall
A9. Lessons from the Rehabilitation of the Water Supply and Sanitation Sector in Post-War Iraq	Sana Agha Al Nimer
A10. Governance in Yemen's Water Sector: Lessons from the Design of an Anticorruption Action Plan	Maher Abu-Taleb and Richard Calkins

The first 10 chapters summarize the World Bank Middle East and North Africa Region (MNA) findings from *assessments* of key policy issues relating to water management in terms of the resource itself (both in terms of quantity and quality), financing, and implications for global public goods.

- The first chapter summarizes the lessons from the 2007 "MNA Development Report on Water."
- The second and third chapters describe the findings of a Public Expenditure Review (PER) on water in Egypt, and analyze who among the various stakeholders have benefitted from existing public expenditures on water.
- The fourth chapter describes how remote-sensing (RS) data and modeling techniques provide new tools for water planners and project managers.
- The fifth chapter looks at how irrigation management practices need to be changed to effectively respond to climate change predictions.
- The sixth chapter describes the new financing mechanisms made available to the irrigation sector in reaction to rising global concerns about climate.
- The seventh chapter presents the Japanese experience in benchmarking the performance of the water and sanitation service providers.
- The eighth chapter presents the case of inter-basin water transfers in Tunisia.
- The ninth chapter describes the lessons learned in Iraq toward reforming the water supply and sanitation sector after the war.
- The last chapter discusses new institutional arrangements in Yemen aimed at governance and anticorruption reforms.

Bargaining among Water Stakeholders

B1. Water Allocation Conflict Management: Case Study of Bitit, Morocco	Rachid Abdellaoui
B2. How Did a Small, Poor, and Remote Rural Village in Djibouti Recently Become a Government Priority to Receive Water Supply and Sanitation?	Sarah Houssein, with Julia Bucknall and Nathalie Abu-Ata
B3. Water Conflict in Yemen: The Case for Strengthening Local Resolution Mechanisms	Christopher Ward
B4. Water Diplomacy in the 21st Century	N. Vijay Jagannathan

The second group of chapters is devoted to *bargaining*, by which affected stakeholders are able to exercise voice and choice in decisions that relate to their water resources and water services.

- The first chapter discusses how bargaining and consequent trading of informal water rights have taken place in a Moroccan village.
- The second chapter describes how a poor community in Djibouti was able to exercise its voice with the government.
- The third chapter describes the role of tribal and local traditions in resolving conflicts over water in Yemen.
- The last chapter describes the emerging lessons for water diplomacy or bargaining among countries sharing watercourses.

Codification Experiences in MNA

C1. Comparative Analysis of Water Laws in MNA Countries	Jackson Morill and Jose Simas
C2. Subsidies for the Poor: An Innovative Output-Based Aid Approach Providing Basic Services to Poor Periurban Neighborhoods in Morocco	Xavier Chauvot de Beauchêne and Pier Mantovani
C3. Use of Output-Based Aid to Jumpstart a Rural Water Supply Service Market in Morocco	Xavier Chauvot de Beauchêne and Pier Mantovani
C4. New Approaches to Private Sector Participation in Irrigation: Lessons from Egypt's West Delta Project	Aldo Baietti and Safwat Abdel-Dayem

The third group of chapters is elucidates *codification* in the water sector.

- The first chapter describes the region's experience with formal codification through water laws and regulations.
- The next two chapters summarize an experience of targeting subsidies to poor households so that they are able to access safe drinking water with house connections in urban and rural areas in Morocco.
- The forth chapter describes a new set of project rules aimed at generating public-private partnerships in Egypt's irrigation sector.

Delegation to the Lowest Appropriate Level

D1. Participatory Irrigation Management and Cost-Sharing in Yemen	Naji Abu Hatim and Ahmed Shawky Mohamed
D 2. Community Management of Rural Water Supply: Evaluation of User Satisfaction in Yemen	Susmita Dasgupta, Craig Meisner, Andrew Makokha, and Richard Pollard

D3. Rural Sanitation within an IWRM Framework: Case Study of Application in the Delta Region, Egypt	Ayat Soliman, Ahmed Shawky Mohamed, Maged Hamed, Wendy Wakeman, and Mohammed Mehany
D4. Water Management in Spain: Highlights Relevant for MNA Countries	Ahmed Shawky Mohamed, Abdulhamid Azad, and Alexander Bakalian

The fourth group of chapters describes MNA staff experiences with *delegation* of services to the lowest appropriate level.

- The first chapter analyzes an interesting experience in participatory irrigation management and cost-sharing in Yemen.
- The second chapter evaluates user satisfaction with community-managed RWSS services in Yemeni villages.
- The third chapter discusses new planning approaches to rural sanitation in Egypt, incorporating both extending sanitation services and improving water quality in receiving bodies.
- The last chapter is a report based on a joint study tour to Spain by MNA water staff and counterparts. During this trip, they learned how that country implemented delegation to the lowest appropriate level in both aspects of water management: the resource itself and water supply, sanitation and irrigation services.

Engineering New Approaches

E1. Egypt: Irrigation Innovations in the Nile Delta	Jose Simas, Juan Morelli, and Hani El Sadani
E2. Water Reuse in the MNA Region: Constraints, Experiences, and Policy Recommendations	Claire Kfouri, Pier Mantovani, and Marc Jeuland
E3. Desalination Opportunities and Challenges in the Middle East and North Africa Region	Khairy Al-Jamal and Manuel Schiffler
E4. Enhancing the Socioeconomic Viability of Spate Irrigation through Conjunctive Use in Coastal Areas in Yemen: Case Study of Wadi Ahwar	Arjen de Vries and Tarun Ghawana. Supervised by Ahmed Shawky Mohamed

The fifth group discusses engineering aspects and comprises forward-looking studies of new water investment approaches.

- The first chapter presents a very interesting experience in Egypt, whereby engineers "right-sized" design standards with community participation.

- The next two chapters summarize the findings of World Bank MNA staff studies that evaluate the potentials of wastewater reuse and desalination, which, given climate change, are two important areas.
- The last chapter looks at the findings of a study on conjunctive use of spate irrigation and groundwater in the coastal areas of Yemen.

References

Bates, B., Z. Kundzewicz, S. Wu, and J. Palutikof. 2008. *Climate Change and Water.* Geneva: Intergovernmental Panel on Climate Change.

Briscoe, J., and R.P.S. Malik. 2007. *A Handbook for Water Resource Management in India*. New Delhi: Oxford University Press.

Delft Hydraulics. 1994. “A Framework for Water Resources Planning.” Research report. University of Delft. April.

Frederiksen, H.D.. 2005. “Addressing Water Crisis in Developing Countries.” *Journal of Environmental Engineering* (May): 667–75. American Society of Civil Engineers.

Milly, X, and others. 2005.

Perry, C.J. 2003. "Non-state Actors and Water Resources Development: An Economic Perspective." Non-State Actors and International Law 3: 103.

____. 2007. ?Efficient Irrigation; Inefficient Communication;

Flawed Recommendations.? Irrigation and Drainage 56: 367?78.

Wiley Interscience.

____. 2008. ?The ABCDE of Water Management.? Draft guidance note contribution to the draft paper for the Arab Water Academy courses.

____. Forthcoming. "River Basin Agreements as Facilitators of Development." In Water Issues in Southeast Asia: Present Trends and Future Directions, ed. L.P. Onn. Singapore: Institute of Southeast Asian Studies.

Sadoff, C., T. Greiber, M. Smith, and G. Bergkamp. 2008. *Share Managed Waters across Boundaries*. Geneva: IUCN Water and Nature Initiative.

Salman M.A. 2006. “Regulatory Frameworks for Water Resource Management.” World Bank.

World Bank. 2004. “Public and Private Sector Roles in Water Supply and Sanitation Services.” April.

____. 2007. “MNA Development Report on Water.”

Assessment

2

Bridging the Practice Gap in Water Management: Lessons from the "MNA Development Report on Water"

N. Vijay Jagannathan

In March 2007, the Middle East and North Africa Region (MNA) of the World Bank launched the "MNA Development Report on Water."[1] It was the culmination of two years of consultations, studies, and analyses of water issues in the region.[2]

The report had three main conclusions:

1. *Water is scarce and has competing uses.* Thus, it needs a management strategy that goes beyond merely finding engineering solutions to include revisiting the rights regime, regulatory framework, and public-private partnerships.
2. To improve water management, *accountability*—whether external to users of water, or internal to sector financiers and policymakers—*needs to be deliberately promoted.* To this end, information about water—on both public expenditures and environmental impacts of existing patterns of use—should be fully shared among all stakeholders.
3. *To improve water management, policies outside the water sector often are as important as those within the sector.* This conclusion applies to macroeconomic, trade liberalization, agricultural, and urban policies.

The overall point of the report is that although the principles of water policies are quite well understood, public policy choices get circumscribed by political, legal, or social considerations. For example, reforms introducing sensible pricing and tradable water rights are constrained by political and social resistance. Fiscal prudence is inhibited by inadequate

[1] World Bank 2007.
[2] This chapter is a modified version of an essay in honor of Dr. V.S.Vyas (IDS 2009).

monitoring of wasteful public expenditures in hydraulic infrastructure. Irrigation subsidies encourage crops that yield low "crop per drop."

The Challenge

The challenge confronting water policy lies in bridging the "practice" gap between choices that would lead to sustainable outcomes and the perceived feasible set. This practice gap could be construed as the chasm between the universally recognized principles (as confirmed in major sectoral events such as Dublin, Rio, Kyoto, and Mexico City) and observed expediency in decisionmaking. For example, the importance of sound water management for sustainable economic development, universal public reverence for clean water, and the potential of leveraging expanding knowledge of the surface and subsurface water cycle all are accepted by stakeholders. However, in the "pragmatic" dimension, decisionmaking is severely constrained by political considerations. Water governance is the business of all levels of the government and is very sensitive to prevailing norms and conventions. In countries of the Middle East, for example, many leaders are reluctant to charge for water services because they fear creating political opposition that could exploit a widely held belief that Islamic traditions require water to be a free commodity.

Box 2.1 Water Is Everybody's Business: Morocco

This photograph of a river basin in Morocco illustrates the reason that stakeholders outside the sector are so important for water reforms. The winding river services the farms and a growing urban and regional economy. Improved agricultural practices have been fuelled by excellent road connections to the export market for fruits and vegetables. Large urban centers have become magnets for migrants from rural areas, attracted by off-farm jobs. However, these centers' untreated wastes pollute the river downstream. Water is everybody's business, and its management is influenced by policy within and outside the water subsectors.

If pragmatism requires focusing on the feasible set of policies, the basic question is: Where does this leave policymakers in an environment in which politics triumphs over principles but in which every succeeding generation faces the cascading of the harmful consequences of past water policy missteps? The thesis of this chapter is that outside drivers often are critical factors in bringing about principled pragmatism.

"Outside" Drivers That Bridge the Practice Gap in MNA Countries

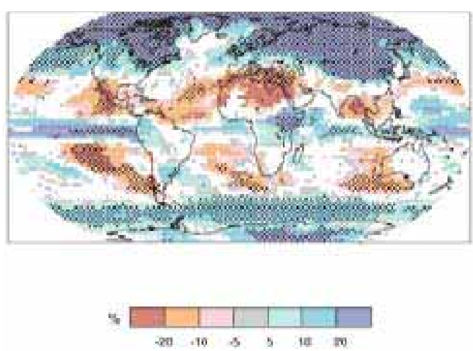
The most important driver from "outside" the water sector in MNA countries is the increasing political recognition of the irreversible adverse consequences of global warming.

"Outside Driver" 1: Climate Change

The recent International Panel on Climate Change (IPCC) findings confirm trends observed over past decades in Algeria, Morocco and Tunisia: that historic data on rainfall patterns no longer provide accurate projections for future precipitation.[3] For example, over the last three decades, dams constructed in Algeria and Morocco have been able to store, on average, only approximately half their design capacity because of inadequate annual precipitation. As a consequence, farmers have become acutely aware of the uncertainty of their water rights, and irrigation agencies in the command areas struggle with rationing uncertain water supply to the politically important farmer constituency. The IPCC report confirms these trends, and what earlier was seen as a prolonged drought is now being interpreted as a secular decline in precipitation caused by global climate change (figures 2.1 and 2.2).

The problems of global warming will affect other regions as well. For example, water resources in Bangladesh, Bhu-

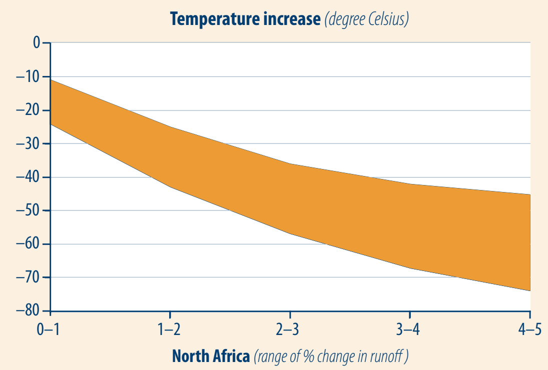
Figure 2.1 Projected Decreases in Rainfall, 2000–70



Source: Background paper, Stern Report.

[3] Bates and others 2008.

Figure 2.2 North Africa Estimates of Change in Runoffs

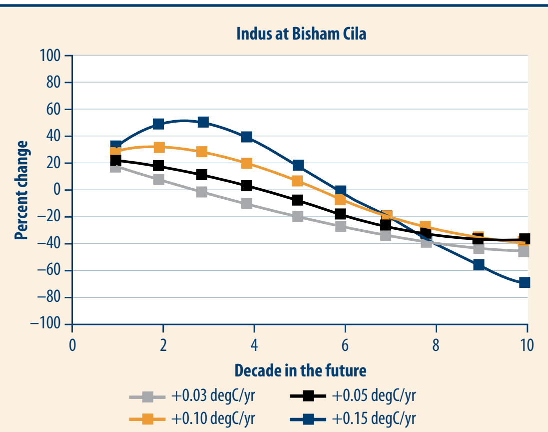


tan, China, India, Nepal, and Pakistan are likely to face rapid shrinking because of reductions in water stored in the Himalayan glaciers as a result of changes in the duration and intensity of rainfall. The effects in the Western Himalayas are likely to be particularly dramatic—with increased flows over the next 4 or 5 decades, followed by dramatic reductions—of 40 percent–60 percent of flow—over the subsequent century. Since the rivers flowing from this massif support the "breadbaskets" of South Asian countries, the impacts will affect agriculture and urban water use (figure 2.3 shows predicted declines in Indus River flows in Pakistan).

The secular decline and increased variability in rainfall will radically affect the flows and seasonality of major rivers in the subcontinent, and seriously put in doubt past assumptions on how to design hydraulic infrastructure.

The solution is to develop a package of reforms that tackle both the demand (incentives to shift to crops with high water productivity) and supply (water conservation through modernized irrigation and better tracking of the water/evapotranspiration cycle) sides.

Figure 2.3 Projected Changes in Flow of the River Indus, 2005–15 *(%)*



Source: Rees 2005.

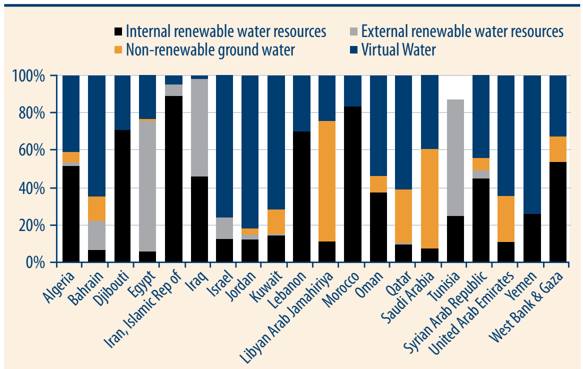
"Outside Driver 2": High-Value Farming Changes the Politics of Irrigation

A second set of factors outside the water sector that is helping to narrow the practice gap is the pressure from farmers benefiting from the recent growth of high-value agriculture. These farmers have secured significant gains in income by adopting agricultural and irrigation practices that have enabled them to join the supply chain to get high-value consumer markets in Europe and North America. Their prosperity is reflected in a change in water consumption usage. They earn significantly higher incomes per drop of water than conventional irrigators are able to earn. The hope is that such leading-edge farmers will support demand-management measures.

The key policy question here is how to allocate water efficiently between its two different forms, namely, high-security water, which is needed by those making major investments in annual crops and in industry; and low security water, which farmers use for annual crops when it is available. Managing water as different products is performed well by water markets in Australia, Chile, Mexico, and the western US. In these countries, users of low-security water sell their water to users of high-security water in times of scarcity, making both parties—by definition, since the transfer is voluntary—better off.

Figure 2.4 illustrates the trends of water use in MNA countries. Green represents renewable sources (from both surface and groundwater), and includes desalinated water, an important source of renewable water in the Arabian Peninsula and North Africa. The pink shaded area represents the proportion of water extracted from nonrenewable sources, and the brown represents the water "virtually" available as the water used to grow agricultural commodities that are imported through trade. For example, increased rice, wheat, dairy, and beef imports result in much more virtual water being available to local consumers, whereas exports of citrus, olives, and vegetables generate equivalent or higher value exports with relatively low water use.

Figure 2.4 Role of Renewable, Nonrenewable, and Virtual Water in MNA Countries, 2005 *(%)*



Source: World Bank 2007.

The preconditions for high-value farm exports were the physical access and information access necessary for supply chain management, that is, roads, high-speed internet, and container terminals. Each of these facilitated the growth of two-way trade, principally with Algeria, Egypt, Israel, Jordan, Morocco, and Tunisia. A similar pattern has occurred in all of these growth centers:

1. Investors and farmers were able to respond to the growing demand for high-value farm products.
2. Farm products in which the Region has comparative advantage—olives, citrus, herbs, and other fruits and vegetables—constituted the bulk of exports.
3. These products generated more value per drop.[4]

State-of-the-art technology is used to sort, pack, and store; and to enable conveyance technologies to bring fresh farm products to the supermarkets within the contracted period (a few hours to Europe and a week to Canada and the US).

Agricultural practices have begun approximating the norms of efficient business enterprises. However, regarding labor productivity, more jobs are generated in the logistics and supply chain aspects than in conventional employment of farm labor. The new paradigm suits the expectations of a changing labor force; rural youth desire a higher quality of life than the drudgery of traditional farming can provide.

Two key actions outside the water sector unleashed the potential of high-value agriculture:

4. On the demand side, changing demand patterns in the EU encouraged large supermarket chains to search for reliable suppliers of cheaper, high-quality fruits and vegetables.
5. On the supply side, the farmer's ability to manage supply chain risks hinged on reliable, good quality, irrigable water.

Typically, a farm entrepreneur begins—with no support from the surface irrigation bureaucracy—by investing his or her private funds in water-conserving irrigation infrastructure (usually drip or sprinkler), and by carefully monitoring his water quality. S/he then invites the supermarket chain to inspect the facilities to ensure that the fruits and vegetables are produced using acceptable technologies. These include being irrigated by water that is free of contaminants, both chemical and biological. Thereafter, the farm secures a Good Agricultural Practices (GAP) certificate from an independent European certification agency. This seal of good housekeeping facilitates contracting with the very quality-conscious European supermarkets. Passing the GAP criteria,

---

[4] These crops generate more value per unit of evapotranspiration (ET) (see chapter by Perry and Bucknall for a discussion on the significance of ET).

rather than the much laxer national regulatory laws, ensures respect for international water quality standards.

The key point is that these entrepreneurial farms have invested in groundwater-based irrigation to informally create water rights for themselves. Furthermore, these farmers expect little, if any, support from the substantial surface water irrigation infrastructure. They are aware that these public sector organizations have neither the institutional capability nor accountability mechanisms to serve the specific quality and timing requirements of the export-oriented farms. In the few cases in which these farmers use surface irrigation, they privately finance investments to mitigate water supply risks by (a) excavating a part of the farmland as a storage reservoir, then (b) developing a pressurized, piped drip, sprinkler, or pivot irrigation distribution system. However, these individual, private solutions are socially costly because productive farmlands are being lost to water storage. They also are inequitable because small farmers who lack financial resources and knowledge of supply chain management are de facto excluded.

Even when a farmer has been able to mitigate supply risks from surface water irrigation, a major remaining risk is the farm's ability to maintain water quality norms required by the importing country's environmental regulations. Nowhere is this challenge more visible than in Egypt. Farms on the desert and scrubland in the periphery of the Nile delta have been able to participate in the export market though groundwater-based irrigation systems. However, hundreds of thousands of farmers in the delta a few miles east and north are unable to do so. The surface water that they receive through Nile surface irrigation system is highly polluted, and therefore not capable of meeting the demanding EU water quality standards for all edible export crops.

Pressure from the high-value farm lobby is helping to narrow the practice gap in water management. For example, in the West Delta area of Egypt and in Guerdaine, Morocco, investors financed high-value agriculture in desert lands that have access to groundwater. Utilizing their knowledge and connections to obtain credit, technical knowhow, and access to European markets, these groups have created large export-oriented markets for grapes, citrus, and other fruits and vegetables. While their entrepreneurship is laudable, the income and employment generated in the regional economies also enabled them to successfully lobby governments for supplemental surface water irrigation once groundwater started getting depleted. On the positive side, one could argue that these groups have influenced political leaders and water policymakers to appreciate the benefits of transferable water rights, irrigation modernization, and water conservation.[5]

Moreover, high-value farm exports generate better jobs with better pay in the services sector. Thus, they help reduce the exodus of the rural population to urban centers and Europe in search of better livelihoods.

With a large and increasingly affluent urban middle class in MNA**,** the demand for high-value crops is growing. To meet this demand, countries have begun investing in large-scale investments in irrigation modernization. The preconditions for such investments are an adequate road infrastructure to ship the produce in a timely manner to markets and ports, stabilizing rural electricity services, and speeding up border procedures. These broad and deep changes must be made for demand for water-conserving irrigation technologies to become strong enough to increase pressure on policymakers for reform.

"Outside Driver 3": The Call for Clean Water

A third set of factors outside the sector that is narrowing the practice gap has been political pressure on decisionmakers to focus more on water quality. Obviously, the exporters of high-value farm products have been one of the influential lobby groups creating this pressure. However, there have been other contributors. Many countries are benefiting from a tourism boom, as "package tours" from Europe and the Gulf countries to the historic and seaside resorts of several MNA countries have grown enormously. Along the Mediterranean and Red Sea coasts alone, many resorts have been developed in the past two decades to take advantage of this boom. By contrast, some other high potential areas, such as the coastline of the Nile delta, have not been able to take advantage of these opportunities because of beach contamination by polluted Nile waters. Tour operators and resort owners are

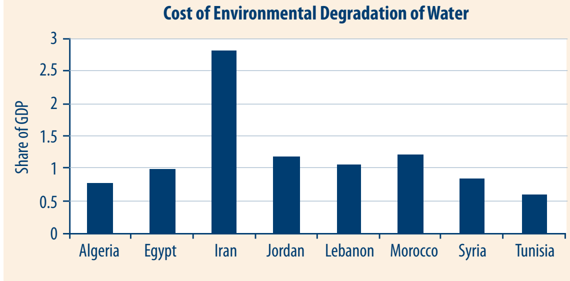
---

[5] For example, in both Guerdaine and West Delta, financing has been obtained from the World Bank Group for surface irrigation infrastructure via public-private partnerships (PPPs). For the former, half of the investment costs was financed by a capital subsidy from the government. For the latter, the investment costs were financed by an IBRD loan but were recovered from the water users. Both projects have enabled the governments to test new models of service provisioning (see Baietti chapter). For the West Delta project, most of the transferred water will originate upstream of the delta barrages, that is, before it gets polluted by the agricultural or sewage return waters. The concentration of the water pollutants in the Rosetta branch culminates only in the downstream.

powerful interest groups who have joined environmentalists and farm exporters to lobby for better water quality management (WQM).

Analytical work also has helped build the case for this coalition of interests to demand better WQM. For example, the World Bank initiated a series of studies estimating the opportunity costs of environmental degradation in major MNA countries, including both water pollution and groundwater degradation (figure 2.5). These estimates, shown as a percentage of forgone GDP, were disseminated to a wide range of stakeholders through workshops, media events, and publications. The study findings coincided, particularly in Egypt, with growing public dissatisfaction with water quality in irrigation canals, so were picked up by the media. The studies' conclusion that poor water management harmed the economy by slicing off percentage points of GDP resonated with decisionmakers in economic ministries and pushed governments to pledge significant increases in public funding for remedial actions.[6] Figure 2.6 estimates the opportunity costs to GDP due to savings losses.

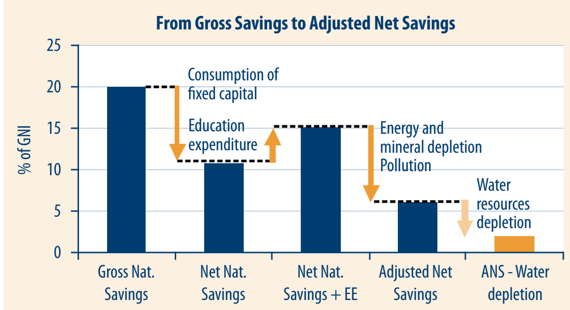
Figure 2.5 Estimates of Environmental Degradation Costs, 2005 *(%)*



Emerging Lessons from MNA for Bridging the Practice Gap

The analysis suggests that countries in the region have taken steps to narrow the "practice" gap in response to powerful political drivers outside the water sector. Influential groups have highlighted the need for water reforms, although usually only for their own narrow reasons. Leveraging these opportunities to promote broad-based reforms is the next big challenge to reduce the "practice" gap. For

Figure 2.6 Cost of Over-extraction of Aquifers, 2006 *(%)*



[6] Estimates include opportunity costs of air pollution.

this, policymakers need to regularly evaluate and feed back the lessons to the sectoral decisionmaking process.

Based on past assessments, the "MNA Development Report" suggests three insights in this regard:

1. Reforms are inherently a political process and one in which the technical and political dynamics are difficult to separate. Politically, an initial driver of change (such as farmers' demand for better water quality) could be leveraged if there were a preexisting broader coalition of stakeholders willing to support more broad-based reforms than the farming lobby wants to promote.
2. Non-water policies are critically central to water policy reforms because the coalition becomes energized when colleagues outside the water sector (agriculture, energy, environment, trade, transport, and banking, to name a few) already are engaging, or are willing to engage, in complementary actions.
3. Improved accountability of government organizations to users of water services is a third essential leg for reducing the gap. Mechanisms for public accountability form the bridge between users of water and their governments by channeling relevant information and voice and ensuring fairness in resolving conflicts that may arise.

How to Bridge the Practice Gap in Developing Countries

Coordination and Strategic Monitoring of Water Policy Actions

The problem of coordination is accentuated by divided responsibilities for water management among various levels of governance, typically, the center, governorates, and citizens. This institutional confusion is compounded by a tendency of rules and norms that focus more on the planning and resource allocation phase than on the actual implementation phase and on thoroughly evaluating outcomes.

For example, in large river basins such as the Nile Delta, pollution from human settlements affects water quality downstream, which in turn reduces the crop choices of farmers. For example, a farmer in the Nile Delta cannot think of growing high-value, export-oriented crops because the water quality does not meet the minimum EU Good Agricultural Practices (GAP) irrigated water standards. The Ministries of Water Resources and Irrigation, Housing, Agriculture, Local Government, Health, and Environment must devise coordinated responses to this challenge. Within the Water Resources and Irrigation Ministry itself, multiple sectors (mechanical and electrical engineering, drainage, irrigation improvement, and planning) need to work together seamlessly to make the irrigation service meet the farmers' needs for high-value agriculture.

On the sanitation side, the practice gap does not get bridged because tackling pollution requires staff from various agencies to work outside their silos, think laterally, and, most importantly, engage stakeholders who are outside their internal organizational structures. Common observations on factors that contributed to this practice gap are:

- *Key stakeholder groups were disinterested*. Pollution abatement had downstream benefits, so was not politically attractive to political leaders and even the local public.
- *Operations and maintenance (O&M) burdens were heavy*. Moreover, in a context in which tariffs are substantially below operating costs and environmental regulations rarely enforced, sewage treatment plants get shut off. The untreated effluents are bypassed to downstream water bodies.
- *Raw sewage can be used for free* for high-value fruits and vegetables by surrounding farmers because environmental regulations are neither enforced nor internalized by communities.

The practice gap can be bridged by coordination and strategic management with stakeholders who have an interest in achieving planned outcomes. Active engagement and dialogue are required among sewerage engineers with urban planners, agriculture and environment ministry staff, and program beneficiaries in both planning *and* implementation.

Establish Water Executive Management Programs

The solution is to radically redefine the learning and capacity building program for water management. Water executive education programs need to be developed to inspire and train water managers to see beyond their narrow specializations. The inspiration comes from successes in the field of business management through executive management programs that promoted "lateral" thinking by visionaries such as Alfred Sloan and Peter Drucker.[7] Through these programs, business management became a more systematic process of directing and motivating people and entities to accomplish an enterprise's goals.

Water management is as multidisciplinary as running a modern business enterprise. The former requires the integration of the different ways of thinking of a diverse range of stakeholders from farmers, slum dwellers, other civil society, media, and political leaders to civil servants, planners, economists, and engineers. Key stakeholders need to debate and discuss the practice gap, and reach a common appreciation of what is required for long-term sustainability in water outcomes. This consensus requires appreciating the human, financial, environmental, and technological aspects of water management through the systematic engagement of stakeholders in learning about water management.

The MNA countries have recognized this challenge. Through the leadership of the Arab Water Council (AWC), they have established an Arab Water Academy so that such learning events are organized and a new genre of "water managers" and water stewards are created from different disciplines and represent all sections of society.

Inclusion of Stakeholders in Water Dialogues

Water is both a finite resource and subject to intense competing demands. Political realities in all developing countries hinder, or prevent, water policymakers from using normal economic policy instruments, such as water pricing and transferable water rights, as mechanisms for resource allocation. In their absence, informal arrangements dominate the institutional environment (Shah 2007). The most noticeable evidence of these are the explosive growth of tubewells, fuelled in most countries by subsidized energy; inadequate water resource regulations; and self-provisioning by urban households (HH) for water supply and sanitation facilities.

Over time, the adverse environmental consequences have become unavoidable, notably in the form of continuous groundwater draw-downs. These sources provide the mainstay for farm production in several regions of the world, despite the knowledge that the long-term consequences will be disastrous to these very same farming communities. Equally

[7] McDonald and others 2003; *Business Week* 2005.

visible is the unequal access to this water by the poor in both rural and urban areas.

Several MNA countries are facing the devastating consequences of similar trends because their groundwater resources, having a very low renewal rate, are already running out. In some of the most affected countries, such as Yemen, entire farm communities have had to leave their villages because the groundwater extraction rates greatly exceeded the replenishment rate, fuelled in particular by cheap subsidized electricity. MNA has other variants of this type of "tragedy of the commons," especially those resulting from unchecked pollution of water bodies from urban, industrial, and agricultural runoffs.

The way out is to communicate with and engage the affected stakeholders in finding solutions. *No amount of executive training and management will work unless there is an educated and informed group of water users* who are aware of the consequences of today's actions on tomorrow. In other words, water management requires all individuals to understand that that they are a part of the problem as well as the possible solution.

Managing the Equity Dimension of Water

An equally important policy instrument is the use of *redesigned subsidies* to put in place incentives for public finance to target the poor and the environment. Some MNA countries now recognize using output-based subsidies as an effective tool.[8] These subsidies work in:

- Urban areas—by targeting low-income households with free piped water supply connections (thereafter, these households must pay tariffs for operating costs)
- Rural areas—rewarding water conservation in surface irrigation areas by subsidizing part of investment costs of low-income farmers who switch from open channels to drip, sprinkler, or other more modern irrigation technologies
- River basins and sub-basins—by reimbursing utilities/operators for every unit of treated effluent that meets national standards.

[8] See chapters 17 and 18 by Xavier Chauvot de Beauchêne and Pier Mantovani.

Focus on External and Internal Accountability

The practice gap can be narrowed by developing a *culture of lateral thinking* in water management similar to modern business management practices. Participation of all stakeholders and use of targeted subsidies are suggested as the first and second legs of this model. The third leg is putting in place mechanisms to enhance accountability. Accountability has two dimensions: (1) an "internal" aspect in which water organizations are accountable to their financiers and management structures, and (2) an "external" aspect in which they should respond to water user preferences and willingness to pay. The practice gap has arisen because, for both aspects, MNA countries have experienced institutional design failures.

The internal failure is accentuated by government pledges of general subsidies for the water sector, with no follow-up to track outcomes of programs (as illustrated by GAP 1). In the urban areas, cross-subsidies for urban water supply reduce the incentives of utilities to manage services based on commercial principles, while the benefits end up being appropriated by the middle class urban consumers. Furthermore, while this group benefits from the higher tariffs charged to industrial and service water users, the poor pay more while buying poor-quality water from vendors. In the irrigation sector, farmers do not have clear, predictable water rights on the basis of which they can plan their planting decisions. Instead, officials of the various state irrigation bureaucracies have the discretion to assign irrigation turns to the water user associations (WUAs) and farmers. This power gets often misused through graft and corruption (Wade 1985; Jagannathan 1987). In both situations, water service organizations have been unable to set in place governance mechanisms that ensure internal accountability of staff to the organizational goals and external accountability to the water users.[9]

Figure 2.7 illustrates how accountability gets diluted by three levels of scarcity observable in the region (World Bank 2007):

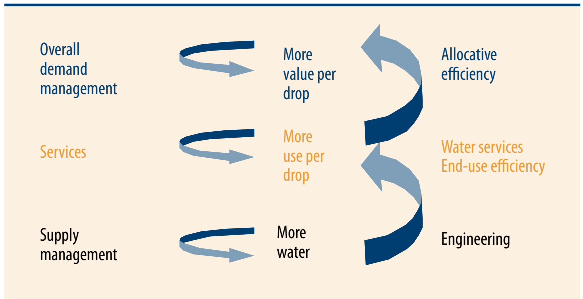
1. *Scarcity of the water resource.* In conditions of water scarcity the response has been to build "solutions" through dams, canals, and distribution systems. These solutions required large outlays of

[9] For discussion on MNA initiatives to improve accountability, see chapter 11 by M. Abu-Taleb and R. Calkins, and chapter 24 by J. Simas, J. Morelli, and H. El Sadani.

public funds. With experience, the IWRM processes recognized that public investments do not necessarily lead to desired outcomes because organizational incentives may be misaligned.[10]

2. *Scarcity of organizational capacity* to actually manage the demands of various water users, and meet the growing needs of the economy.
3. *Scarcity of accountability* to achieve sustainable outcomes In the past decade, with climate change concerns raising serious concerns about sharply declining water availability in the MNA region, this third level has assumed prominence.[11]

Figure 2.7 Changing Nature of Accountability



Source: World Bank 2007.

The thesis of the "MNA Development Report" is that, with the growing scarcity of water, *policy focus needs to shift to allocative efficiency among competing water uses*. For irrigation, which uses 80 percent–90 percent of all water, redesigning incentives that direct farmers toward maximizing income per drop is one obvious focus. On the urban side, the focus needs to be on rationalizing water and sanitation subsidies. As mentioned earlier, general subsidies in MNA have tended to benefit the well-to-do (water), or no one (sewerage investments). Establishing clear rules for subsidies that are based on measurable outcomes is one obvious solution. Tracking the effectiveness of public expenditures through regular public expenditure reviews is another obviously useful instrument.

External accountability is generated when lobby groups outside the water sector (NGOs, high-value farmers, tour operators, resort owners, media) pressure political leaders for efficient and high quality water services. As the MNA illustrations indicated, these fairly narrow drivers could be leveraged for broad-based reforms when the debate is opened up to the other suggestions in this chapter (targeted subsidies, user participation, and effective use of public funds that foster internal and external accountability.

[10] See chapter 4 by Shawky Mohamed and others in this volume.
[11] See chapter 1, figure 1.1, and subsequent discussion on this topic.

However, there is a need to set up appropriate organizational structures to govern water management. The experience of the MNA Region suggests that empowering river basin organizations, branch canal users, or aquifer-based user associations is necessary to create awareness of water management issues. These are relatively new organizations and have difficulty in acquiring legitimacy when faced with conflicts with established national or local political or administrative groupings, such as governorates, provinces, and districts. Obviously, there are no general solutions. Each country must work out solutions that fit its own context.

Concluding Remarks

Bridging the practice gap requires a fundamental rethinking of the way that water is managed and that stakeholders learn about sustainable management of water resources and water services.

Over the last three decades, the dramatic shift from surface to groundwater in many parts of the world—by agriculture, municipal users, and industry—has been essentially a water privatization process, with no rules of the game. What is needed now are to (1) acknowledge de facto rights and (2) make a major effort to educate and inform on the need for "rights, but with rules."

The experience suggests that water managers must recognize and manage the several external drivers of water use. Policies outside the water sector often cause unintentional harm to it. Water management, therefore, requires active engagement, discussion, and debate among all parts of society before the practice gap between principles and pragmatic solutions can be bridged.

References

Bates, B., Z. Kundzewicz, S. Wu, and J. Palutikof. 2008. *Climate Change and Water*. Geneva: Intergovernmental Panel on Climate Change.

Briscoe, J., and R.P.S. Malik. 2007. "India's Water Economy: An Overview." In Briscoe and Malik, *Handbook of Water Resources in India*. New Delhi: Oxford University Press.

Business Week. 2005. "The Man Who Invented Management: Why Peter Drucker's Ideas Still Matter." November 28.

Jagannathan, N.V. 2009. "Bridging the Practice in Water Management: An Appreciation of V.S.Vyas." Jaipur: Institute for Development Studies.

____. 1987. *Informal Markets in Developing Countries*. New York: Oxford University Press.

McDonald, J., and A.D. Chandler. 2003. *A Ghost's Memoir: The Making of Alfred P. Sloan's "My Years with General Motors*. Cambridge: Massachusetts Institute of Technology (MIT) Press.

Mohanty, N. 2007. "Scaling up Water Investments." In J. Briscoe and R.P.S.Malik, *Handbook of Water Resources in India*. New Delhi: Oxford University Press.

Saleth, R.M. 2007. "Water Rights and Entitlements." In J. Briscoe and R.P.S.Malik, *Handbook of Water Resources in India*. New Delhi: Oxford University Press.

Shah, T. 2007. "Institutional and Policy Reforms." In J. Briscoe and R.P.S. Malik, *Handbook of Water Resources in India*. New Delhi: Oxford University Press.

Vyas, V.S. 2007. "Economic Reforms through Principled Pragmatism." In J. Briscoe and R.P.S.Malik, *Handbook of Water Resources in India*. New Delhi: Oxford University Press.

Wade, R. 1985. "The Market for Public Offices: Why the Indian State Is Not Better at Development." *World Development* 13 (4).

World Bank. 2007. *Making the Most of Scarcity: Accountability for Better Water Management in the Middle East and North Africa*. MNA Development Report on Water.

3

Egypt: Water Sector Public Expenditure Review

Ahmed Shawky Mohamed and N. Vijay Jagannathan

Key Findings

In 2003–04, the Government of Egypt (GOE) budget spent 4.087 billion LE on water infrastructure in the irrigation and agriculture subsectors, and 6.697 billion LE in the WSS subsector.[†] Of this, approximately 79 percent and 61 percent, respectively, were allocated for new investments; the balance was allocated for recurrent costs. The outcomes of such significant public outlays have been mixed. On the positive side, there have been impressive gains in agricultural productivity due to water investment and in water supply and sanitation coverage. On the negative side, fiscal dependence on the government remains, and a new concern that requires significant public finance needs immediate policy attention. The latter has arisen because of pollution externalities in the lower Nile Delta, which are exacting a heavy toll on public health and the environment. A 2002 World Bank study on the costs of environmental degradation estimates the damage costs at 1.6 percent–3.2 percent of GDP.

This chapter assesses the recent trends of public expenditures of the water sector. It focuses particularly on the irrigation and water supply and sanitation (WSS) subsectors, the two major recipients of public financing in the water sector. It also investigates different sources of fiscal stress and sources of finance, and explores the efficiency and equity implications of the current arrangements.[1]

[†] This chapter updates World Bank Water Policy Note 2 (2005), written as part of the analytical work supporting the 2005 Public Expenditure Review (PER) in Egypt, a Government of Egypt-World Bank collaboration.

[1] See chapter 4, "Assessing the Efficiency and Equity of Water Subsidies: Spending Less for Better Services" by Shawky Mohamed and others in this volume.

The following is a summary of the key findings:

Finding 1: Most investment as well as operation and maintenance (O&M) costs of water services in Egypt are funded from the national budget.[2] Cost-recovery levels still are below international comparators. As a consequence, the sector is heavily indebted.

Finding 2: Over the last two decades, the *composition of* water-related public expenditures has changed. A higher proportion is being allocated to new investments—at the expense of recurrent expenditures and debt repayments, thereby increasing the sector's long-term liabilities.

Finding 3: Water service coverage (in relation to both drinking water and irrigation) is adequate in the Nile Delta area. However, it is generally lacking in the rural/southern areas, in which water services are particularly inequitable for low-income communities.

Finding 4: Reallocating budget appropriations among different budget chapters of water agencies, among departments within agencies, and among water user groups (WUGs) requires a fundamental rearrangement of current budget planning and management.

Finding 5: The irrigation and water supply and sanitation (WSS) subsectors have three options available to finance future O&M and investment costs. These are identified in the Integrated Water Resource Management (IWRM) Action Plan:

a. Increase contributions from users, requiring changes in legislation.
b. Decrease transaction costs and overhead expenditures through decentralization and improved efficiency in service delivery. The main sources of "avoidable" transaction costs are overstaffing, duplication of responsibilities, oversized designs, suboptimal technology, and procurement inefficiency.

---

[2] O&M costs pertain to the following items in the budget chapters of the water-related ministries:

a. Partly chapter 1: Wages that relate to O&M, as opposed to planning and other central administrative functions.
b. Chapter 2: Goods and services for O&M.
c. Partly chapter 3: Only regular/preventive rehabilitation (as opposed to occasional/major rehabilitation).

c. Facilitate private sector participation in financing, developing, and operating the irrigation systems in line with user preferences and willingness to pay.

Finding 6: The WSS subsector is moving toward corporatization. It urgently needs to address the debt overhang caused by the past policy of service expansion without cost recovery. Under the present circumstances:

a. For the holding company to fulfill its mandate of reforming the sector, restructuring and/or writing off existing debt is inevitable.
b. Any debt write-off needs to be contingent on achieving monitorable financial and operational performance outcomes.
c. Future donor financing could be structured around assisting the holding company to achieve the above outcomes in the medium term, perhaps through a sector-wide approach (SWAp) operation.

Sector Background

Egypt is an arid country with very limited rainfall. The Nile-Lake-Nasser system is one of the largest hydraulic infrastructure complexes in the world. It consists of a series of large barrages, canals, pumping stations, water and sewage treatment plants, and water supply and sewerage networks.

Importance of Water Resource Management for the Egyptian Economy

The Nile-Lake-Nasser system is Egypt's only renewable supply source for surface water, and constitutes 95 percent of the country's total water resources. The rest of Egypt's water resources is mainly fossil (nonrenewable) groundwater found in the coastal zones, deserts, and Sinai; and estimated at 3–4 BCM/yr.

Egypt's water requirements are increasing as a result of growing population, rising living standards, and the needs of industries and agriculture (particularly in the reclaimed new lands). Of the subsectoral shares, agriculture (including fisheries) is the major user; it consumes approximately 70 percent of water. Municipal/potable and industrial subsectors consume only 3.5 percent and 1.5 percent, respectively. The balance, estimated at roughly one-quarter of the overall water stock, is lost through evaporation (5 percent), and, more significantly, as drainage water (20 percent) discharged into the Mediterranean Sea and the desert fringes of the Nile system.

Sectoral Challenges

A major challenge facing Egypt is to close the gap between the limited water resources available and the escalating demand for water from competing users. Available water per capita per annum amounts to some 900m^3, which is already below the "water poverty" index of 1000 m^3/capita/annum. This figure is expected to fall to 670m^3 by 2017, unless policies are implemented to sustainably manage growing demand. Managing sustainably requires developing appropriate pricing and financing rules along with an institutional framework that encourages sustainable use.

Until the early 1990s, GOE's attention was focused on "balancing" water supply and demand through supply augmentation. The result was significant investments in water supply, drainage, and rehabilitation of irrigation infrastructure, from both the national budget and donors. Nonetheless, by the mid-/late 1990s, the need for a more integrated approach became apparent due to:

- Continued deterioration of water quality
- Growing demand-supply gap
- Intensification of inter-sectoral and inter-regional water allocation problems
- Inadequacy of government funds to sustain new investments and O&M at current levels
- Poor operational performance of water agencies.

Since then, the government policy has shifted to integrated water quality and quantity management. The integrated water resources management (IWRM) approach seeks to address sectoral concerns through a mix of institutional reforms, changes in incentive structures, and technical innovations.

"Public-Good" Perspective to Water Services

Water resource management (WRM) is seen as a cornerstone of national security. Consequently, a significant part of the hydraulic infrastructure is regarded as a public good and receives financing from the national budget. This infrastructure includes not only the "trunk" system, comprising the production, treatment, and distribution of water to various users/subsectors from a system of dams, barrages, and main canals; but also the recipient or "feeder" subsectors, which include irrigation, municipal, industrial, navigation, and hydropower users. For the latter system, there is both a public and a private good dimension because these users obtain privately appropriable benefits either by consumption or by using water as an input in production.

Past policies have not rigorously distinguished these two aspects. For example:

- An Egyptian farmer in the Nile Delta pays the incremental cost of water delivery at the farm level but not the conveyance (and lifting costs) from the river system.
- A water supply consumer pays a tariff of approximately only 20 percent of the treatment and delivery costs.

The rest of the "feeder" costs gets picked up in the public goods account. One could argue that apportioning the public and private costs in this very large, integrated hydraulic system is complex. Nevertheless, there clearly is significant potential to increase user contributions for water usage that yields private benefits.

However, *greater user financing of water services requires a fundamental reorganization of Egyptian water delivery systems*—from sectors and departments that rely on budgetary subventions to service-oriented utilities that respond to user preferences and willingness to pay. For example, in Egypt's WSS subsector, users receive subsidized but poor quality services from utilities. These consumers are unwilling to pay higher tariffs because their expectations of service improvements from these providers are low. However, unless higher tariffs are paid, the utility will never be in a position to reduce its dependence on the national budget.

While public money is financing private services, *a genuine public service is in desperate need of public funding: infrastructure to improve water quality*. Concerns with water quality distress urban and rural users of water in the Nile Delta area. The areas of concern require actions on several fronts: from technological innovations with greater user feedback and participation to improved coordination among water agencies.

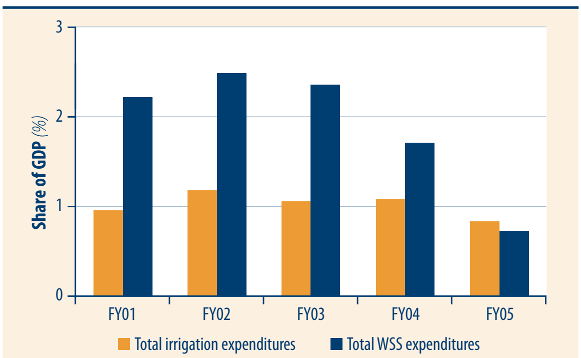
This *vicious cycle of poor performance, debt overhang, and private sector lack of interest must be broken*. The current attention on public expenditures provides one such opportunity.

Consequent Institutional Challenges

Centralized but fragmented management and inadequate mechanisms for ensuring accountability to service users affect sectoral financial and operational performance. For example, responsibilities—planning, design, construction, operation, research, monitoring, and regulation—are carried out through multiple agencies and departments within these agencies, and each is funded through a parallel budget line. These agencies are in the nature of "budget-maximizing" bureaucracies and have very little incentive to be accountable to the service users.

In recent years, GOE began moving toward addressing these concerns. On the institutional side, "holding companies" have been established for both irrigation services in the "new lands" outside the Nile Delta and for WSS services. The explicit objective is to reduce the recurrent fiscal burden of the government, while improving the efficiency and sustainability of O&M services. The eventual objective is to convert these holding companies to off-budget entities that attract private sector participation.

Figure 3.1 Irrigation and WSS Expenditures



Source: MOF annual data on expenditures of the two subsectors.

In the irrigation subsector, two holding companies have been established: one for the South Valley/West Delta and one for Northern Sinai. For the WSS subsector, a holding company subsuming 14 subsidiary companies nationwide has been established. However, before they can be effective, these holding companies face two major challenges:

1. There is still no suitable regulatory framework that enables tariff-setting to respond to user demand.
2. There is no strategy on how to write off/restructure the overhanging debt and create organizational structures that can respond to user demand/attract private sector participation.

In the Nile Delta area, the IWRM action plan already has instituted measures that enhance user voice in the O&M of services. MWRI successfully delegated O&M responsibilities to water user associations (WUAs) at the tertiary-canal (*mesqa*) level. MWRI also is embarking on an action plan to empower Water Boards to manage irrigation and drainage O&M at the secondary or branch-canal level. *The key measure required is an amendment to Law 12/1984 (to empower WUAs),* which is expected to be enacted by the end of 2009.

Assessment of Expenditure Trends

Trends in Water Expenditures

Total water expenditures, thus including investment and recurrent investments, implemented between 1981 and 2000 reached LE 23 billion.

The notable trend was variability in WSS project investments over 2001–05, marking the end of an expansion phase that began 2 decades back. It generated an increase from 5.8 million m^3/day in 1982 to 18.2 million m^3/day in 2000. Coverage figures achieved during this period were quite impressive vis-à-vis MDGs: potable water supply coverage was almost 100 percent and 95 percent for the urban and rural populations, respectively. Per capita potable water use increased from 130 liters/day in 1981 to 275 liters/day in 2000. Sewerage and sanitation coverage also increased substantially: from 1982–2000, wastewater collection increased eight-fold. On the MWRI side, the trend line was steadier, perhaps reflecting its consistent appropriations to maintain the "trunk" hydraulic infrastructure.

Figure 3.2a Trend of Irrigation Public Authorities' Expenditures to Total Expenditures *(%)*

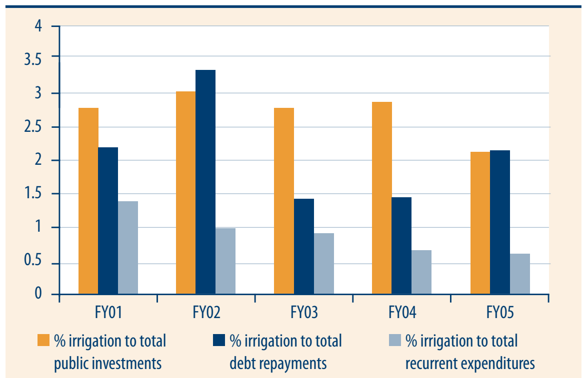


Figure 3.2b Trend of Ratio of Expenditure of Irrigation Economic Authorities to Expenditures of all Economic Authorities *(%)*

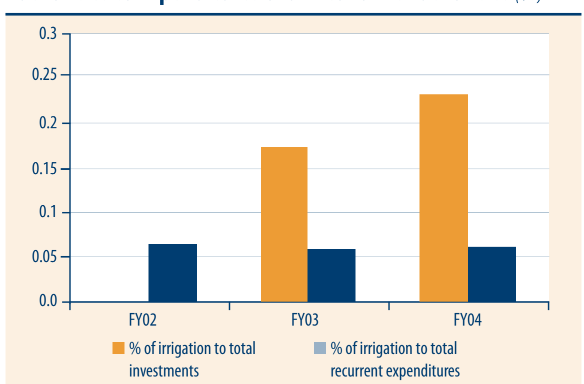


Figure 3.3a Trend of WSS Public Authorities' Expenditures to Total Expenditures *(%)*

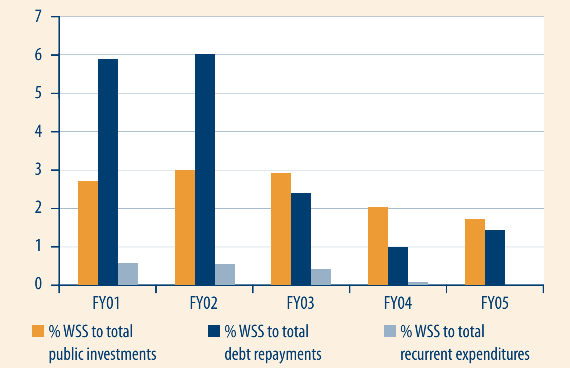
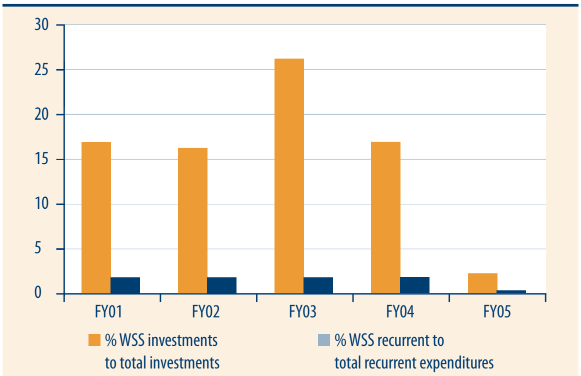


Figure 3.3b Trend of Ratio of Expenditures of WSS Economic Authorities to Expenditures of all Economic Authorities *(%)*



New Investments vs. Maintenance

Unlike other sectors of the economy, investment spending by water utilities was a relatively high proportion of total expenditures (figures 3.2a, 3.2b, 3.3a, and 3.3b), because of the significant increase in water supply expansion investments. For the overall water sector, the ratio of investment-to-recurrent spending has ranged from 200 percent–300 percent since FY01, while investment spending has averaged only 20 percent of recurrent expenditures in other sectors. Within the water subsectors, there is a declining trend in recurrent expenditures and debt repayments, while investment expenditures have remained relatively steady. This divergence suggests that new investments may be getting higher priority than the operation and maintenance of existing assets. These practices could lead to significant costs in the future in deferred maintenance and should be investigated.

Water Resources and Irrigation Subsector

Among MWRI departments, which are responsible for these activities, Sovereign Services Aid and Domestic Loans annually comprise on average approximately 75 percent of financing. However, domestic loans are actually long-term subsidies. The reasons are that they are either (a) not repaid (for example, National Water Resources Center), or (b) only partly repaid (for example, Egyptian Public Authorities for Drainage Projects, or EPADP, which repays approximately 28 percent), or (c) expected to be repaid by holding companies that do not have the requisite cash flow from revenues. In general, user/service fees represent only a few percentage points for most departments (figures 3.4

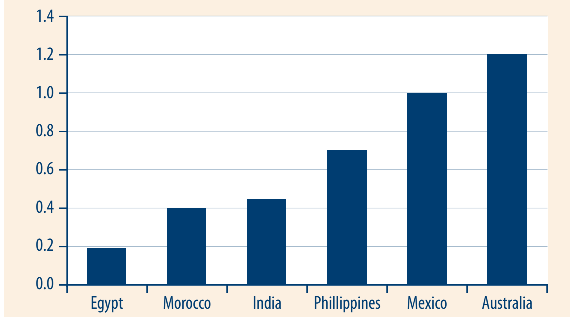
and 3.5). The same issue applies to the WSS subsector: Figures 3.6 and 3.7.

In aggregate terms, from 2000 to 2005 approximately 12 billion LE has been spent on national irrigation infrastructure and water-resources related programs. This level of spending translates to an average annual rate of 15 percent of total Egyptian public investments since 2000.

User contributions: Costs of publicly financed investments in subsurface drainage are fully recovered from farmers, while investments in tertiary-canal (or *mesqa*) improvements are partially recovered through the land tax. Overall, farmers incur approximately 43 percent of the tertiary-canal improvement costs.

In some cases (such as the World-Bank-supported Irrigation Improvement Project), farmers are fully responsible for O&M of the improvements provided by MWRI at the tertiary-canal (or mesqa) level. Collections are made through land taxes, levied at 30 LE/feddan/year on average, which accrue to local governments at a collection efficiency of 60 percent–75 percent. The collected taxes amount to only 20 percent and 6 percent of the recurrent and total budget appropriations, respectively, channeled by the Ministry of Finance (MoF) to MWRI.

Figure 3.4 Irrigation O&M Cost Recovery Ratio *(%)*

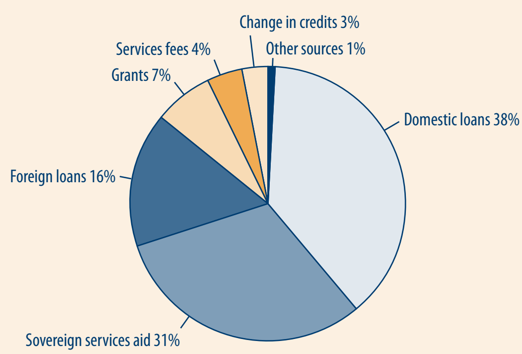


Source: World BanK 2003.
Note: Ratios greater than 1 indicate user repayment not only for O&M but also for Capital-replacement costs.

Figure 3.5 Financial Resources of Irrigation Subsector, 2001–05

	2000/01	2001/02	2002/03	2003/04	2004/05
Sovereign service	315,547	297,609	307,801	356,629	401,912
Domestic loans	206,220	390,101	437,008	486,770	544,700
Foreign loans	58,232	177,392	175,069	219,988	205,587
Grants	67,241	91,443	93,274	93,150	30,720
Internal finance	10,102	4,587	530	800	701
Services fees	40,243	38,644	36,730	40,799	35,325
Change in credit	71,813	45,252	25,514	0	0
Other sources	45,231	13,300	11,946	0	0
Total	**814,629**	**1,058,328**	**1,087,872**	**1,198,336**	**1,218,945**

Sources of Financing MWRI – Irrigation Department Budget

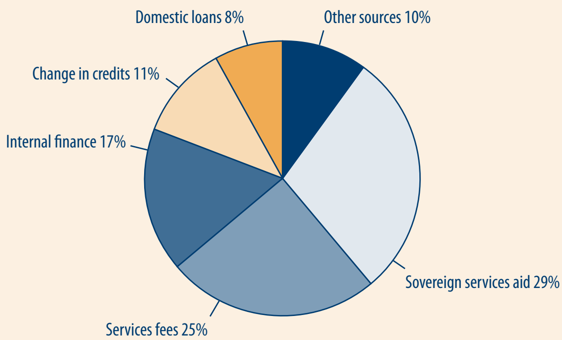


Source: MWRI data.

Figure 3.6 Financial Resources of the WSS Subsector: Cairo

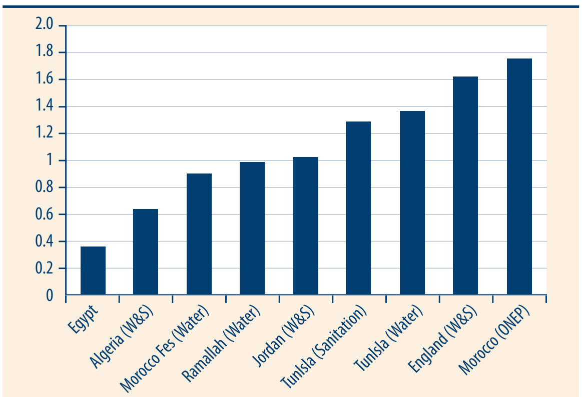
	2000–01	2001–02	2002–03	2003–04	2004–05
Sovereign service	553,932	527,485	623,159	493,234	468,500
Domestic loans	104,925	114,599	74,962	174,000	229,000
Foreign loans	3,189	796	1,164	4,000	4,000
Grants	2,662	210	42	0	0
Internal finance	130,693	167,402	153,183	559,818	494,068
Services fees	347,544	387,433	411,030	515,500	576,645
Change in credit	285,848	125,089	0	285,847	285,847
Other sources	201,720	220,242	458,536	0	0
Total	**1,630,513**	**1,543,256**	**1,722,076**	**2,032,399**	**2,058,060**

Sources of Financing Cairo Potable Water Authority Budget



Source: MWRI data.

Figure 3.7 Water Supply and Sanitation: Cost Recovery *(%)*



Source: World Bank Cross-country data (2003–2004).
Note: Ratio > 1 indicates user repayment not only for recurrent costs, but also for capital costs.

For the future, there are two means of financing the rising O&M and investment costs: (1) increase contributions from users through reforms of the pricing system or (2) reduce costs by improving efficiency of service delivery. Through the Integrated Irrigation Improvement and Management Project (IIIMP), MWRI has been testing new options to enhance cost recovery from water users in the Nile Delta. In addition, the proposed (World Bank-supported) West Delta irrigation project would test full cost recovery from farmers producing high-value agricultural products in the new lands reclaimed from the desert.

WSS Subsector

The WSS utilities are responsible for the management of water supply and sewerage networks serving domestic, institutional, and industrial water users. Normally, these networks should be expected to recover at least all of the O&M costs. The PER data indicated a continued reliance on the public budget, perhaps because these utilities had been caught in a vicious circle of low tariffs, poor services, and low consumer expectations of service improvements, which increased consumer resistance to price increases. There is a wide

Table 3.1 Recurrent Unit Costs and Associated Subsidies in WSS

System	NOPWASD (Municipalities)	GOGCWS (Cairo)	AWGA (Alexandria)
LE per m^3			
Estimated capital, O&M costs	1.0[a]	1.1[b]	NA[c]
Subsidy	0.8	0.9	NA
Average user fee[e]	0.2	0.2	0.3
Rate: Piaster /m^3 [d,e]	15–25	15–25	25–35

Notes:
a. National Organization for Potable Water and Sanitary Drainage.
b. General Organization for Greater Cairo Water Supply.
c. Alexandria Water General Authority.
d. Wastewater tariff is 20% of water tariff for Cairo and 35% for Alexandria.
e. These are applicable to the residential units, which have water meters. Those who do not have meters or whose meters are not working pay a fixed monthly charge for water consumption (LE 5–20 monthly/unit). The charge changes with house area.

gap between the actual costs of water supply (0.8–1.00 LE/m^3) that they incur and the user-tariffs (average 0.15 LE/m^3) that accrue to them. For example, Cairo water tariffs are among the lowest among developing country megacities and pay for only 25 percent and 10 percent of the actual costs of water supply and sanitation, respectively. Cost recovery in secondary cities/towns is better for water supply (Alexandria's is as high as 50 percent), although equally low (10 percent) for sanitation. Consequently, since establishing NOPWASD (1981) and the economic authorities (1995), these entities regularly have been bailed out through sovereign aid and domestic loans that are never repaid.

Recent attempts to increase Cairo's tariffs are awaiting concurrence from the local councils and the national Parliament. Low tariffs not only impose a heavy recurrent fiscal burden on the national budget but also generate disincentives for operational efficiency and responsiveness to consumers.

Prior to establishing the WSS holding company, governors had the authority to set water prices to a ceiling of LE 0.23 /m^3. Although this ceiling was below actual production costs by a factor of 3–4, not many governors utilized even this authorization.

The final outcome was that domestic loans and sovereign services aid (figure 3.6) became the sources of finances for even routine O&M. The O&M subsidies to the subsector were estimated at 3–4 billion LE/annum, or 2.0 percent–2.5 percent of total public recurrent expenditures. Thus, the debt overhang of the WSS subsector reached 14 billion LE.

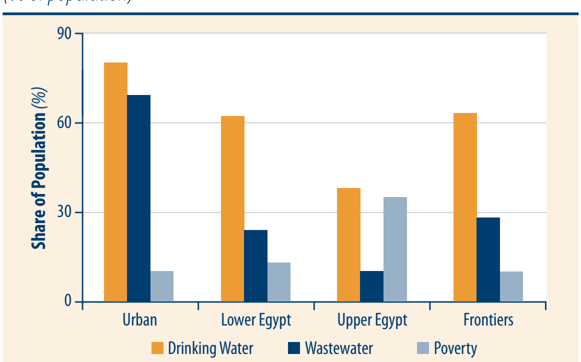
Sources of Debt

In Egypt the WSS debt overhang has escalated (figure 3.9) for two reasons:

a. First, WSS economic authorities (overseen by governorates) are expected to pay for their O&M costs through user fees. However, there is a wide gap between the actual cost of water supply (0.8–1.00 LE/m^3) that the authorities incur, and the user-tariffs (0.15 LE/m^3 on average) that accrue to them. The consequence is that since the National Organization for Potable Water and Sanitary Drainage (NOPWASD) was established in 1981, and the economic authorities in 1995, these entities have been bailed out regularly by sovereign aid and domestic loans that rarely get repaid.
b. Second, in the absence of adequate cash flow from service users, these agencies are fully dependent on O&M government budget transfers. As these transfers often are based on historical precedents, they often become biased toward paying wages rather than toward creating an effective O&M; or they become biased toward existing assets (such as water/wastewater plants and distribution networks) rather than new ones. The consequence is "deferred maintenance," a situation that leads to unnecessary deterioration of assets and (eventually) costly rehabilitation that could have been avoided by less costly routine/preventive maintenance.

The rehabilitation of WSS infrastructure triggers cycles of debt because the utilities/NOPWASD are forced to borrow from the National Investment Bank (NIB) or seek (often off-budget) subventions to meet their pressing rehabilitation needs. Under these circumstances, passing on the debt to the newly created holding company does not resolve the problem. It simply passes on the problem to a new organization that lacks the capacity to manage the problem.

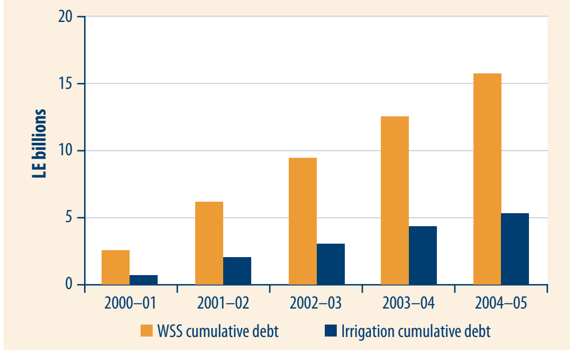
Figure 3.8 Poverty and Access to Water and Wastewater
(% of population)



Source: World Bank 2005.

A similar analogy can be applied to MWRI's holding companies for new lands. However, GoE has not been as apprehensive about the debt of the irrigation subsector as it has about that of WSS. The reasons are two. First, irrigation debt has not reached such an unwieldy level as has WSS (figure 3.9). Second, much of the irrigation debt has been used to finance trunk-infrastructure investments of the "public good" type, which can be deemed sunk costs.

Figure 3.9 Cumulative Debts of WSS and Irrigation Subsectors



Source: MOF annual data on the debt repayment by, versus loans to, the irrigation and WSS subsectors (reference year is 2000).

Inequitable Outcomes

The equity impacts of the existing sectoral arrangements can be summed up in four points:

1. Customers in secondary cities and rural areas incur higher WSS service prices than in major cities. In many rural/periurban areas, water vendors supply potable water to households that have standpipes, charging more than 10 times the actual cost for piped-water prices. Moreover, poor farmers already pay as much as 10 percent of their incomes for wastewater removal from cesspools, which fact suggests their willingness to pay for a better service-provision option.
2. WSS tariffs are heavily subsidized. Hence, increasing block tariff structures may end up targeting cross-subsidies on the nonpoor (for example, because the nonpoor may have smaller families or may be able afford to use water-saving appliances, compared to the poor), not penalizing the wasteful users.
3. Poorer areas have the worst WSS services (figure 3.8).
4. A fee of 70 LE–100 LE per feddan/year is estimated to be adequate to meet the full O&M costs for irrigation services. This amount would be an average reduction in farm incomes of 5 percent, a percentage likely to be affordable to big and medium holders. In the absence of targeting, subsidies are benefiting the richer farmers, who use the most water.

Responding to Challenges: GOE Policy Actions Taken

The government's vision for sustainable financing for the water sector is to (a) explore alternative cost-sharing arrangements with decentralized service delivery institutions, (b) progressively turn over financial responsibility for O&M to water utilities or water user organizations, and (c) establish full cost-recovery arrangements between the government and farmers/investors in the new lands.

GOE proposes to encourage public-private partnerships (PPP) in the financing, operation, and management of irrigation and water supply infrastructure. Recently established holding companies are being encouraged to seek out private partners who can share capital and O&M costs for both the expanded irrigation network in Toshka and El-Salam canal, and for the WSS subsectors.

Irrigation

The Water Boards Project is testing ways to transfer water management responsibilities at the secondary level of the irrigation system from MWRI to user organizations. This transfer would reduce the government's contribution to O&M costs by approximately 50 percent. The extra burden on farmers is expected to be partially compensated by exempting them from paying land taxes to local governments. The IIIMP will be testing new organizational arrangements that link the MWRI's investment and operational functions to user organizations' responsibility for operating and maintaining the irrigation network below the branch canal level.

Water Supply

While GOE's efforts at WSS decentralization have focused on changing the institutional arrangements, the latter have not as yet adequately addressed service efficiency concerns:

- Increased WSS tariff collection responsibilities at the governorate level very well could end up simply topping-up employee wages, unless the latter are made contingent on either increased labor productivity or improved O&M services.
- There are as yet no policies for penalizing nonpaying customers. Government and public sector institutions often are exempted from paying water bills.

- The cost of water treatment and distribution has not been fully borne by industrial users because government subsidies supporting O&M costs benefit all users (for both water and wastewater treatment). On average, for example, industries are billed 1 LE /m^3 for water, which is often substantially below the costs of delivering the service.
- There also is a pronounced regional bias in WSS services that favors major cities in the Nile Delta and along the Suez Canal. Even though rural population densities are high in the delta, there is almost no sewerage in Upper Egypt or generally in rural areas. Sanitation has been defined as an urban public service, and no institution/agency has adopted providing sanitation to the rural areas (figure 3.8).

Recommended Policy Orientations

Increase Recovery of Recurrent Costs

Egypt's hydraulic infrastructure has been constructed over several millennia and is dependent on a storage, distribution, and collection system around a single river. The public-good aspect of a significant part of MWRI expenditures (headworks and main canal systems) always will remain. However, significant budgetary savings could be accomplished by devolving irrigation and WSS service functions to locally accountable institutions. To this end, holding companies should be vested with wider authorities to raise tariffs and recruit employees. These companies also should be entrusted with more proactive roles beyond O&M and undertake new investments. Concerning WSS services, the medium-term policy should focus on recovering O&M and amortization costs from the users. Increased private sector interest will take place only when there is clear evidence of reliable cash flow from users.

Over recent decades, public finance of irrigation expansion in the "new lands" has taken place over vast expanses of the desert around the Nile River system. Mega projects such as Toshka in southwest Egypt, and El-Salam Canal east of the Nile Delta and Sinai have been implemented. These decisions have been based on economic, social, and political considerations that include developing agroindustrial communities and investment zones outside the Nile Valley to decongest the valley system. However, there are significant opportunity costs of these investments, which have absorbed billions of dollars of scarce public resources. Future investments could follow two criteria:

1. Maximize "crop value per drop," meaning that the revenues generated from irrigated agriculture should focus on high-value crops that generate income and employment opportunities.[3]
2. Cost-recovery through volumetric pricing of water services.

Use a Part of Recurrent Cost Savings to Leverage Investments That Focus on Low-Income Communities and Urgent Environmental Expenditures

The recurrent cost savings could be used to leverage donor financing to support a nationwide targeted program aimed at improving water and sanitation services in low-income communities. For water supply, the focus could be on the low-income communities of Upper Egypt through national budgetary finance. Concerning water quality, one subregion's untreated wastewater becomes the downstream community's pollution problem. Moreover, the financing requirements to tackle the costs of environmental degradation are enormous and require significant long-term donor concessional commitments.[4]

Establish Criteria to Ensure That New Public Investments Do Not Substitute for the Maintenance of Existing Hydraulic Infrastructure Assets

Until the above reforms are instituted, public expenditures will continue to be the main sources of maintaining existing assets. In this case, developing new assets financed through public appropriations[5] should not substitute for public appropriations to maintain existing assets.[6]

[3] The "old lands" in the Nile Valley are restricted by heavy soils, very small tenures, and traditional farming systems dating back thousands of years. Each of these restrictions impedes fostering a cropping pattern that maximizes net exports.

[4] See Shawky and others, ""Assessing the Efficiency and Equity of Water Subsidies: Spending Less for Better Services" in this volume.

[5] Chapters 3 and 4 of the budget (according to the budget structure of the Ministry of Finance in 2005).

[6] Chapter 2 of the budget for regular/preventive maintenance and chapter 3 for occasional/major rehabilitation.

Decentralize

Decentralization of governmental responsibilities and community participation in service planning and delivery must be deepened. It requires the participation of water user groups in the planning, design, implementation, and O&M of water works; in setting and administering tariffs; and in supervision and quality control. Decentralization also intends to eliminate government involvement in routine O&M/rehabilitation of irrigation systems. In the WSS sector, utilities need to be accountable to local users and elected bodies, such as municipal councils. Meaningful participation cannot be achieved unless there is greater transfer of responsibility, authority, and resources to grassroots user groups.

Deal with Debt

Most of the water sector's domestic debts have short maturity and therefore are not appropriate instruments to finance this type of long-term investment. Furthermore, as the domestic debt is not actually repaid through revenues from water tariffs, its write-off by the government becomes inevitable.

As in the Philippines (box 3.1), the long-run success of decentralization requires the resolution of the debt overhang.

A possible solution is to link debt relief with the accomplishment of the key institutional reform milestones: improving financial and operational efficiency. For example, the WSS holding company's debts could be written off after the accomplishment of milestones linked to

Box 3.1 Water Management in the Philippines

In the Philippines, after the law devolved O&M responsibilities from the National Irrigation Administration (NIA) to the local governments/communities, local governments/communities have been reluctant to take over the O&M of communal irrigation systems. In addition to the lack of capacity at the local level, reluctance was due to the debt overhang that also was to be passed from NIA to the local governments/communities. Eventually, national legislation was necessary to write off most of the debt. NIA also offered a pilot program in which a considerable part of the debt is waived if local governments/communities contribute immediate equity through fostering local private investment in irrigation and raising user fees.

financial and operational efficiency. Performance could be monitored through five key indicators, such as debt service ratio, unaccounted-for-water (UFW) percent,[7] number of staff per 1,000 connections, total number of connections, and 100 percent metering of all water connections/subscriptions.[8] External support through a sector-wide approach (SWAp) operation or debt restructuring could improve service performance.

Address Procurement Inefficiencies

One glaring example of procurement inefficiencies is the lack of transparency. Inappropriate procurement practices can be controlled if oversight of the tendering process explicitly involves the *participation of beneficiary communities*. Current procurement practices are designed to safeguard the integrity of public spending but often end up creating the opposite effect. Delays in awarding contracts and in honoring government payment commitments to contractors result in the lack of interest among highly competent Egyptian companies in bidding for government contracts. Overstaffing in departments has resulted in unnecessary procedures and paperwork, often as "make-work" assignments for government staff. Furthermore, the practice of retaining retirees as senior management advisors/consultants demotivates middle-level staff.

Ensure Appropriate Design of Water Facilities and Choice of Technologies

The technologies selected in providing water services often are *oversized* and *not cost-effective*, and *increase O&M costs to users*. An example from the irrigation subsector at the tertiary-canal level is pumping facilities (pump set and pump house) and pipelines that have been oversized to "guarantee" reliable irrigation deliveries. A cost-effective alternative would be to involve the Ministry of Agriculture and Land Reclamation (MALR) in improving extension services and MWRI in improving the ability of a farmer to receive water on demand, that is, through continuous

---

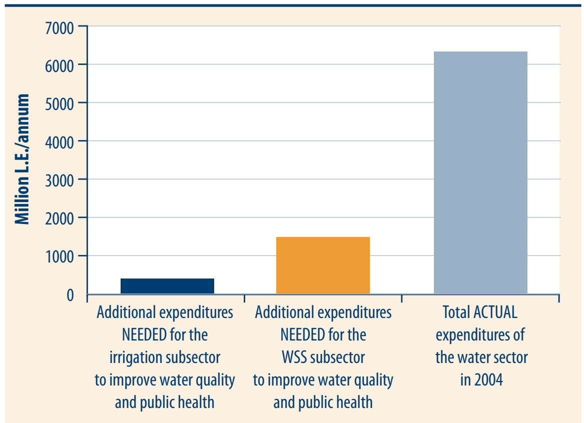
[7] Unaccounted-for-water (UFW) includes leaks and water supplied to illegal connections.

[8] See example on Egypt's WSS benchmarking indicators in chapter 4 by Shawky and others.

flow. These concepts are being tested in the IIIMP.[9]

Rather than being unilaterally imposed by one agency solely to meet engineering/technical criteria, technology choice should be based on comprehensive (multi-agency) and cost-effective plans. These comprehensive plans should be coordinated jointly by MoF, Ministry of Planning, NOPWASD, Egyptian Environmental Affairs Agency (EEAA), MWRI, Ministry of Health and Population (MoHP), and Ministry of Local Development (MoLD). Therefore, sequential and prioritized spatial coverage of services and adoption of low-cost technologies should be sought.

Figure 3.10 Actual Expenditures vs. Needs *(M LE/yr)*



Source: MOF (2004) data and World Bank (2005).

In figure 3.10, actual public expenditure[10] (light blue) vs. needs (orange plus blue) show that savings from expenditure rationalization can be reallocated to meet the unfunded needs.

Savings from the public expenditure can largely be achieved through:

- The aforementioned policy orientations 1 and 2: financing recurrent expenditure through targeted end-user fees will free some public funds that then can be spent on public-like needs, such as water quality. This is an example of an "allocative" efficiency.
- The aforementioned policy orientations 6 on procurement efficiency and 7 on "right-sizing" the works. These are technical efficiencies

Rationalize the Institutional Architecture

There is room for cost-saving toward through reducing overhead costs. The WSS subsector has begun to reduce overheads through establishing

---

[9] See in this volume the chapter entitled "Egypt: Irrigation Innovations in the Nile Delta" by Jose Simas and others, in which the W-10 pilot has tackled this oversizing issue (albeit on a demonstration scale).

[10] Summation of the long-term capital investments "annualized" for 2004, plus recurrent expenditure actually spent in 2004.

the holding company described above. In the irrigation subsector, MWRI is piloting programs to reduce overheads within the governorate level, namely, at the *water directorates and water districts* levels. Supported by a USAID project and IIIMP, MWRI is piloting *Integrated Water Management Districts* (IWMDs), which assume the *O&M* roles. The IWMDs are entities integrated at the district level based on hydrological rather than administrative boundaries. To remedy the current fragmented structure, in the IWMDs, all MWRI departments are represented in one organization. This structure is expected to reduce O&M transaction costs as well as to improve O&M at the district level. The next step is to pilot *Integrated Water Management Directorates,* which assume *design and construction* roles. The lessons from these pilots will be used to scale up the concept throughout Egypt.

It is advisable to change the accounting practices by posting all water-related costs under one account within the general state budget. This change could unify the present fragmentation among different institutions.

Form Partnerships with the Private Sector

Beyond the adoption of holding companies, more advanced PPP models in irrigation and WSS need to be piloted. The depth and mode of private participation will depend critically upon measures taken to improve cost-recovery.

Recommended Immediate Actions

The short-term policy recommendations drawn from this PER analysis are:

1. a. *Amend Law 12/1984*. Irrigation Management Transfer (IMT) to water user associations/groups is envisaged to reduce the fiscal burden on the government, while improving local irrigation services. These groups need the authority to collect, retain, and administer user fees. There is an enforceable legal basis for WUAs to raise (land) taxes to recover O&M costs of the tertiary canals, because these canals are privately owned by farmers. However,

branch canals are public assets, and there is no legal basis for WUAs and Water Boards to recover O&M costs. Unless Law 12/1984 is amended, the suggested reforms cannot be effected.

2. b. *Put in place a subsectoral investment and restructuring program in WSS*. By virtue of two presidential decrees,[11] a legal basis has been initiated for the WSS holding company and its affiliated companies to raise tariffs and achieve financial autonomy. However, these utilities face a difficult organizational challenge. The basic infrastructure, such as universal metering, is not in place; users are skeptical of their capacity to improve services; the debt overhang restricts the flexibility of financial management; and the organizations are heavily overstaffed.

What is required is a wide-ranging investment and restructuring program to simultaneously improve service quality and the financial autonomy of WSS companies.

References

World Bank. 2002. "Cost Assessment of Environmental Degradation." A Sector Note. Middle East and North Africa Region. Report #25175. June.

[11] In 2004, two Presidential Decrees were issued that regulated the WSS subsector under the responsibility of the MHUNC. The first decree, 135 for 2004, is concerned with the creation of a Holding Company for Drinking Water and Sanitation and its affiliated companies that include the General Economic Authorities for Drinking Water and Sanitation operating in the governorates. The second Presidential Decree, 136 for 2004, covers the creation of the *Central Authority for the Drinking Water and Sanitation Sector, and Protection of the Consumer*. This decree aims at regulating and monitoring for quality control and consumer-price control.

4

Assessing the Efficiency and Equity of Water Subsidies: Spending Less for Better Services

Ahmed Shawky Mohamed, Alexander Kremer, and Manish Kumar

Background and Objective

This chapter is a sequel to chapter 3 on water sector issues and expenditure patterns in Egypt.[1] This chapter identifies how public expenditure could be reallocated to improve equity and productivity.

Water Has Public and Private Features

A public good is "nonexcludable" because it is costly or unrealistic to link end-user charges to usage. A public good is also "nonsubtractable": one person's use of the infrastructure or the service does not detract from another person's use. Trunk water infrastructure[2]—multipurpose dams/barrages, multipurpose conveyance canals, flood control infrastructures, and major water/wastewater treatment plants—are public goods. They may be efficiently funded by flat charges or general/sovereign revenues, and there is no reason to link end-user payments to their usage.

However, when water reaches the end-user, it becomes a private good. A private good is *subtractable*, meaning that one person's use subtracts from another's; and *excludable*, meaning that one can

[1] This chapter originated as Water Policy Note 2 (World Bank 2005b), the second on Egypt's water sector, as part of the analytical work supporting the Public Expenditure Review (PER) in Egypt, a collaboration between the Government of Egypt and the World Bank. The aim was to inform government decisionmaking on increasing the value added from water and curbing the socioeconomic costs of water pollution, while reducing the burden on the government budget.

[2] This is true for the infrastructure although not, of course, for the water resource base.

stop nonpayers from using it. In other words, it is efficient to charge the user and earmark user charges to cover the costs of the service. Charging can help to ensure that the good is not over-consumed. One example of a private good is "on-farm" water, the water flowing into tertiary/quaternary canals of the irrigation network. Another example is household water supply and sanitation connections.

Figure 4.1 Breakdown of Capital Spending between Public and Private Goods

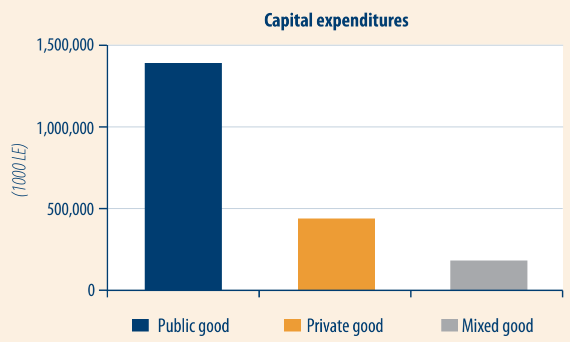
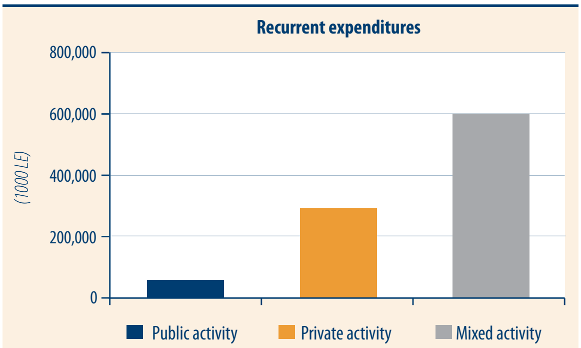


Figure 4.2 Breakdown of GOE Recurrent Spending on Public and Private Goods



Government Spends on Private Goods

Egypt's capital spending on irrigation is primarily for public goods, but the Egyptian government also makes a major allocation to private goods (figure 4.1). The message in figure 4.2 is more dramatic: public recurrent expenditure has been almost entirely on private-good aspects of water delivery.

This observation can be coupled with the observations of chapter 3 (first published as World Bank 2005a). Egypt's water infrastructure is suffering from inadequate maintenance. Increased user charges for downstream operations and maintenance (O&M) could release public resources for priority maintenance of deteriorating upstream infrastructure. These resources, in turn, would reduce the need for public funding of infrastructure rehabilitation. They also would release public resources for under-funded public priorities such as wastewater collection and treatment.

Potential Efficiency Gains

One can measure the potential for improved efficiency by benchmarking institutions' performance.

Water for Irrigation

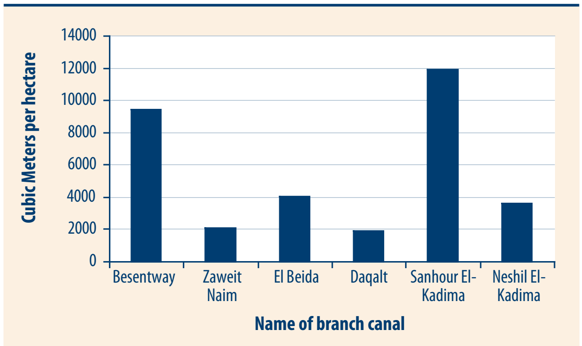
Performance benchmarking in irrigation and agricultural drainage

The three common types of irrigation benchmarking indicators are[3]:

a. *Service reliability indicators.* These indicators may include (1) the intra-farm uniformity of water application, measured at the root zone and (2) the adequacy and reliability of irrigation delivery, assessed against engineering/technical benchmarks.
b. *Internal indicators.* These compare system outputs with inputs. The indicators may include (1) assessing the ratio of the water usage to the water actually delivered at various levels of the system and (2) economic efficiency (cost-benefit ratio).
c. *Comparative indicators.* These indicators assess impacts of irrigated agriculture across comparable irrigation systems and/or through time. An example would be to assess productivity as the actual production per unit of water divided by the norm.

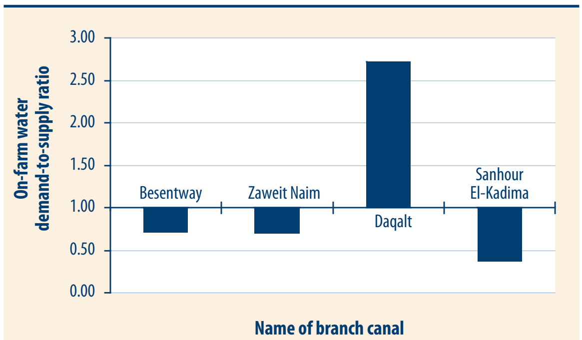
The performance benchmarking undertaken below for the irrigation subsector tends toward the internal and comparative types.

Figure 4.3 Seasonal Irrigation Water Supply per Unit Agricultural Area



Source: Agriculture and Rural Development Department (ARD), World Bank, communicated by Safwat Abdel Dayem, former World Bank Drainage Advisor.

Figure 4.4 On-Farm Water Demand/Supply Ratio
(Ratios Exceeding 1 Indicate Shortage; Less than 1, Excess)



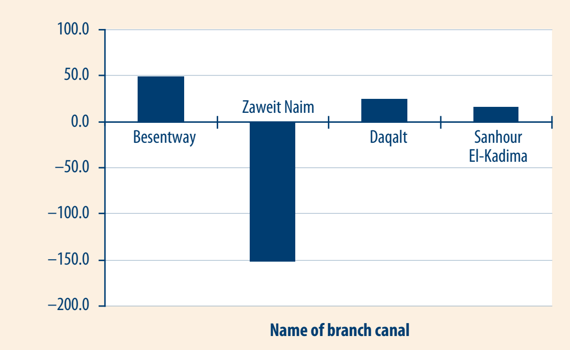
Source: Agriculture and Rural Development Department (ARD), World Bank, communicated by Safwat Abdel Dayem, former World Bank Drainage Advisor.

Better use of water and efficient irrigation practices

The analysis supported by figures 4.3–4.11 draws from a 2002–03 dataset, which may not be representative of the current nationwide

[3] See International Programme for Technology and Research in Irrigation and Drainage, www.fao.org/iptrid/

Figure 4.5 Canal-System Efficiency of Water Delivery
(Water Supply at Canal Level vs. Farm Level) (%)



Source: Agriculture and Rural Development Department (ARD), World Bank, communicated by Safwat Abdel Dayem, former World Bank Drainage Advisor.

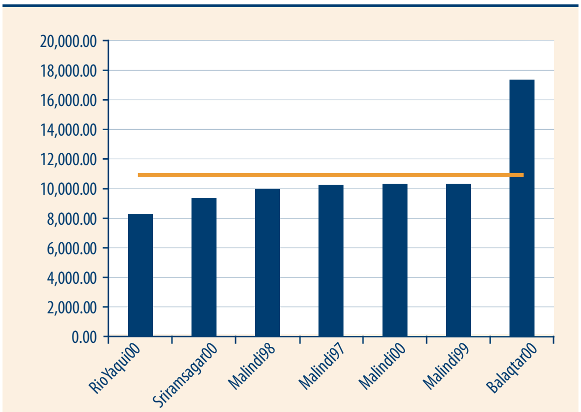
context. Therefore, the results and the argumentation drawn may not apply to all irrigation schemes in Egypt. The intention was more to make a case for scaling up the benchmarking exercise (when more ample data sets are available), as part of the IWRM *ASSESSMENT* exercise advocated in this volume.

Figures 4.3–4.5 compare the irrigation *technical efficiency* of 6 *branch-canal* command areas in Egypt. They show that some regions use water much more productively than others. Figure 4.3 compares seasonal water supply per hectare; figure 4.4 compares the on-farm water supply-demand ratios; and figure 4.5 compares the canal-system efficiency of water delivery.

The branch canal level is the secondary level in the Egyptian irrigation delivery system, below the trunk/main canal level. Being under public ownership, the branch canal level is managed and financed by the Ministry of Water Resources and Irrigation (MWRI). However, the MWRI piloted various programs to hand over its management to Water Boards (World Bank 2005). The rationale was that the canal-drainage system is a private good from the branch-canal level downward.

The data in figures 4.3–4.5[4] depict a significant disparity in performance among the 6 command areas. MWRI distributes water among command areas in proportion to crop water requirements, adjusted for cropping area. Therefore, any variation in water availability per unit area at

Figure 4.6 Annual Irrigation Supply per Unit Irrigated Area
(m^3/ha)



[4] Figures 4.4 and 4.5 lack 2 of the 6 observations of figure 4.3 due to lack of data.

the field level can be attributed only to water management inefficiencies downstream of the allocation point, namely, at the secondary level and below.

Figures 4.6–4.8 compare the technical and operational performance of Balaqtar, a representative canal in Egypt, with comparable canals in India (Sriramsagar), Mexico (Rio Yaqui), and Kenya (Malindi) (World Bank 2003). The comparison reveals a significant potential for improving the operational and managerial performance of the feeder level of Balaqtar.

The data in figures 4.3–4.8 support the argument for transferring the management and finance of the nonheadwork canal systems to water user organizations (with temporary technical backstopping from MWRI). This would not only reduce public spending but also ensure more efficient irrigation practices (World Bank 2005).

Economic efficiency of irrigation

Figure 4.9 compares the economic efficiency of irrigation in Egypt and other countries. The monetary value of agricultural production per unit of water is used as an indicator of economic efficiency. Although the crop-yield-per-unit-area in Egypt is quite high (particularly with rice), figure 4.9 clearly suggests that

Figure 4.7 Cost-Recovery Ratio

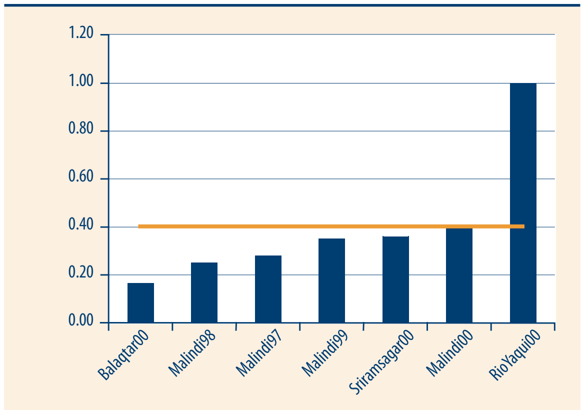


Figure 4.8 Average Depth to Shallow Water *(m)*

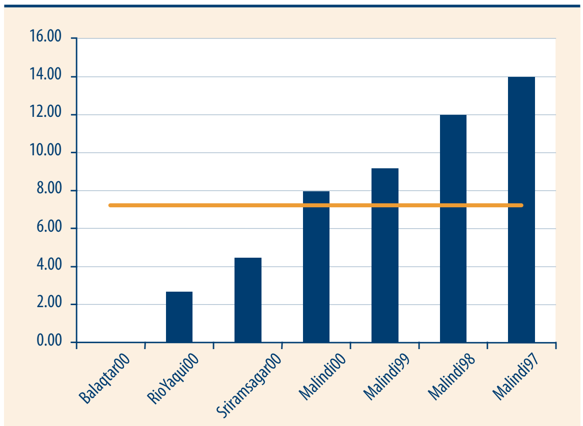


Figure 4.9 Average Production Value per Unit of Irrigation Supply *(US$/m³/annum)*

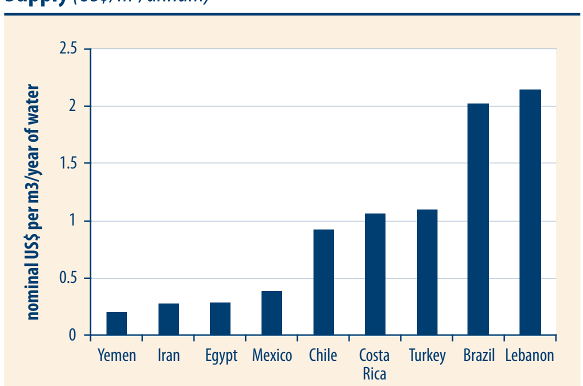
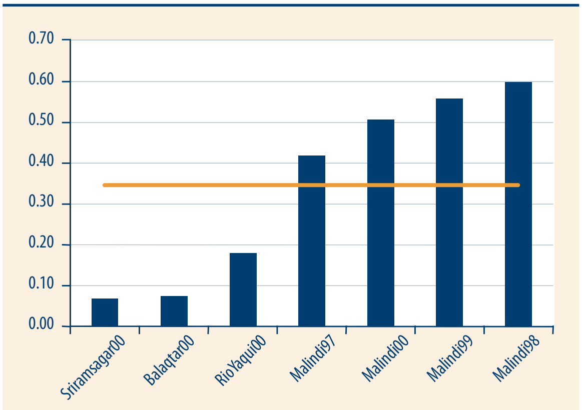


Figure 4.10 Production Value per Unit Irrigation Supply *(US$/m³/season)*



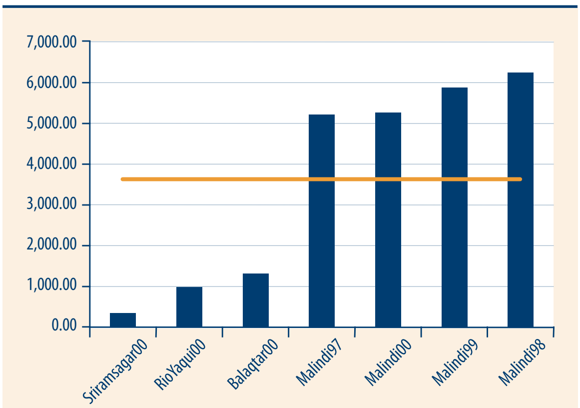
the economic returns to irrigation water in Egypt are lower than international norms.

Figures 4.10 and 4.11 (World Bank 2003) support this argument by comparing the performance of Balaqtar Canal with comparable canals in India, Kenya, and Mexico.

The causes of the low socio-economic returns to irrigation water are twofold:

a. Inefficiency in agricultural production and supply chains. Even though this is outside the water sector, it reduces the return on irrigation sector investment.
b. Low technical efficiency at the canal/farm level.

Figure 4.11 Production Value per Unit Irrigated Area, Including Multiple Cropping *(US$/ha)*



Potable Water and Sanitation

Robust indicators for the WSS subsector have been established and used world-wide. Cost-recovery in Egypt is very low (table 4.1).

Unaccounted-for Water (UFW) Is High

Unaccounted-for water (UFW) is one of the most important indicators of efficiency in the WSS subsector. UFW is defined as water that is not metered or billed to customers. It is calculated by subtracting the metered consumption from the total amount of water supplied to the water system. UFW comprises:

1. Apparent water loss arising from meter inaccuracies and improper accounting of water used in filling new mains, connections, and service reservoirs, and for flushing the water distribution system during maintenance.

Table 4.1 Benchmarking Water and Sanitation Subsector

Governorate/ indicator	Capital cost-recovery ratio *(%)*	Consumption *(liter/capita/day)*	Debt service ratio *(%)*	No. staff/1000 connection	
Benchmark (norm)	50	80 rural/150 urban		1 to 3	
				Water	Wastewater
Aswan	3	108	−383	NA	10
Alexandria Water	4	351	−16	14	DNA
Alexandria Wastewater	32	NA	41	4	NA
Beheira	14	85	111	8	NA
Beni Suef	6	52	−8	7	20
Cairo Water	3	252	−192	NA	14
Cairo Wastewater	9	NA	−450	14	NA
Dakahlia	6	DNA	−4	6	6
Damietta	14	DNA	0	7	DNA
Fayoum	8	102	−15	4	DNA
Gharbia	5	81	−3	7	17
Kafr El Sheikh	12	124	0	7	15
Minia	6	DNA	0	9	DNA
Sharqeya	7	100	−4	6	10

Source: Personal communication with USAID.
Notes: NA = Not applicable; DNA = Data not available.
1. Capital cost-recovery ratio = Revenues/total net fixed assets.
2. Debt service ratio = Debt service/operating profit (loss) before depreciation.

2. Actual water loss due to leaks and theft.

In Egypt, quality UFW data is scarce. Studies on specific areas show UFW values from 50 percent–67 percent. This percentage is usually higher for smaller municipalities. A data set for 15 governorates shows a UFW range among governorates of 15 (Cairo) to 56 percent (Fayoum), with a weighted average for the 15 governorates of 30 percent.

In developed countries, UFW usually ranges from less than 10 percent for new systems to 25 percent for older systems. However, some Eastern European and African countries regularly reach 40 to 50 percent, or even 60 percent.

Comparing the indicators for Egypt with those observed from the comparable international norms, one can conclude:

- A number of staff per 1,000 population served well above 5, indicating heavy overstaffing

- Very low cost-recovery ratios and debt service ratios
- Accurate UFW percentages not known, but probably at typical developing-country levels (30 percent–50 percent)
- Large disparities in liter/capita/day usage rates across country.

Government policy is that water utilities should be financially autonomous. However, because of low end-user tariffs, the government inevitably bails out loss-making utilities with grants from the Ministry of Finance and loans from the National Investment Bank (NIB). Higher rates would help GOE to achieve its goal of financial autonomy for water utilities. Rate increases also would enable and encourage the utilities to improve technical efficiency (unit service per unit expenditure).

In conclusion, Egypt's water and sanitation services are less financially sustainable than the developing-country norm. Regarding water management efficiency, the country's services are possibly on a par with utilities in Eastern Europe and Sub-Saharan Africa.

Improved Wastewater Disposal Will Benefit the Entire Nation

We have shown above that a disproportionate volume of public spending is allocated to *private* goods. At the same time, there are great unrealized opportunities for public spending on *public* goods. Wastewater disposal is a case in point.

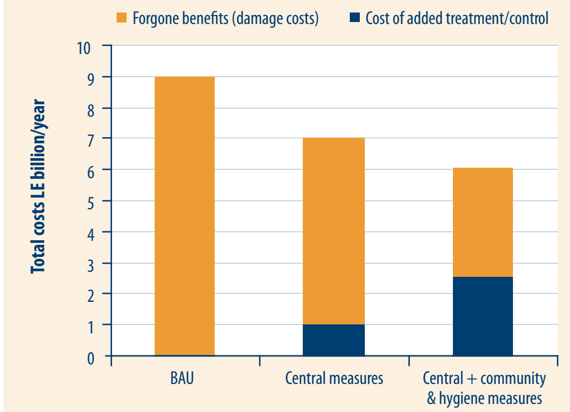
As part of the Country Environmental Analysis of Egypt (World Bank 2005), a study was undertaken to estimate the socioeconomic cost of the disposal of maltreated or untreated wastewater. Three policy options were compared:

1. Business as Usual (BAU), the status quo
2. Government-led centralized actions including those executed in urban and suburban areas, as proposed by the National Plan for the Protection of the Water Resources of Egypt (2003)
3. Option b plus community-based and hygiene measures to control the unsafe disposal of rural sewage.

The study has estimated that the socioeconomic cost of maltreated/untreated wastewater is higher than LE 9 billion, or 2 percent of GDP (figure 4.12). These costs represent the harm caused to human health, agriculture, and fisheries.

Better wastewater disposal is a classic case of a public good because it would benefit the entire nation, particularly those downstream who cannot easily protect themselves. By implementing the measures cited in the 2003 National Plan for the Protection of Water Resources, Egypt could achieve a net benefit of LE 2 billion. The addition of community-based and self-financed sanitation programs could produce an extra net benefit of LE 1 billion. See details in appendix 2 and in chapter 3 (World Bank Policy Note 2005).

Figure 4.12 Cost-Benefit Analysis of Improving Wastewater Disposal



Do Water Subsidies Support Incomes of Poorer Households?

As argued above, downstream O&M expenditures provide private goods and should be covered by user charges. Switching to user charges would release public expenditures for priority public needs, such as wastewater treatment.

However, one possible justification for public subsidies to downstream O&M is that it is an efficient way to support the incomes of poorer households. According to this argument, water subsidies would play the role of a social welfare transfer from the taxpayer to the poor.

The methodology of Benefit Incidence Assessment (BIA) can test whether water subsidies are an effective social welfare transfer. BIA studies the distributional impact of public expenditures and whether it is pro-poor. A subsidy is defined as progressive if the absolute value of the benefit is greater for a poor household than for a rich one. The information acquired can be a useful input for policymakers concerned with the improved targeting of programs and subsidies.

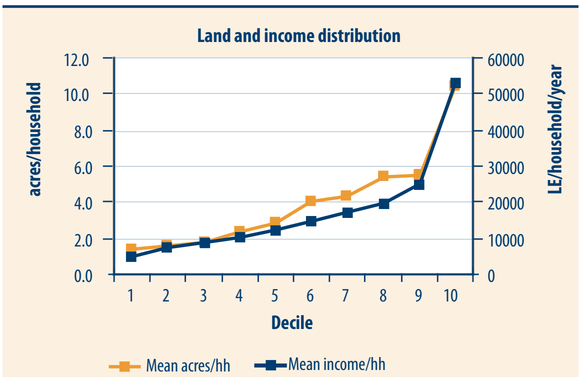
This BIA analyzes whether the current irrigation subsidy is progressive (appendix A4.1). The analysis is run for two samples of agricultural households from the western areas of the Delta region

There are inherent difficulties with BIA of the irrigation sector. BIAs for education or health services utilize the difference in *participation* by the poor vis-a-vis the rich. However, this methodology is inadequate for irrigation because households use irrigation to different degrees. Therefore, the study attempts to differentiate the level of participation among households. Ideally, this differentiation would be achieved by measuring *water utilized* on each household's farm, but it is difficult to measure water utilized on a farm. In fact, in Egypt, irrigation water is not metered at canal-to-farm turnouts. Irrigation water utilization is a function of area cultivated, crop type, soil type, climate, and on-farm irrigation technology.

Two samples were taken at different times and in zones with different socioeconomic characteristics. Sample A was taken from districts in three governorates and used landholding as a proxy for water use. Sample B was drawn from 7 villages in 1 governorate and included water-use data collected by interviewing a random sample of rural householders.

Findings

Figure 4.13 Farmer Land and Income Distribution



Sample A

Figure 4.13 shows the relationship between households' landholdings and incomes. Households in the richest income decile own on average 10.8 acres, compared with 1.4 acres in the poorest decile.

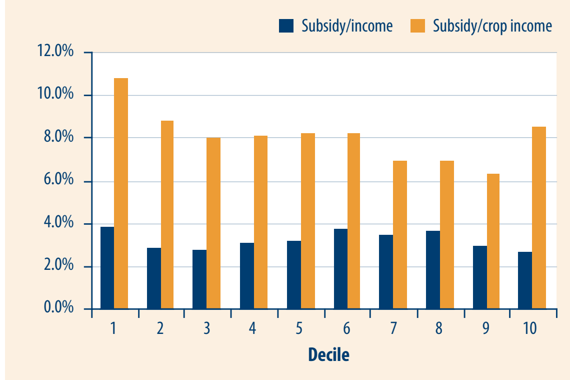
On the assumption that water use and subsidies are proportional to landholdings, there is a strong correlation between a household's income and its benefit from water subsidies. The richer households benefit most. According to the data in this sample, exactly 75 percent of the water subsidy benefits the richest 50 percent of households, whereas only 25 percent benefits the poorest 50 percent. Only 9.7 percent of the total public subsidy is received by the poorest 25 percent of households.

These findings indicate that irrigation subsidies are not justified as a policy instrument for the redistribution of income. The main beneficiaries of subsidies are the rich, not the poor.

The average value of the irrigation subsidy is LE 137/acre. Using this figure, it is possible to (1) calculate the importance of the irrigation subsidy as a percentage of total household income for richer and poorer households and (2) see whether removing the subsidy would have a disproportionately severe impact on the livelihoods of poor households.

The irrigation subsidy is worth 2.5 percent–4 percent of the income of rural households of all income classes (figure 4.14). There is no clear correlation between household income and the importance of the irrigation subsidy as a share of income. The irrigation subsidy is therefore not a major contributor to household income for the poor.

Figure 4.14 Irrigation Subsidy as Share of Income



The delegation of the management and financing of downstream irrigation systems to water user associations (WUAs) would involve an increase in water charges to farmers. Delegation also would help farmers improve their crop yields through better water management. Therefore, it is useful to calculate the irrigation subsidy as a percentage share of farmers' crop income. This method would show the increase of crop income needed (as a result of better water management) to compensate farmers when the irrigation subsidy is withdrawn.

The required increase in crop income to compensate farmers for losing the irrigation subsidy would range from 6 percent–11 percent. The required increase in crop production is higher for poorer farmers than for richer farmers. The reason is that richer farmers achieve higher levels of crop income per acre, so the subsidy is lower as a share of their crop incomes. However, even for poorer farmers, the yield increases required are well within the range that is expected to result from improved water management.

Sample B

Sample B represents 60 farms (not households) in the Western Delta area. This zone of newly developed land is characterized by larger, more commercial operations specializing in high-value cropping. Thus, it is not representative of Egyptian farming as a whole. For Sample B, farm

Figure 4.15 Mean Water Use by Crop Income Quintile

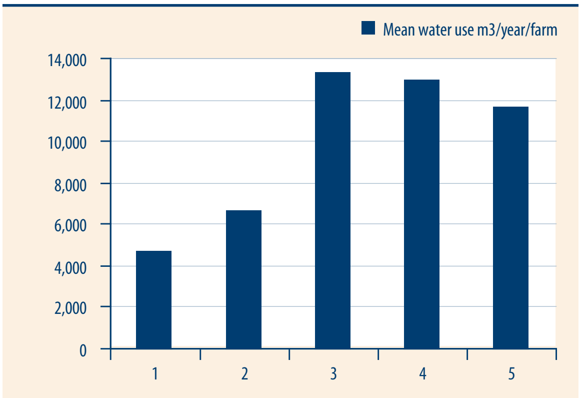


Figure 4.16 Use of Water-Saving Systems by Crop Income Quintile

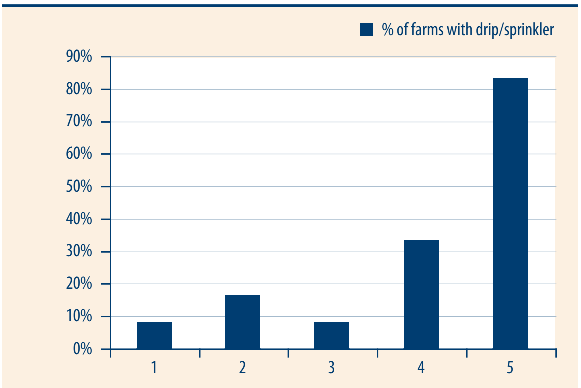
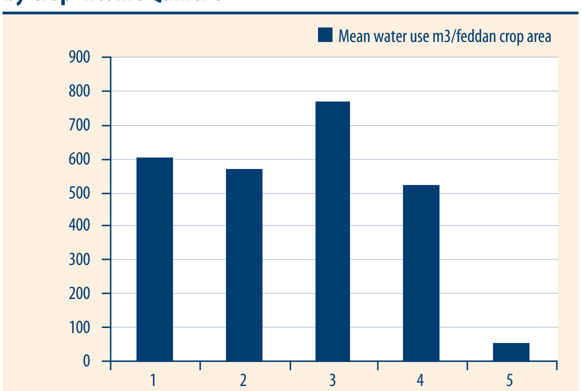


Figure 4.17 Water Use per Cropped Area by Crop Income Quintile



crop income—not household income—has been the measure according to which the income quintiles are established.

As noted above, the dataset for Sample B includes estimates of water use in irrigation by farm. Thus, it is possible to do without the assumption that water use is proportional to landholding. Indeed, water use per unit area is significantly different among farmers of different income groups.

Figure 4.15 plots the benefit incidence by income quintiles. Again, the allocation of the subsidy is regressive, meaning that most of it is captured by high-income farms. In this case, the 50 percent of farms with the lowest incomes receive only 36 percent of the subsidy, and the 25 percent of farms with the lowest incomes receive only 13 percent of the subsidy.

The reason that the subsidy distribution in Sample B is less regressive than that in Sample A is that the larger farms in Sample B are more likely to use water-saving irrigation equipment (drip and/or sprinkler), instead of furrow irrigation. For this reason, even though the land area is significantly larger, the volume of water used per farm is slightly lower in the fourth and fifth income quintiles than in the third. Rates of usage of water-saving equipment are illustrated in figure 4.16. Investment in such systems is a characteristic of the high-value commercial farming practiced in the Western Delta region, from which Sample B is drawn.

However, it is likely that the analysis above understates the regressivity of the water subsidy. According to the data from Sample B, the volume of water used per cropped feddan in the fifth quintile is approximately a one-tenth of that in the other 4 (lower-income) quintiles (figure 4.17). While part of this difference may be attributable to the use of water-saving systems, the differential is too great to be credible. It is possible that the larger farmer operations have understated their levels of water consumption, leading to an underestimation of the regressivity of the water subsidy.

Conclusions from the Benefit Incidence Assessment

Water use by the poorest 25 percent in Sample A was 9.7 percent of the total, implying that 90 percent of the irrigation subsidy is being captured by the non-poor. The annual subsidy in the irrigation subsector (recurrent plus amortized capital expenditures spent on quasiprivate goods/services) is approximately LE 1.8 billion. Thus, approximately LE 1.6 billion annually, or approximately 0.3 percent of Egypt's GDP, could be being spent on irrigation subsidies for the non-poor.

Targeting this money at the poorest would significantly reduce poverty rates. If the irrigation subsidy received by the richest 75 percent in Sample A instead were allocated to the poorest 25 percent, it would raise their total household incomes by as much as 30 percent.

Conclusions

The findings of this analysis are:

- There is a pressing need for additional state expenditure on wastewater collection and treatment, a public good that could add at least 1 percent to GDP.
- A disproportionate volume of public expenditure on water is on "private" (nonheadwork/trunk) water infrastructure and services.
- When benchmarked against established performance norms, this expenditure is inefficient.
- There is no equity justification for public irrigation spending on private water benefits because most of these benefits are captured by the better-off farmers.

These findings provide a quantitative foundation for the recommendations proposed in chapter 3 in this volume, namely, the gradual transfer of the finance and management of downstream infrastructure and services from public agencies to WUAs and autonomous utilities. Responsibilities to be delegated to water user organizations would include water allocations and the assessment and collection of charges. Such reforms would release funding for priority expenditures on public goods such as upstream maintenance and wastewater management. These reforms also would improve the equity of water-financing by ensuring that farmers' contributions are more proportionate to their benefits.

Appendix A4.1 Data Used in the Benefit Incidence Assessment

The B/A analysis is based on two separate surveys, Sample A and Sample, B. They were conducted by local consultants over different periods and followed different methodologies. Besides other variables, the first survey has data on area used for cultivation; the second includes actual irrigation water used. Finally, the sample sizes were different; and the survey data represent 2 distinct rural compositions.

Sample A was drawn from a random sampling survey conducted over 8 counties in 3 governorates of Egypt's West Delta region. These governorates and the counties are listed below, with the number of samples from each region in parentheses:

1. Beheira Governorate: Zarcoon (45), Depono (65), Barseeq (40)
2. Alexandria Governorate: Mohagrein (20), Abu-Sombel (27), El-Basrah (27)
3. Matrouh Governorate: El Ola (30), El-Tanmiah (30).

The Sample A survey collected data at the household level for 2003–04 on the following:

1. Land owned by the household (net area cultivated)
2. Gross income from the farm
3. O&M cost for water management on the farm
4. Net income from livestock
5. Net income from off-farm activities
6. Total net income (net farm, net livestock, and net off-farm income)
7. Number of family members.

The per-unit irrigation subsidy was computed using the expenditure of MWRI for the corresponding year. The figures were taken from Egypt Public Expenditure Review, May 2005, table 1 (World Bank 2005). The review note states that in 2003–04 approximately LE 4.09 billion was spent on water infrastructure by the irrigation and agriculture subsector, of which nearly 79 percent was spent on new investments. Table 1 of the review also gives MWRI expenditure as LE 1.2 billion, which includes 0.04 billion collected as user fees. The total irrigated land in Egypt is 8.45 million acres. The per-unit irrigation subsidy therefore is computed as follows:

Unit subsidy = (1.2–0.04)/0.00845 = LE 137 per acre (approx.).

Sample B collected data from the following villages in the Western Delta area:

1. El Hussain
2. Bostan
3. Nobaria
4. Bangar Souker/Banger Elsokar
5. Rowaisat
6. El Fekra Station
7. El Omayed.

Sample B was undertaken over a short period and is representative of the rural area constituted by the villages above. Consequently, the result of this analysis is not generalized for the country. However, the survey provides insight into the differential subsidy allocation within the sample range.

Appendix A4.2 Assessing the Social Benefits of Sanitation

As part of the Country Environmental Analysis of Egypt (World Bank 2005), one study evaluated the full social and economic costs and benefits of the country's water use and disposal. The study put particular emphasis on rural water and sanitation. Three policy options were analyzed: (1) Business as usual (BAU); (2) centrally planned actions, as of the *National Plan for the Protection of the Water Resources of Egypt*; and (3) the latter plus controlling rural water pollution (assuming both partial and full coverage).

The study factored in:

- Three key at-recipient parameters: Fecal coliforms (combined with "exposure-risk" parameters)[5] to infer health benefits, dissolved oxygen (DO) for fishery production benefits, and total dissolved solids (TDS) for crop production benefits.
- Corresponding "dose-response" for estimating the fishery/crop losses, and corresponding "exposure-risk" for estimating the disease incidences; translation of the forgone benefits into monetary values.
- Weighing the discounted forgone benefits against the discounted expenses regarding each of the three inaction/action options.

For the BAU option, the damage cost assessment undertaken for water pollution included two types of forgone benefits:

---

[5] Agricultural damages were estimated at the "Consumer and Producer Surplus," forgone as a result of the high TDS concentration (using FAO yield-to-salinity production functions). Health damages were based on relating the diarrhea incidence rates to the risk factors associated with the level of "water, sanitation and hygiene," as these factors are determined by the following transmission pathways:

a. Transmission through ingestion of water

b. Transmission caused by lack of water linked to inadequate personal hygiene

c. Transmission caused by poor personal, domestic, or agricultural hygiene

d. Transmission through contact (through bathing or wading) in water containing organisms such as Schistosoma

e. To a certain extent, transmission through vectors proliferating in water reservoirs or other stagnant water or certain agricultural practices

f. Transmission through contaminated aerosols from poorly managed water systems.

Thereof, six exposure scenarios were considered. Each is associated with a combination of different levels of water supply, sanitation, and hygiene. Thus, each scenario reflects a different fecal-oral pathogen exposure. Populations were grouped according to their level of water and sanitation access, and each group was attributed a different relative risk (obtained from the literature) of contacting the disease. Hence, the total respective incidence rates of diarrhea were estimated.

- *Income losses from the use of polluted water* (for example, crop/fishery/livestock production losses due to salinity and toxicity), as well as *well-being losses*, for example, from water-related diseases, food chain contamination, and occupational health impacts.
- *Cost of avoiding the use of polluted water* such as (1) added cost of pumping groundwater when surface drainage water was too polluted to be reused and (2) forgone benefits when (a) farmers unofficially reused highly saline water from secondary drains, and (b) official reuse from main drains was halted because of pollution by untreated sewage. The study included the additional costs of the erected hydraulic, mechanical, and electrical facilities that became idle due to the halting of a number of drainage reuse schemes.

Results of the Study

The study estimated the total cost of forgone benefits as approximately LE 5.35 billion in 2003, or 1.8 percent of GDP (World Bank 2005, figure 7). In 2014, factoring in population growth and if no additional actions are taken, the forgone benefits will reach as high as LE 9.5 billion/yr or 3.2 percent of national GDP. On average, from 2003–14, the costs of inaction would average 7.4 billion LE/year (undiscounted).

On the other hand, if taken, the intervention corresponding to the National Plan for the Protection of the Water Resources of Egypt (Central Action) would cost approximately 1 billion LE/year. However, in 2014 the plan would reduce the damages to only 6.7 billion LE/yr, or a decrease of 30 percent.

An alternative intervention corresponding to the national plan but adapted to include community-driven-and-financed, low-cost/unconventional remedies for rural areas (central plus decentralized actions, including improved hygiene) could be carried out for a total cost of 2.0–2.5 billion LE/yr. Using this option, in 2014 the value of the damages avoided would be reduced by an additional LE 2.5 billion/yr, or by a total of LE 5.3 billion/year (9.5-6.7+2.5) billion.

The above results suggest that the best option is the latter. It would comprise government central/sectoral plans for the urban/district areas augmented by community-driven-and-financed unconventional plans for controlling rural water pollution.

References

Ajwad, M.I., and Q. Wodon. 2001. "Marginal Benefit Incidence Analysis Using a Single Cross-Section of Data." World Bank.

Van de Walle, D. 1997. "The Incidence of Public Social Expenditures in Zimbabwe." World Bank.

El-Saharty, S., G. Richardson, and S. Chase. 2003. "Egypt and the Millennium Development Goals: Challenges and Opportunities." World Bank. December.

Government of Egypt. 2003. "National Plan for the Protection of the Water Resources of Egypt." Draft Policy Paper. Ministry of Water Resources and Irrigation, Cairo.

Lanjouw, P., and M. Ravallion. 1998. "Benefit Incidence and the Timing of Program Capture." World Bank. July.

Shawky, A. 2001. "Water Demand Management: Approach, Experience and Application to Egypt." Delft University of Technology, The Netherlands. June.

World Bank. 2003. "Holistic Benchmarking in the Irrigation and Drainage Sector." Washington, DC Workshop Proceedings. March 6–7.

____. 2004. "Cost Assessment of Environmental Degradation in Egypt." IBRD Report 25175.

____. 2005a. "Cost Effectiveness and Equity in Egypt's Water Sector." Egypt Public Expenditure Review. Water Policy Note 1. May.

____. 2005b. "Egypt Country Environmental Analysis."

5

Applications of Latest Technologies and Hydrological Models in Water Resource Management and Planning in MNA Region

Bekele Debele Negewo, Julia Bucknall, and Ahmed Shawky Mohamed

Water Resource Management (WRM): A New Approach for Monitoring Water Use

The Introduction to this volume suggests that the management of water resources in the Middle East and North Africa (MNA) region is likely to become far more challenging in the rest of this century because of increased variability in rainfall and increased demands on the resource from rapidly growing populations. These new challenges require investing much greater effort in monitoring the use of water by various sectors of the economy than in the past—particularly on whether this resource is being put to its most beneficial use. For example, consumptive use through irrigation could have a sizeable non-beneficial component if either water from open canals and reservoirs is lost through evaporation, or profitable plants (such as bananas) use up considerably more water through transpiration than other less water-intensive plants. Under these circumstances, evapotranspiration (ET) rates become a key benchmark of efficient water use. Similarly, concerning nonconsumptive water use, despite increased urbanization, with the appropriate investments in treatment, a growing proportion of wastewater is recoverable for beneficial use.

This chapter suggests the need to develop new approaches that comprehensively monitor the water balance as a means of managing variations in water supply as well as demand. Such an approach basically improves understanding of the sources and sinks of water by collecting better quality datasets and by employing state-of-the art models to advise water regulators, policymakers, and communities on the state of a country's water resources at a given point in time.

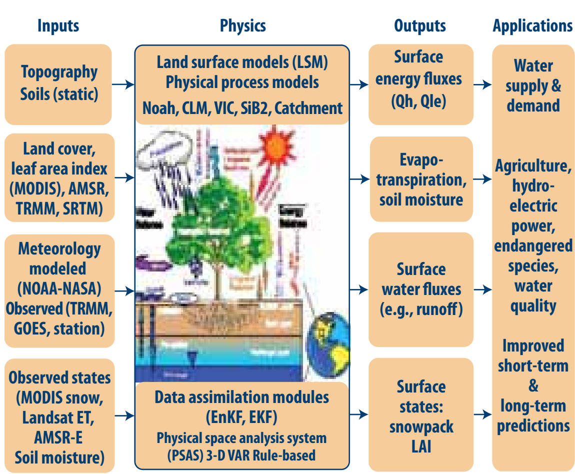
Applications of New Technologies to Collect and Process Water-Related Data

An understanding of the availability and quality of water resources as well as current and future uses of these resources is necessary for sound water decisionmaking. Furthermore, clear, undisputed information on water availability and consumption is a critical component of improving governance and accountability in the sector.

Nevertheless, developing and disseminating good information on water remains a challenge in MNA for a number of reasons. First, data collection and analysis are costly. Second, countries lack data management systems. Third, neither definitions nor data management is standard across countries. Fourth, communities and policymakers (outside the narrow group of WRM specialists) are still not fully aware of the benefits of investing in reliable data on water usage.

On the supply side, technological developments are beginning to enable scientists to combine traditional water data systems with models and remote sensing (RS) information in ways that greatly reduce the cost of collecting data and increase its accuracy. These advances include a combination of the use of geographic information systems (GIS), RS, data assimilation, and modeling techniques. Figure 5.1 provides a detailed illustration of (1) how the latest technologies help collate both dynamic and static characteristics of the land, vegetation, and climate; and (2) how to combine these datasets with the latest hydrological modeling capabilities to produce outputs that facilitate making critical water resources decisions in water supply and sanitation (WSS) and irrigation.

Figure 5.1 Latest Technologies in Water Resources Data Collection, Assimilation, and Modeling to Improve Decisionmaking

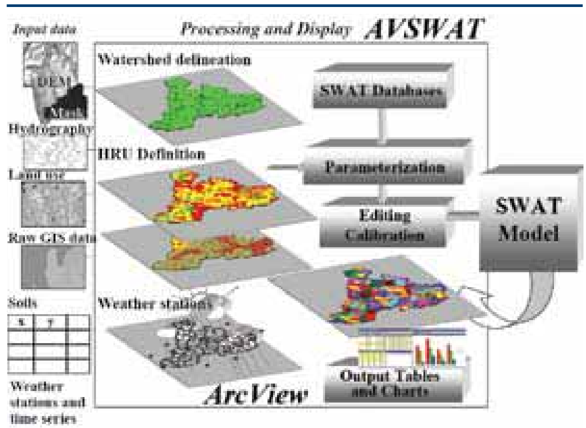


Use of Geographic Information System (GIS)

Advances in GIS technology have revolutionized the way that spatially distributed water resources data are managed (ESRI 2008). GIS captures, visualizes, and correlates spatial data. Not too long ago, it was practically unthinkable to spatially represent all variables that directly or indirectly dictate the movement and availability of water resources in a basin to the extent that can be done today. This array of variables includes topography and land use/land cover at as low as 30m resolution; and soils, soil moisture content, and climate data at sub-km resolution. Thanks to advances in computer capacity and GIS technology, resource managers can better mimic the reality on the ground. Today, if one has the primary data and model structure at any spatial scale, computer capacity and GIS technology support the analyses to provide water resource managers and decisionmakers with the decision tools needed at the scale of interest.

Advances in GIS technology become especially important when dealing with complex river basins whose climate, soils, and land use/land cover distributions vary significantly with space. GIS technology is equally important in addressing a basin being used and managed by multiple actors. In this case, to facilitate optimal joint resources management and development decisions, one needs to spatially identify the sources and sinks of water and associated pollutants. GIS tools will help identify hotspots within a given basin whose WRM needs to be the focus, and for which the maximum dividend is expected from implementation of some best management practices. Figure 5.2 depicts a sample application of GIS in organizing and assimilating physiographic data (topography, land use/land cover, soils) and climate data (precipitation, temperature, wind) for use in one of the complex hydrological models (Soil and Water Assessment Tool, or SWAT) in WRM.

Figure 5.2 Sample Applications of GIS (ArcVIEW) in SWAT Model Use



Source: DiLuzio and others 2002.
Note: SWAT is a complex hydrological model designed to assess the impacts of land management on water resources.

Applications of GIS technology are extremely diverse: from epidemiology (monitoring disease outbreaks) to analyzing the vulnerability of water resources to point or nonpoint source pollution. In water resource management, GIS facilitates the manipulation of spatial data that otherwise are difficult (if not impossible) to handle. The manipulation includes storing, querying, displaying, integrating, and analyzing spatial water-related data in a complex basin. For example, using GIS, one can overlay the map of land use/land cover with a soils map to generate a unique map of hydrologic response unit (HRU), the smallest unit of water balance computation in some hydrological models (figure 5.2). Similarly, GIS is used to generate hydrographic maps from topographic maps (digital elevation maps, or DEM) (figure 5.2). Such hydrographic maps document stream networks in a given basin that drain water from one end of a basin to the basin outlet. The same GIS can help to determine stream orders, lengths, and slopes—all of which are critical factors in the computation of hydrological variables such as runoff and soil erosion. Finally, given its rich selection of colors and ability to designate each item with a different color, GIS is an extremely helpful tool in creating pleasing and easily accessible figures and tables.

Applications of Remote Sensing Technologies in WRM

Advances in RS technology in recent years have given water resource managers and decisionmakers the ability to capture—from a distance—the detailed characteristics of physiographic and natural resources (surface and groundwater, vegetation, soils, topography) and climate variables (temperature, precipitation, solar radiation). For example, the technology of remote sensing is such that one can now measure the amount of precipitable moisture in the atmosphere, air temperature, evaporation and transpiration (ET), soil, moisture content, and aquifer storage of the soil, without putting a sensor close to the objects of measurement. Table 5.1 depicts a partial list of variables that can be measured/estimated by remote sensing.

In WRM, given the need to capture the variability of resources distribution across space and time, RS technology also should offer such capability. Whereas some state variables can be assumed to be stable over a certain period (topography, geology, soil texture), others change very frequently (weather conditions, vegetation growth, soil moisture) By the same token, some variables can be assumed to be stable over a given swath of area (air temperature[1]) whereas others are not (soil properties, elevation, precipitation).

[1] Air temperature can be assumed stable over a good-sized field unless the field has a sharp rise in elevation over a short distance, in which case the elevation lapse rate comes into play.

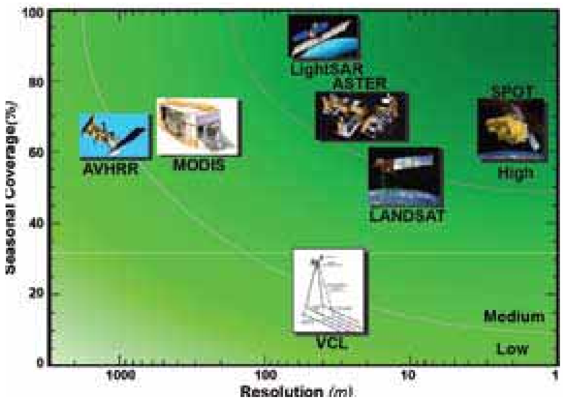
In general, however, most state variables in water resources vary both spatially and temporally. Therefore, it is imperative to select the most appropriate remote sensing technique (and data) to address a given water resource issue. For example, a satellite that provides observations every week may not be appropriate to study water resources issues on a daily basis. Similarly, a RS technique that provides observations at 100-km pixel would not be appropriate to analyze the water resources issue at plot-scale level, that is, a 10-km by 10-km area.

Table 5.1 also provides the spatial scope of a suite of satellite (mission names) in measuring/estimating water-related variables. Common links to water-resource-related datasets also are provided in appendix A5.1.

Table 5.1 Summary of Spatial Data Availability from Remote Sensing

No.	Data type	Spatial scale	Satellite name/mission name
1	Rainfall	3 to 25 km	TRMM (25km); GOES; NEXRAD; METEOSAT; IRS; ESA
2	Skin soil moisture	25 km	AMSR-E
3	Root zone soil moisture	30 m to 1 km	Nimbus SSM/I (25km);
4	Air temperature	1 km	AVHRR
5	Solar radiation	1 km	AVHRR
6	Leaf Area Index	30 m to 1 km	MODIS; LANDSAT
7	Biomass production	30 m to 1 km	LANDSAT; MODIS
8	Snow cover and snow accumulation	30 m to 1 km	GOES
9	Land use/land cover	30 m to 1 km	MODIS; LANDSAT
10	Crop types, surface albedo, vegetation fraction	30 m	MODIS; SPOT-4
11	Crop yield	30 m	MODIS; LANDSAT
Secondary spatial data			
12	Air humidity	1 km	NASA's UARS
13	Wind speed and direction	1 km	LIDAR
14	Water depletion by land cover	1 km	MODIS
15	Water productivity	30 m	MODIS
16	Stream flow and water quality	1 km	LANDSAT; MODIS
17	Groundwater recharge/abstraction; terrestrial water storage	30 m to 1 km	GRACE
18	Irrigation water demand, irrigation intensity, and irrigation efficiency	30 m to 1 km	MODIS; LANDSAT
19	Carbon sequestration	30 m to 1 km	MODIS
20	Topography, geology	30 m to 250 km	ASTER; RADARSAT
21	ET (based on, e.g., SEBAL and METRIC approaches)	30 m to 1 km	MODIS (30 m to 1 km); LANDSAT

Figure 5.3 Availability of Remote Sensing Data at Various Spatial and Temporal Coverage



Source: Droogers 2006.

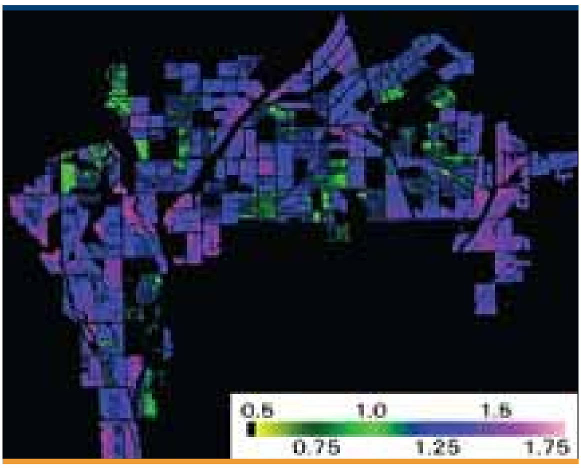
Figure 5.3 depicts the availability of various RS data sources at different spatial resolutions and seasonal coverage (percent). Figure 5.3 provides a menu of options for water-related data sources to be used under a range of data needs (small plot scale, river basin scale, national scale).

Sample applications of RS

Remote sensing has been utilized for different purposes, from monitoring deforestation and predicting the effects of climate change on glaciers in the Arctic and Antarctic to estimating the amount of water in the clouds. Some use RS to capture distributions of climate variables such as thunder storms, hurricanes, and floods in real time. Others use RS for early warning—including for flood and drought. Still others also use RS to monitor changes in land use/land cover and soil moisture content. Some also use RS to estimate the amount of water lost to ET.

Figures 5.4 and 5.5 depict sample applications of RS technology in WRM. In both figures, RS is used to gather relevant data to estimate water productivity in irrigated agriculture to guide WRM decisions. In figure 5.4, RS was used to analyze the productivity of water to spatially evaluate where water was being productively used. Such information can be used to make decisions to reallocate water among different users, leading to improved total water productivity. In contrast, in figure 5.5, RS was used to estimate the amount (liters) of water used to produce a liter of wine. As can be seen from both figures, water productivity

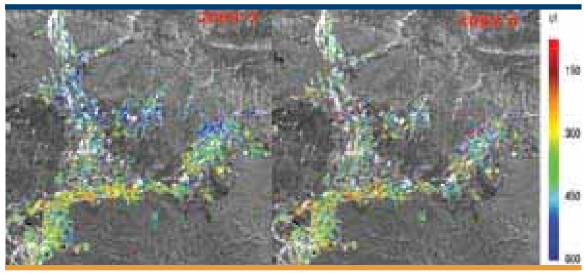
Figure 5.4 Where Is Water Not Used Productively? Data from Sacramento, CA



Source: Bastiaanssen 2007.
Note: Legend depicts a water productivity range of 50%–175% of the average water productivity in the Sacramento Valley, implying a wider range of water productivity.

is not uniform across the Sacramento Valley. Figure 5.5 clearly shows that farmers in the northern parts of the valley use more water to produce the same amount of wine than do their southern counterparts. Such data are very important for WRM, particularly in making decisions on water allocation and pricing.

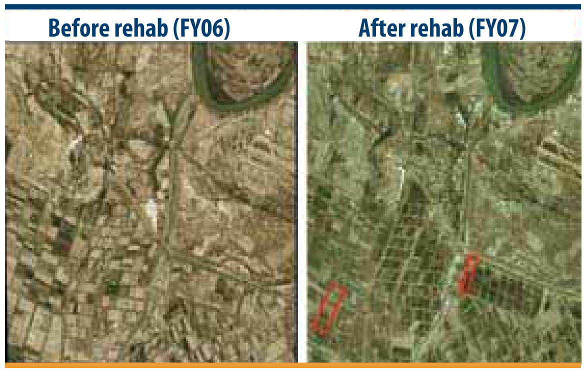
Figure 5.5 Water Productivity in Sacramento, CA: Liters of Water Needed to Produce 1 Liter of Wine



Source: Bastiaanssen 2007.
Note: Legend depicts the amount (liters) of water needed to produce one liter of wine across the Sacramento Valley.

RS also can be used to augment available data and to fill data gaps, including in areas in which collecting data through traditional means is constrained. For example, since 2003, the World Bank has been using RS techniques to supervise the implementation of Bank-supported irrigation projects in Iraq, in which ground accessibility has been limited for security reasons (figure 5.6). As can be seen from figure 5.6, differences between areas served by the *Wazzak* Canal before and after the canal rehabilitation are notable. In contrast, incremental productivity (project *outcomes*) has been validated through low-resolution satellite images. The impact evaluation for the incremental outcomes can be performed through either of two approaches:

Figure 5.6 Agricultural Lands Served by "Mazzak" Canal in Wasit Governorate before and after Project Implementation



Source: World Bank 2006.
Note: The red rectangles on the "After" map show areas that were put under cultivation after rehabilitation of the canal systems.

1. Comparing the before-project and the after-project cases (thus comparing *over time*, which was the approach followed in Iraq (figure 5.6)
2. Comparing the without-project and the with-project cases (thus comparing *in space*, that is, comparing with an adjacent command area outside the project's command borders).

The Bank is assisting several MNA governments to obtain more accurate and up-to-date water-related RS data in the water-stressed areas (Egypt, Gaza, Morocco, West Bank, and Yemen). As a result of coordination among the Arab Water Council, NASA, USAID, and the World Bank, a new regional initiative is being launched to help MNA make better WRM decisions and share comparable data across member countries. Such coordination envisages developing a set of tools that, taking advantage of the latest technologies, will provide regular, accurate, and standardized information on the availability and consumption of water resources in the Arab world.

Cautionary note: The latest RS technologies have enabled water resources decisionmakers to use easily accessible information to make better decisions. Nonetheless, to ensure a reality check, it is *very important to calibrate the data collected through RS techniques against those collected on the ground*. RS technology changes rapidly. To keep up with such rapid advances, one needs to continually compare the quality of data derived from each generation of techniques with those obtained on the ground.

Moreover, satellites lack the ability to take measurements over small footprints (smaller spatial resolution). Similarly, satellites currently are unable to have "active" systems that can penetrate the soil below a certain depth. For now, the final word is that, in the foreseeable future, RS will not replace ground measurements. However, RS measurements can provide important augmentations to other data to improve the quality and spatial coverage of existing data.

Data-sharing also is cost-sharing and obtaining better data. In many MNA countries, multiple agencies collect similar data, often not knowing that the other agencies are collecting the same data. Moreover, when one agency/country wants to do an assessment, it often starts from the beginning without first talking to the other agencies/countries to find out what data they already have. *The amount of wasted resources expended in this way cannot be underestimated*. Agencies should instead first identify what already has been done, then document and improve upon the data already present. To this end, data-sharing among agencies and/or countries is a prerequisite.

Applications of Hydrological Models in WRM

Need for Hydrology

For any realistic implementation of WRM at a basin scale, a better and fuller understanding of the hydrology of the basin is crucial. For example, the quantity and quality of runoff measured at a basin/sub-basin outlet are a collective signal of the characteristics of the whole basin/sub-basin, in the same way that pathological tests can tell much about the well-being of a person. Therefore, WRM requires a good hydrology dataset to provide an accurate basis for water accounting.

Hydrological Models

In parallel with the advances in GIS and RS, there have been many improvements in the understanding of the physical processes and interrelationships between climate-soils and ecosystem response. A large number of mathematical equations have been developed to mimic the understanding of these interrelationships—from simple black-box empirical models to more sophisticated, physically based and distributed parameter models. As a result, the number of hydrological models today is so large that many users spend a great deal of time selecting the most appropriate model for the problem(s) at hand. *The fundamental principle of any hydrological model emanates from closing the mass, energy, and momentum balances*. All hydrological models should respect at least *one fundamental principle: a mass balance signifying continuity*.

Equation 1 (Eq. 1) provides the general continuity equation of hydrological balance, which dictates that the summation of all inflows

$$\sum_{i=1}^{n} Inflow_i$$

minus the summation of all outflows

$$\sum_{i=1}^{n} Outflow_i$$

over a period of time (t) should equal the change in storage (Δ Storage) over the same period of time (t).

$$\left(\sum_{i=1}^{n} Inflow_i - \sum_{j=1}^{m} Outflow_j\right)_t = (Storage)_t \qquad \text{(Eq. 1)}$$

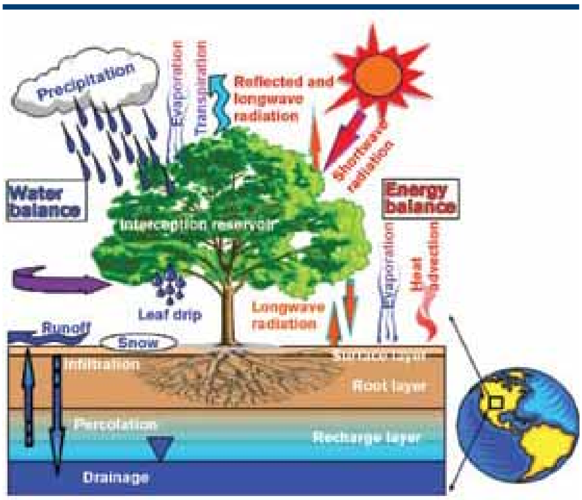
where *m* and *n* are the different categories of outputs (extracts) from the system and inputs (additions) to the system, respectively. For most common hydrological models, Eq. 1 is rewritten by expanding the water balance components (figure 5.7) as in Eq. 2 below.

$$PCP - \left(ET + Runoff + R_{deep} \right) = \quad S \qquad \text{(Eq. 2)}$$

where PCP = total precipitation (snowfall + rainfall); ET = amount of water lost to evapotranspiration; *Runoff* = total net water amount that leaves the system as surface and subsurface runoff (this is a net figure after subtracting inflow to the system from adjacent basins—runon, return flows, and inter-basin transfer); R_{deep} = is the net water amount lost to deep aquifer (this is a net figure after subtracting extractions from deep aquifer); and ΔS is the change in water storage of the system over a given period of time—the same period over which total inflow and outflow are computed.

Equation 2 above could equally be subdivided into water consumptive uses and losses as described in the Introduction (figure I.1). For example, the ET in Eq. (2) could be subdivided into beneficial and nonbeneficial ET based on where in the basin the water is lost to ET. Runoff from the system could be subdivided into recoverable fraction and nonrecoverable fraction based on where the water that is lost to runoff is destined. In a similar way, the amount of water that is percolating to deep aquifer and stored in the upper soil horizon could be subdivided into recoverable and nonrecoverable components based on their accessibility for further use. In this case, whereas it is feasible to further divide the water balance components into consumable/nonconsumable and recoverable/nonrecoverable for water accounting purposes, keeping Eq. (2) above intact is still very important, especially for hydrological analysis in the upland watershed.

Figure 5.7 Major Components of the Hydrological Balance



Source: Toll 2008.

Similarly, for the energy balance, the summation of all incoming energies

$$\bullet_{i=1}^{r} E_{incoming\,i}$$

minus the summation of all outgoing energies

$$\sum_{i=1}^{r} E_{incoming\,i}$$

must equal the change in the amount of energy stored

$$\left(E_{Stored}\right)$$

within the system (Eq. 3).

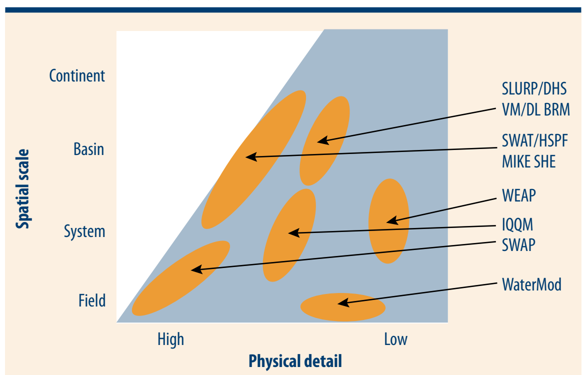
$$\sum_{i=1}^{r} E_{incoming\,i} - \sum_{j=1}^{s} E_{Outgoing\,j}\;{}_{t} = \left(E_{Stored}\right)_t \qquad \text{(Eq. 3)}$$

where r and s are the different incoming and outgoing energy categories, respectively. More complex and physically based models account for more than one physical principle (for instance, mass and momentum, mass and energy, or a combination of all balances).

Another very important issue to consider when dealing with hydrological models is the spatial scale to be incorporated in the model and how much physical detail should be included. Figure 5.8 illustrates the negative correlation between the physical detail of the model applied and the spatial scale of application. Figure 5.8 also depicts the position of some commonly used hydrological models in this continuum.

Application of Hydrological Modeling and Its Classification

Figure 5.8 Most Commonly Used Hydrological Models and Their Suitability in Both Physical and Spatial Scale



Source: Debele 2008 modified from Droogers 2006.

Hydrological models commonly are categorized based on their physical detail (physically based models, empirical models), spatial coverage (spatially distributed models, lumped parameter models), and temporal coverage (event-based models, continuous time models). Hydrological models also can be grouped based on their uses, such as for water quantity and/or quality assessment, water allocation among different users (riparian countries, sectors), evaluation of policy impacts on water resources, or payment for environmental services or assessment of climate change impacts. Whereas some models are multipurpose in their applications, others are developed to tackle specific water-related problems. The following are the main reasons that most people use hydrological models.

Models are economically more feasible than monitoring (M&E).

Once a model is calibrated against available data and the state of the system as a whole, and the causal relationship is established, the model can be used as a tool to monitor the implications of *changes* in inputs or outputs, instead of collecting primary input and output data at every time interval. These models provide additional benefits, such as running scenario analyses to guide decisionmaking in WRM. Scenario analysis could be done without having access to observed input data. This is a *very powerful advantage of models: they help not only to monitor but also to guide any future decisions*.

With the help of the latest technologies in RS and GIS to collect and process/assimilate data, models also could be used for monitoring and evaluation (M&E) of water projects. As indicated in the previous section, the Bank's use of RS data to (1) monitor project implementation progress in Iraq and (2) estimate water productivity using a combination of hydrological model and RS tools are good examples of how models can be used as an M&E tool. For example, in the case of water productivity monitoring in the Sacramento Valley, a hydrological model (in combination with SEBAL[2]) was used to determine crop water consumption. Alternatively, a METRIC[3] approach could equally be used to determine the amount of water consumed by crops. Hydrological models have also been successfully used to monitor and evaluate the impacts of best management practices on in-situ soil and water conservation, and management of groundwater recharge and diffuse pollution.

Models advance scientific understanding in water resources and help identify knowledge gaps.

Some models also are tools to further understand the linkages among different variables and how each factor dictates overall water movement in and above the soil surface. Models that come under this category include the physically based and spatially distributed models that simulate the interrelationships among soils, climate, and vegetation response in the ecosystem. Models under this category usually are developed

---

[2] SEBAL stands for Surface Energy Balance Algorithm of Land.

[3] METRIC stands for Mapping Evapo-Transpiration with High Resolution and Internalized Calibration.

from mathematical equations that fulfill the continuity, momentum, and energy balances in all relevant dimensions. Such models are used primarily to deepen one's understanding of the processes involved in water resources movement and storage. All other models are derived from models under this category by simplifying one or another parameter, or combining a few parameters.

Models enable good decisionmaking and guide policy options.
Models are tools best suited for guiding decisionmaking at various levels. This function ranges from identifying what datasets to collect for what sets of decisions to make to achieve certain goals in an integrated water resource management (IWRM) setup. Similarly, models are used to guide the selection of policy choices in the water sector. For example, one can employ a combined hydrological and economic model to assess the implications of various water allocation measures/policies on different sectors that are competing for shares of the same water. In a similar fashion, one can use hydrological models (especially those that are physically based and spatially distributed) to assess the implications of different best management practices on improving in-situ soil moisture and groundwater recharge, and reducing nonpoint source pollution. Such an exercise can be done either before project implementation to see the implications of various "IF" scenarios, or after project implementation to monitor and evaluate the impacts of such interventions on the end results.

In an IWRM setting, models are useful to identify the optimum objectives that take into account the social, economic, and environmental issues in a given basin, including interests of its upstream and downstream riparian users. For example, many models have been developed to identify the optimum number and locations of water projects and compensation mechanisms (payment for environmental services, or PES). One very good (win/win) example of models' applications in PES is the New York City (NYC) water supply. The NYC Department of Environmental Protection (DEP) uses hydrological models to identify areas that are hotspots in the watershed to bargain (to support onsite land management and/or provide cash for easements) with farmers who own the lands to implement best management practices that will reduce diffuse pollution. In this way, the city benefits by preserving the pristine water quality of NYC (instead of spending billions of dollars to treat its water supply to the EPA standards, as required by the US government). The farmers also benefit by obtaining funds (PES) from NYC to protect their lands, and hence protect the NYC water supply watersheds.

Another equally important but less known application of such models is in the implementation of the PES initiative in Costa Rica. The purpose is to reduce deforestation to (a) sequester carbon dioxide and (b) improve the water quality of groundwater for mineral water production industries. The authorities used hydrological models to identify areas in the watersheds in which groundwater recharge is significant and pay farmers accordingly for the environmental services that their lands provide. This initiative is very successful in reducing the rate of both deforestation and groundwater contamination.

As indicated earlier, the latest advances in GIS and RS technologies have improved the application of hydrological models to assess the implications of different water projects on overall water resources availability. For example, the World Bank has supported the government of Tunisia in its assessment of the implications of water-saving investments in Tunisian agriculture (World Bank 2008). Over the last decade, the Tunisian government has been implementing modern irrigation schemes, including sprinkler and drip irrigation, to better manage its agricultural water resources. The study used remotely sensed data to determine the water balance in its irrigated areas. It disaggregated the water balance into its components (precipitation, ET, soil storage, and runoff) and was able to evaluate the impacts of water-saving investments on the country's overall water resources availability.

The study concluded that although implementation of water-saving investments is very important, equally essential is the need to properly manage the saved water. For example, investing in modern irrigation schemes may reduce the amount of water that is applied to a given farm land. However, if one decides to use the saved water to increase irrigation intensity and/or horizontally expand the area of irrigated land, in the end, the amount of water saved at a basin scale might be none or even become negative (more water withdrawn than previously under traditional irrigation schemes). Therefore, one needs to *approach water resource management from a comprehensive water balance perspective and at a basin scale*.

To date, in the Arab region, regional integration and inter-regional collaboration on development and management of shared resources have been weak. For this reason, a combination of objective water-related data and decision-aiding hydrological models would be very useful in the use and management of their shared water resources.

Moreover, even at a country/basin level, optimal allocation of limited water among various competing needs/sectors can be addressed using a combination of hydrological and economic/social models.

Conclusions

This chapter discusses the use of the latest technologies, such as GIS, RS, and hydrological models, in the WRM of the MNA Region. It highlights the applications of such technologies to capture, store, and process most datasets needed for making water resources decisions. The chapter also explores the many types of hydrological models available and their very useful and flexible applications to guide decisionmaking and balance the demands of different uses.

References

Aliewi, A.S., R. Mackay, A. Jayyou, K. Nasereddin, A. Mushtaha, and A. Yaqubi. 2001. "Numerical Simulation of the Movement of Saltwater under Skimming and Scavenger Pumping in the Pleistocene Aquifer of Gaza and Jericho Areas, Palestine." *Journal of Transport in Porous Media* (43) 195–12.

Almasri M.N., and S.M.S. Ghabayen. 2008. "Analysis of Nitrate Contamination of Gaza Coastal Aquifer, Palestine." *Journal of Hydrologic Engineering*. 13 (2): 132–40.

Bastiaanssen, W. 2007. "Adaptation to Climate Change: New Technologies for Water Management and Impact Assessment." Lecture at the World Bank.

Debele, B. 2008. "Applications of Watershed Management Tools for Bank Operations: Pushing the Frontiers of River Basin IWRM." Training at World Bank Water Week 2008, Washington, DC.

Droogers, P. 2006. "Applications of Hydrological Models in Watershed Management." Lecture at World Bank Water Week 2006, Washington, DC.

DiLuzio, M., R. Srinivasan, J.G. Arnold, and S.L. Neitsch. 2002. "ArcVIEW Interface for SWAT 2000. User's Manual." Grassland, Soil and Water Research Laboratory, USDA Agricultural Research Service, Temple, TX.

Elewa H.H., and A.H. El Nahry. 2008. "Hydro-Environmental Status and Soil Management of the River Nile Delta, Egypt." *Journal of Environmental Geology*, DOI: 10.1007/s00254-008-1354-5.

ESRI (Environmental Services Research Institute). 2008. ArcGIS 9.3 Desktop extensions @ http://support.esri.com/index.cfm?fa=knowledgebase.documentation.viewDoc&PID=83&MetaID=1404

Goossens R., B.M. De Vlegher, and M. De Dapper. 1998. "Water Logging and Soil-Salinity Modeling Using Remote Sensing and GIS: A Case Study for a Sebkha Area South of Ismailia (Egypt)." *Journal of Natuur-en Geneeskundige Vennootschap* 78 (1–4): 137–48.

IPCC (International Panel on Climate Change). 2007. *Regional Climate Projections. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Ed. S. Solomon, D. Quin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller. Cambridge University Press.

Salman, M. 2004. "The Euphrates and the Tigris: The South Boundary Utilization and Views." IPTRID, AGL, FAO, Rome.

Smedema, L.K. 2005. "Irrigation Performance and Waterlogging and Salinity." *Journal of Irrigation and Drainage Systems*, (4):367–74, DOI: 10.1007/BF01103714.

Toll, D. 2008. "Applications of NASA's Modeling and Satellite Products in Water Resource Management." NASA presentation made at World Bank, Washington, DC.

World Bank. 2006. "Supervision of Project Implementation Progress Using Remote Sensing Techniques: Iraq Emergency Community Infrastructure Rehabilitation Project." Presentation of Mission Report, Washington, DC.

____. 2007. "Making the Most of Scarcity: Accountability for Better Water Management Results in the Middle East and North Africa. MNA Development Report on Water."

____. 2008. "Water Balance and Evaluation of Water-Saving Investments in Tunisian Agriculture." Unpublished report.

Appendix A5.1 URLs for Water-Resources-Related Datasets

- Real-time Heavy Rain Maps (updated every 3 hours)
  http://trmm.gsfc.nasa.gov
- Hydrology for the Environment, Life and Policy
  http://www.unesco.org/water/ihp/help
- Regional Visualization and Monitoring System ("SERVIR")
  http://servir.msfc.nasa.gov/
- Global Hazard System (Floods) Quasi-global Runoff Model Running in Real-Time
  http://trmm.gsfc.nasa.gov/publications_dir/potential_flood_hydro.html
- Stream flow Monitoring and the Dartmouth Flood Observatory
  http://www.dartmouth.edu/~floods/
- Remote Sensing Application In Irrigation
  http://www.sage.wisc.edu
- ET Estimation
  http://www.kimberly.uidaho.edu/ref-et/
  http://www.cimis.water.ca.gov
  http://www.sebal.nl/
- Real-time Precipitation Forecast and Other Remote Sensing Products
  http://chrs.web.uci.edu/

6

Water Resource Assessment in the Arab World: New Analytical Tools for New Challenges

Christopher J. Perry and Julia Bucknall

This chapter examines how, over millennia, societies in Arab countries developed arrangements for water management that reflected the region's conditions of extreme water scarcity. It notes that these traditional arrangements have been undermined by growing imbalances between demand and supply, exacerbated by new technologies that disturb stable traditional systems. The first step toward putting replacement arrangements in place, especially as climate change exacerbates the imbalances, is to build a shared understanding of the hydrology of the system in which one is working.[1] This chapter shows the role of hydrological information as a basic element of establishing sustainable water management. The chapter concludes by showing how remote sensing (RS) applications can contribute to knowledge of the status and trends in hydrological data.

With very limited exceptions, the Arab countries are water short, and supplies are highly variable from year to year.[2] Definitions of water availability are not always consistent, which can lead to confusion when different source materials are quoted. However, UNESCO (2002) used the FAO-AQUASTAT database and FAOSTAT population data to rank 180 countries on the basis of water availability. Of the Arab countries, only Sudan ranked above the bottom quartile. The majority of Arab countries—including Bahrain, Gaza, Jordan, Kuwait, Libya, Oman, Qatar, Saudi Arabia, Tunisia, UAE, and Yemen—were in the bottom 10 percent. Even within this select group of water-short countries, the disparities in endowment were enormous. The most water plentiful of this group,

[1] Throughout this chapter, "hydrology" is used to include both surface and groundwater.

[2] Based on a background paper prepared by the authors for the Arab Water Council for the Fifth World Water Forum, Istanbul, 2009.

Tunisia, has less than 25 percent of the availability of Sudan. The least plentiful, Kuwait, has less than 0.5 percent of the availability of Sudan.

The basic human needs for drinking and sanitation are rather small. Gleick (1996) researched actual water use in various scenarios and climates and estimated the following ranges of water needs (in liters per capita per day):

Table 6.1 Ranges of Human Domestic Water Needs *(1/cap/day)*

Drinking water	2–5
Sanitation	0–75
Bathing	5–70
Cooking/kitchen	10–50
Average total	50 (= 18 m^3/year)

Thus, 1 m^3 of water supplies the various needs of 1 individual for 20 days, or the absolutely fundamental need for drinking water for as much as 1 year.

According to these data, only Kuwait (10 m^3/cap/year) has less than the total human requirement. In striking contrast, Yemen—widely identified as one of the most seriously water-short countries in the world—is endowed with more than 200 m^3/cap/year. (Of course, the timing and location of supply may be quite different from the timing and location of demand.)

The problem, the competition, and the scarcity arise when irrigated agriculture is significant: the same 1 m^3 of water that provides drinking water for 1 person for 1 year produces only 1 kg of food grain when used for irrigation in a dry climate. Thus, Singapore, with less water per capita than Yemen, is not considered water scarce because the water is used almost exclusively for residential and industrial needs. In contrast, the demand for water for irrigated agriculture in Yemen creates a situation of extreme scarcity.

In the Arab world, irrigated agriculture is the dominant user of water and is thus the primary topic of this chapter. Scarcity of water in the Arab countries is not a new phenomenon—although population growth and economic development exacerbate the scarcity. Therefore, it is useful to examine how the problem has been dealt with during millennia of experience in the Arab world.

Historically, countries (at the national, local and individual levels) have developed indigenous approaches to cope with water scarcity. Four examples with several millennia of experience are:

1. *Inundation canals* in Egypt diverted the Nile's annual floods onto farmers' lands via below-grade channels, from which the farmers, usually operating in groups, would pump water by animal-powered *sakias*.[3]
2. *Spate irrigation systems* have been significant in a number of Arab countries since the early 1990s (table 6.2). They account for approximately 20 percent of the irrigated area in Algeria and Yemen. These systems consist of dams—often temporary—that divert water from fast-flowing ephemeral streams onto farmers' fields after heavy rain.

Table 6.2 Spate Irrigation in Arab Countries, 1989–1995

Country	Data *(yr)*	Spate irrigation *(ha)*	Total irrigation *(ha)*	Spate *(%)*
Algeria	1992	110,000	555,500	19.8
Morocco	1989	165,000	1,258,200	13.1
Sudan	1995	46,200	1,946,200	2.4
Tunisia	1991	30,000	385,000	7.8
Yemen Rep.	1994	98,320	481,520	20.4

3. *Qanats* (also variously known as *kareez, foggara, aflaj)* are found in many Arab countries, probably after originating in Iran. Certainly, in the early part of the last millennium, the Moors took the technology to Spain (where some are still functioning). The Spanish, in turn, took the technology to Mexico, and qanats are now found in Peru and Chile as well. A qanat consists of a tunnel that starts at ground level in foothills and is cut into the hill, sloping upward at a lesser angle than the ground so that the tunnel becomes progressively deeper, eventually intersecting the water table in the hillside (figure 6.1). Qanats are essentially man-made springs that provide a route for infiltration from higher areas to flow out at a single point. The vertical shafts allow access during

Figure 6.1 Cross-Section of a Qanat

Source: Livius.Org, with permission

[3] Sakia is also known as the "Persian wheel." It is an effective technology for lifting water from canals with animal or mechanical power to irrigate farmlands.

construction. Some qanats are kilometers long. One example in Jordan exceeds 90km.

4. *Shallow wells* are found everywhere that the groundwater table is relatively near the surface. Historically, wells had to be shallow due to the limits of suction lift pumps (approximately 10 meters).

These are four quite different technical approaches to enhance local water availability: exploitation by inundation of the regular heavy Nile River floods; diversion of irregular flash-foods in wadis; exploitation of infiltration into hillsides; and exploitation of shallow water tables. Nevertheless, they have a number of important similarities that offer important insights into how scarce water has been managed successfully, productively, and sustainably by irrigators in the Arab world.

Each approach exploits natural flows. Each approach, therefore, is limited by actual rainfall and the resulting runoff. These restrictions, in turn, mean that over-exploitation is not possible (unless shallow wells are over 10 meters in depth).

Experience over the years has given water users a clear idea of how much water to expect—on average—in a wet year and in a dry year. This knowledge has provided the basis for them to decide how the water should be allocated. Where farmers had collectively built the infrastructure (as in the case of qanats and spate systems, and sometimes in the case of wells), the beneficiary group was already clear. However, contributions might not have been equal. Differences in cropping patterns might require nonuniform allocation of water, or priority to domestic or livestock use. In Egypt, for example, by the time that flood irrigation had evolved millennia ago, the scale of the system was already such that there were at least two levels of management: one for the major diversion structures and one for the local distribution of water among users at the sakia.

For qanats, Mehraby (undated) describes the distribution process as follows:

> "Since ancient times, there have been laws as to how to distribute water fairly among various small and large villages on the *kariz* routes to prevent any disagreements resulting in consequent disorder, clashes or disturbance.
>
> "The distribution of the water of a kariz route is based on time as determined by the users through their representatives. If the flow of

a kariz is considerably high and the users of the water are numerous, the distribution of the water has to be under a trustworthy official known as *mirab* who is chosen by the joint users or the government and is paid a certain salary."

Mehraby's brief summary delineates three elements:

1. The principles for allocation of the water among users have been agreed.
2. There are rules implementing the allocation ("based on time").
3. A management structure to oversee the operation may be necessary.

The nature of the rules and how they are implemented will vary among these different technologies. In Yemeni spate systems, for example, it is reported that the farmer is entitled to take water until the depth reaches his knee. The signal that the next irrigator should divert the water to his field is for the first farmer to fire a gun into the air.[4] While this may seem crude, it ideally suits the need in a spate system to share a very uncertain quantity on the basis of simple rules and quick communication. The outcome is an apparently rather uniform distribution of water among users in a wadi (figure 6.2).

Figure 6.2 Spate System in Yemen

Photo: Gerhardt Lichtenthaeler.

The infrastructure of all of these systems provides the capacity to deliver the service that the other elements—how much water is available, priorities for sharing, rules, and management arrangements—combine to define. In addition to the channel or diversion structures that deliver the water, the infrastructure also may comprise facilities

[4] Charles Abernethy, personal communication.

Figure 6.3 Water-Dividing Structure in a Foggara, Algeria

Photo: Gerhardt Lichtenthaeler.

to assist in allocation. Figure 6.3 shows a water-dividing structure in a foggara in Algeria.

Abdullah Al-Ghafri and others (undated) describe various timing devices, ranging from pots with holes in the bottom that provide a measure of time while slowly sinking, to complex, seasonally adjusted sundials.

These techniques are designed to enable water shares, first divided among user groups by structures such as shown in figure 6.3, and then subdivided by time among individual farmers.

This brief review of the successful and sustainable local approaches that have developed in the Middle East to deal with water scarcity supports some significant, generalizable conclusions. These are described in the Introduction to this volume as the *ABCDE approach*.[5]

Current Challenges

Thus, we know the ingredients of sustainable and productive water resource management. Moreover, the Arab countries have developed successful approaches that have been exported to, and implemented in, Europe and South America. We can assume that farmers receiving scarce but well-defined water supplies will use these as productively as circumstances such as market opportunities and input availability permit. Overall production may be lower because water availability will be lower, but the expertise exists in the region to make the best of whatever is available. So what is the problem?

The central problem is that variations in availability have surpassed the "typical" range to which "traditional" operations were adapted. Water management systems are now out of tune with water availability patterns, requiring changes in the associated processes to determine which

[5] A = Assessment, B = Bargaining, C = Codification, D = Delegation, and E = Engineering. Such features are identifiable worldwide in successful systems. For example, see Trawick (2003) for a sociologist's perspective, derived largely from experience in the Andes, which reached similar—certainly compatible—conclusions; and Frederiksen and Vissia (1998) for an engineering viewpoint.

sectors or users will suffer and by how much. These changes require the political bargaining process to be reopened, may change the rules of operation, and require new or revised institutional responsibilities. Infrastructure also may require modification.

Four important challenges to "traditional" water management systems can be identified:

1. Unsustainable, "Individualized" Withdrawals

Over recent decades, for many countries, the most important development has been the break of the "natural" link between the renewable supply and the level of use. In the past, as noted, rainfall generated runoff and infiltration supplied the traditional water systems. If rainfall was low, availability was low, and utilization was low.

Then, in the 1970s, cheap pumps and tubewell technology arrived. They enabled farmers to withdraw water from any source at much higher rates than with animal power and to tap deep aquifers by using submersible pumps. Their advent has had three profound negative consequences:

a. Specifically in the case of groundwater, *users can and now do "mine" aquifers*. The logic of the "tragedy of the commons" provides an incentive for the individual to derive benefits as extensively and quickly as possible.

   Aquifers are complex and difficult to observe—especially deep aquifers. Recharge may be vertical from rainfall; or lateral, as rainfall on surrounding hills moves down to the valleys and plains. Geological structures can constrain or redirect recharge. Thus, understanding how much water is actually available in total or on a renewable basis is extremely difficult. In many areas, the assessment of availability is partial and unreliable.
b. As water sources have become individually owned and operated, the amount of water actually being abstracted has become difficult to measure. Controlling such use is even more difficult. The individual farmer who has invested in the pump or well feels entitled to exploit it. Setting the rules (*codification*) and enforcing them (*delegation*) is extremely difficult.[6]

[6] Indeed, to the authors' knowledge, there are few if any examples of successful control of dispersed groundwater exploitation anywhere in the world. There are,

c. The effects of over-exploitation go beyond the direct users. Falling water tables reduce flows to qanats. Excessive pumping from one reach of a river or canal affects all other users. For example, it is reported that the qanats serving palmeries around Marrakech dried up in the 1970s so wells are now the main source of water.

2. Increased Variability and Reduction in Rainfall

Adding to this problem of unsustainable water use, IPCC projections imply increased variability and reduced river flows in areas that rely on surface storage in reservoirs. This situation already is a reality in parts of the Arab region. For example, in Morocco, due to reduced annual precipitation, dams constructed over the last three decades have been able to store, on average, only approximately half of their design capacity. As a consequence, farmers have become acutely aware of the uncertain nature of their access to water. Irrigation agencies in the command areas struggle to ration uncertain water supplies to the politically important farmer constituency.

Variability has local and regional implications. For the individual farmer, investing in the inputs for high-value crops is less attractive if there is a possibility of water shortage affecting yields. At the regional level, the relationship between rainfall and runoff is not linear. Runoff typically declines much more sharply than precipitation. Thus, variability is concentrated in the downstream areas. Therefore, the foundation for current allocation priorities, rules, institutional arrangements, and infrastructure is in doubt.

3. Political Uncertainty of Cooperation with Upstream Riparians

The Arab countries are dependent for some two-thirds of their water supplies on transboundary water. Egypt is the most extreme case, with some 95 percent of its water coming from the Nile. Apart from natural variability, investments in hydraulic infrastructure by upstream riparians change water availability to downstream users. For example, the Greater Anatolia Project affects water availability in Syria and Iraq. The Israeli water utility affects the availability of water in Palestine and

---

however, many examples of uncontrolled depletion: much of India, Mexico, Pakistan, US, and Yemen. An ongoing collective effort in Andhra Pradesh, India shows considerable early promise.

Jordan. Dams constructed in Ethiopia and Sudan affect the calculus of Egyptian water planners.

4. Deteriorating Water Quality

A fourth factor has been the political and economic pressure on decisionmakers to focus more on water quality. An IWMI survey of government irrigation officials in Egypt in 1995 produced the surprising result that many ranked pollution as the most important problem facing the sector.

For example, in the congested rural settlements along the Nile River Delta, residents and farmers have become an important lobbying group. They have been demanding that municipal and agricultural pollution be cleaned out of their canals and rivers. Among farmers, exporters of high-value farm products have been concerned that the marketability of their products is affected by water pollution.

Similarly, along the Mediterranean and Red Sea coasts, many countries are benefiting from tourism to historic and seaside resorts. However, development of other high potential areas—such as the coastline of the Nile Delta—is constrained by beach contamination from polluted Nile waters. Tour operators and resort owners are powerful interest groups who have thus joined environmentalists and farm exporters to lobby for enhanced water quality management.

A problem facing many countries in which groundwater is overused is the deterioration in quality that occurs as water tables fall. Deterioration is caused either from saline water that flows laterally into the depleted zone (especially near coasts); or from the deeper layers of water, which are more saline.

Understanding the Present: Traditional and New Data Sources

To recapitulate, climate change is likely to increase the imbalance between supply and demand for water in the Arab countries. However, there is ample evidence that scarcity has been successfully managed in the Arab world for centuries. *The components required to manage scarcity are information on resource availability; a bargaining process among the users to determine how water should be allocated, resulting in rules and responsibilities; and infrastructure to deliver the service.* Although their details vary, similar patterns have been common across many MNA countries for centuries. However, traditional processes increasingly are under threat from ever-growing demand and new technologies that upset the "traditional" balance between availability and utilization. Climate change is adding to the strain.

The process that will be induced by declining availability, more uncertainty and variability, and declining quality will be multidisciplinary. It will draw in hydrologists, engineers, economists, agriculturalists, lawyers, and institutional specialists—just as the ABCDE process does.

Success will depend, among many factors, on (1) the ability of the participants in the process to communicate as effectively and unambiguously as possible across disciplines—that is, it will depend on developing a common *terminology*—and (2) placing the analysis of options in a *basin* context.

Terminology for Water Accounting

Before discussing how water management can adjust to reflect the new context of declining availability and increased demand, we need to clarify our terminology. Without agreement over the definitions of concepts such as "efficiency" and "consumption," it is not possible to have a consistent view of what constitutes a successful water management policy.

Consider, for example, how a different viewpoint on the water resource gives a different understanding of efficiency in water management:

For a *water supply and sanitation engineer*, one design objective often is to recover, treat, and return to the hydrological system in good condition as *much* as possible (perhaps 95 percent) of the water withdrawn. A poorly functioning system would return a much smaller percentage and with a heavy pollution load.

In contrast, for an *irrigation engineer*, the design objective is to return as *little* as possible (perhaps 10 percent) of withdrawals to the system, preferably including *all* of the salts that were in the original abstraction.

Individual cases will vary, but a downstream environmental "water user" might be puzzled to find that, when *urban water efficiency* improves, s/he gets more and cleaner water. The same downstream user would find that improvements in *irrigation efficiency* reduce water availability and perhaps increase the salt load.

The source of this paradox is simple. Irrigation engineers have, quite rationally, designed irrigation systems to maximize the amount of water that reaches the crop, and is then consumed in transpiration. This is the purpose of an irrigation system, and understanding how much water arrives at its destination is central to operational planning and designing cropping patterns.

For irrigation, water allocations usually are defined in terms of right to withdraw water (either as a volume per season; or a rate of withdrawal, or an irrigation "turn"). A common irrigation performance indicator is "how much area did we irrigate per unit of water withdrawn." Improving on this indicator (by lining canals, or using modern irrigation technology) is a valid objective at the project level, or for the individual irrigator with a well. Improvements often will lead to substantial increases in the area irrigated (and hence consumption of water by crops) for the same quantity withdrawn.

However, this "local" perspective is unhelpful, even misleading, when water is scarce at the wider basin or aquifer scale. From this perspective, the question of where the "losses" actually were going is critical. Certainly, if the irrigated area is increased, transpiration is greater and, to that extent, return flows will be reduced. Return flows to rivers may contribute to downstream human, agricultural, or natural demands. Infiltration to aquifers from leaking canals or excessive irrigation applications contributes to groundwater recharge. Thus, an improvement as observed at one location may have a negative impact elsewhere.

In response to this problem, the International Commission on Irrigation and Drainage (ICID) recently published a review of the literature on irrigation efficiency (Perry 2007) and recommended terms that were suitable for application in all water sectors. The draft was for reviewed by all of ICID's relevant national committees and working groups, and thereby represents a wide consensus. Other writers and organizations have similar views. The American Society of Civil Engineers (ASCE) is debating a change in terminology. The California Department of Water Resources makes no mention of efficiency in its regular accounts of water allocation and use in the state. Recent research publications take the same view (Ward and Pulido-Vasquez 2008). The recommendations have been summarized in terms of water *consumed* by users (irrigation, water supply, and industries) and *nonconsumed* water (usually in the form of environmental flows or as groundwater stock).

This approach to water sector terminology has a number of important features:

1. It closely follows hydrological concepts (conservation of mass. The fractions add up to unity at any given level of aggregation).
2. It differentiates between consumptive and nonconsumptive uses (so that the water supply and sanitation sector is characterized quite differently from irrigation).
3. Consumption we *want* (transpiration by irrigated crops) is distinguished from *unwanted* consumption (such as transpiration by weeds and evaporation from wet soil).
4. Outflows that are recoverable are distinguished from those that are not.
5. In water-short environments, these terms enable sectoral specialists to communicate unambiguously to point directly to the priorities that will deliver more benefits from the same—or less—water:
   a. Reducing nonbeneficial consumption
   b. Minimizing nonrecoverable flows
   c. Recovering as much as possible of the recoverable flows.

The use of these terms greatly clarifies the discussion of interventions. When these terms are not used carefully, the ambiguity can generate misconceptions. For example, respected authorities can quote data suggesting that production can be substantially increased while water use is cut by 50 percent–75 percent (Brown 2008). This wording could indicate this outcome without clarifying that the "saving" is in water applied, not water consumed, and that crop water transpiration is linearly related to crop production—so that, in reality, *beneficial water consumption* will *increase* with crop production.

One conventional response to scarcity is to introduce "water-saving" technologies. Most MNA countries are pursuing such interventions (either government sponsored or farmer initiated). Typically, the expectation is that crop production will be increased, and water will be saved. However, normally, the water-saving indicator does not signify water *consumed in* the irrigation process but, rather, water *applied to* the process.

In the framework proposed by ICID, such interventions must be very carefully evaluated:

- To the extent that transpiration is increased, the consumptive use of water is proportionately increased. The source of water for that increase then must be traced.

- If the impact is to shift nonbeneficial evaporation into beneficial transpiration, then production is increased at no incremental water cost. However, the literature suggests that, once irrigation practices are reasonable, the proportion of applied water going to evaporation is rather small.
- However, if the impact of the intervention is to reduce runoff or infiltration, the ultimate destination of that excess must be identified. If the water is fully or partially recovered, the actual saving is proportionately reduced.

The impact of improved irrigation "efficiency" and irrigation management always will be somewhere between two extremes on a spectrum of possible impacts:

1. At one extreme, water that otherwise would have been unproductive makes a full contribution to crop transpiration and hence production. The resource cost is zero; the outcome fully positive.
2. At the opposite end of the spectrum, incremental water consumption as a result of improved irrigation technology in one location takes water away from a more productive alternative use in another location—future domestic consumption, for example—so the impact is strongly negative.

River Basin Context

For each part of a river basin, a water balance can be constructed comprising precipitation and surface inflows as sources; and evaporation, transpiration, runoff, and changes to storage as end uses (or destinations). The uses can further be classified into the ICID beneficial/nonbeneficial, recoverable/nonrecoverable flow categories. Some areas are "sources" of water, that is, precipitation exceeds local use and the excess goes to runoff or groundwater recharge. Other areas —including wetlands, irrigated areas, and saline sinks—are "sinks" in which consumption exceeds precipitation. The balance is met by natural inflows, managed diversions, or pumping.

Table 6.3 provides a schematic, with completely notional data, of how basin accounts can be represented in accordance with this approach. As is discussed later, models are available that enable various data types to be integrated into this format.

The first row of table 6.3 defines the major categories of land and water use. Some are essentially natural and "unmanaged." Others consist of managed land use. The third is managed water use. In the next row, typical classes within these categories and the percentage of the area under each class are specified.

Sources of water consist of rainfall and any committed inflows (in this case, restricted to the requirement for irrigation). The rainfall is distributed across land classes—here, for simplicity, in proportion to area.

The remaining lines correspond to the ICID classification of uses. The data in each column—which correspond to a water balance for that use class—then can be estimated, calculated, or modeled for each cell (elaborated below).

What is deemed "nonbeneficial" is, in large measure, a political decision. Clearly, water that is consumed by weeds among irrigated crops is nonbeneficial, as is water that evaporates from bare soil (after rainfall or during poorly managed irrigation). However, water evaporated and transpired from wetlands, riparian vegetation, and natural forests often may be considered as environmentally useful, hence a beneficial use.

This basin-scale overview would be complemented by more detailed analyses of specific areas of interest. For example, the estimated overall net groundwater recharge of 45 units (recoverable recharge = 145 units, transfers to irrigation = 100 units) may well disguise areas in which recharge is substantially positive or negative.

As mentioned, the data in the table are invented, but the advantages for a country of creating such a data set are considerable. The set clarifies the most significant water sources and uses:

- Natural forest is the most significant source of stream flow, so changes in this land use class should be monitored carefully.
- Nonbeneficial use in irrigated areas is significant. Thus, better management or technologies offer scope for significant increases in beneficial use, hence crop production, without negative impacts on downstream areas.
- Recoverable river flows (209 units) are entirely utilized. Additional use of surface water would require either transfers from one sector to another, or construction of facilities to capture more of the currently nonrecoverable flows.

Table 6.3 Tabulation of Land Use Classes and Water Balances at Basin Scale

	Basin	Natural landcover (water and land not managed)								Managed land use		Managed water use			
	Mm³	Rocks *(%)*	Glacier *(%)*	Desert *(%)*	Natural forest *(%)*	Saline sink *(%)*	Grazing land *(%)*	Natural wetland *(%)*	Lakes *(%)*	Forest plantation *(%)*	Rainfed ag *(%)*	Cities *(%)*	Managed wetlands *(%)*	Irrigated ag *(%)*	Transfers
		5	*1*	*5*	*40*	*1*	*20*	*2*	*4*	*3*	*10*	*3*	*1*	*5*	
Sources															
Rainfall	2,500	125	25	125	1,000	25	500	50	100	75	250	75	25	125	
Surface water transfer														209	209
Groundwater transfer														100	100
Uses															
Evapotranspiration	2,191	5	1	80	800	40	400	80	80	45	200	10	50	400	
Beneficial	1,535				700		300	80		30	120	5	50	250	
Nonbeneficial	656	5	1	80	100	40	100	0	80	15	80	5	0	150	
Surplus/deficit	618	120	24	45	200	–15	100	–30	20	30	50	65	–25	34	
Runoff	359	95	24	15	140	–15	30	–30	20	10	30	40	–30	30	
(Rec)	209	80	24	15	60	–15	20	0	20	5	20	10	–30		–209
(Non-rec)	150	15	0	0	80	0	10	–30	0	5	10	30	0	30	
Recharge	259	25	0	30	60	0	70	0	0	20	20	25	5	4	
(Rec)	145			20	10	0	60		0		20	10		25	–100
(Non-rec)	114	25	0	10	50	0	10	0	0	20	0	15	5	–21	

- Rainfed agricultural areas contribute substantial recharge, so in these areas there could be scope to develop groundwater and thus increase agricultural production.

This framework forces recognition of the linkages among the components of a basin, which is an essential basis for understanding and analysis.

The output from models is, at best, only as good as the data we put in to them. Remote sensing (RS) now offers important additional sources of information, from rainfall through evapotranspiration (ET) (with the potential to distinguish between the beneficial and nonbeneficial components), to stream flow, lake levels, and groundwater storage. Each of these data types—especially when combined with ground-truthed observations—now can be estimated at various scales through RS technologies.

Information from Remote Sensing

This section summarizes the potential contribution of RS information to the various information needs identified in table 6.3.

Land-Use Classes

One of the earliest uses of RS data was to classify land use. Initially, classification was little more than visual identification. However, in the past decade or so, more and more characteristics have become observable with different sensors and the data can be processed in computers. Thus, it has become possible to identify more classes with greater precision and at higher resolution.

Rainfall

The Tropical Rainfall Measurement Mission, launched in 1997, provides real-time estimates of rainfall derived from microwave data at 1 degree resolution. More recently, data from this and other sources have been integrated through the PERSIANN (Precipitation Estimation from Remotely Sensed Information Using Artificial Neural Networks) algorithm to generate rainfall data at a resolution of 0.25 degrees (25km) at the equator, at 3-hour intervals.

Evaporation and Transpiration

One of the most active areas of research in the interpretation of RS data in the last decade has been evapotranspiration (ET). The Surface Energy Balance for Land (SEBAL) (Bastiaanssen and others 1998) has been applied successfully in a large number of countries. It provides spatial estimates of ET at resolutions from a few meters to several kilometers, depending on the source data. The METRIC algorithm (Allen and others 2007) is computationally similar to SEBAL. Anderson and others (1997) use an approach that does not rely on ground-based information. It generates frequent estimates of ET at a resolution of 5km–10km. Integration of these data with finer resolution sources enables downscaling the ET estimates.

Table 6.3 disaggregates ET into beneficial and nonbeneficial components. This separation is important, but not easy to make. Some nonbeneficial ET is evaporation from wet soil and can be identified because it occurs in the absence of vegetation. Similarly, ET occurs from nonbeneficial vegetation. Whether a given vegetation type is considered beneficial or not is essentially a political decision. Perhaps most importantly for irrigation managers, there is nonbeneficial evaporation when irrigation deliveries are excessive or poorly managed at the farm level. Estimates of the distribution of ET between E and T also can be made based on known crop characteristics. The potential T is known, so if ET exceeds this figure, the excess must be evaporation.

Runoff and Recharge

Once precipitation and evapotranspiration are mapped, the total runoff and recharge for a given area can be estimated as the difference between these two. Partitioning further between runoff and recharge generally requires ground data, and/or further modeling. RS data also is beginning to make a contribution in this area. The GRACE project, sponsored by NASA, measures variations in the water stored in the soil and underlying aquifers. To date, the resolution of these data is coarse (approximately 100km), making it hard to interpret local changes. However, already such information provides a degree of independent confirmation of other observations or modeling results. Thus, it can be anticipated that, in future, estimates at finer resolution will be possible.

Information from Conventional Measurements

The information sources outlined above provide important clues to how a basin is operating. Additional, more traditional sources of information are essential to complement and confirm such data. They include streamflows, releases from reservoirs, water table information, cropping patterns and planting dates, land cover, and meteorological data.

Integrating Information and Scenario Analysis: Hydrological and WEAP Models

An appropriate model can greatly facilitate the process of organizing the analysis, linking components of the system, and, especially, exploring the impact of future scenarios. *The main challenge is not to try to build in all the processes that we can model, but to identify the most relevant processes.* Models can address either very narrow issues in great detail—for example, how stomata react to salt—or much broader issues at a lower level of detail. For the type of analysis relevant to the issues of concern here, hydrological models are most relevant.

Table 6.3 makes clear that RS data can contribute extensively to identify the main "sources and uses" (rainfall and ET) components as well as to understand recharge. These data sets are basic to the formulation of a hydrological model. This model then adds the capacity to define the interactions between storing and diverting runoff, and pumping groundwater. These interactions are susceptible to managed interventions.

A gargantuan number of hydrological models exist, and applications are growing rapidly. The number of online pages that include the words, "hydrological model." is over 1.2 million (Google January 2007). Using the same search engine to find "water resources model" came up with 86 million pages. Therefore, a *critical question for hydrological model studies relates to the selection of the most appropriate model.* One of the most important issues to consider is the *spatial scale* to be incorporated in the study and *how much physical detail* is to be included.

WEAP (Water Evaluation and Planning System) is well suited to integrate the types of data described above to produce a practical "accounting framework" for planners and decisionmakers. It was created in 1988 to be a flexible, integrated, and transparent planning tool to evaluate the sustainability of current water demand and supply patterns and to explore alternative long-range scenarios (SEI 1997).

WEAP is freely available to academic, governmental, and nonprofit organizations in developing countries.

WEAP follows an integrated approach to water development that places water projects in the context of multisectoral, prioritized demands; water quality; and ecosystem preservation and protection. WEAP also is distinguished by its integrated approach to simulating both the natural (rainfall, evapotranspirative demands, runoff, baseflow) and engineered components (reservoirs, diversions, groundwater pumping) of water systems. This holistic approach gives the planner access to a comprehensive view of the broad range of factors that must be considered in managing water resources. WEAP, thus, is an effective tool for examining alternative water development and management options.

WEAP operates on the basic principles of a water balance. Using this tool, the analyst can represent all of the system's complexities: supply sources (rainfall, rivers, creeks, groundwater, and reservoirs), withdrawal, transmission and wastewater treatment facilities, ecosystem requirements, water demands, and pollution generation. The data structure and level of detail easily can be customized to meet the requirements of a particular analysis and to reflect the limits imposed by available data.

Operating on these basic principles, WEAP is applicable to many scales; municipal and agricultural systems, single catchments, or complex transboundary river systems. WEAP incorporates not only water allocation but also, if required, water quality and ecosystem preservation modules, making this model suitable for simulating many of the freshwater problems that exist in the world. SEI 2005 and Droogers 2008 explain more about the WEAP model and present an example—loosely based on a known basin—with guidance for operating and modifying the model to explore future scenarios.

However, the most important aspect of choosing a model is its capacity to explore different scenarios. Scenarios may be driven either by exogenous factors such as population growth and climate change (Droogers and Aerts 2005) or by management decisions (reservoir operation rules, water allocation among sectors, investment in infras-tructure such as water treatment or desalinization plants, and agricultural irrigation practices). Understanding how changes in one part of the basin are likely to impact on other areas and, indeed, which linkages are the most important are very powerful features of an appropriate modeling system.

Conclusions and Recommendations

The water situation facing most Arab countries is difficult: water supplies are scarce, and the demand for water is high.

These conditions have existed for millennia so a variety of approaches evolved to ensure that whatever water is available is productively and sustainably used. Water management arrangements vary in scale, complexity, technology, and purpose. However, they also have important common features: the group sharing the water had a clearly defined water source; agreed priorities for allocating the water formed the basis of formal or informal rules; responsibilities for administering the rules were assigned; and the appropriate infrastructure to deliver the service is implied by this entire process.

In fact, the elements that provide for stability are clearly identifiable across a wide range of countries and techniques. They comprise an understanding of availability (*assessment*); a political *bargaining* process to establish priorities for allocation; *codification* of the results of this process into laws and rules; *delegation* of powers to institutions and governmental and nongovernment agencies: and *engineering* works suitable to deliver the water to the users (ABCDE).

However, in many countries, the precarious balance that developed over centuries to manage naturally available water supplies has been disturbed in many countries by the pressures of economic development and demographics as well as the introduction of new technologies that made over-exploitation for irrigation purposes easier to practice and harder to control. The outcome is often chaotic competition, inequitable distribution, and over-exploitation.

Climate change is an additional destabilizing factor. Sharp declines in water availability are projected over the coming century. Increasing temperature and aridity will increase crop-water demand, thus accentuating the deficit between supply and demand.

Addressing these issues must be a multidisciplinary effort. Consequently, communication among the participants in unambiguous terminology about the nature of water use will be essential—to distinguish between consumptive and nonconsumptive uses of water; as well as to carefully identify which return flows are already exploited elsewhere and which are genuine losses to the system. *Hydrology provides the scientific framework within which solutions must be found*.

Presenting hydrological information to policymakers and planners is not always easy. However, the combination of modern analytical tools, new sources of spatial data, and diligent measurements of key "ground" data provide a proven base. Integrating these data sources will enable sectors, regions, and countries to better understand how these data interrelate and will enable the inevitable disputes about allocation to be based, as far as possible, on facts rather than assertions.

Furthermore, well-formulated models enable exploration of possible scenarios that can reflect management options, technical options, and investment options in the context of projected climate scenarios.

The potential contribution of new RS techniques to these efforts is substantial. Through different types of satellites and analysis, RS can provide historical time series as well as near-real-time data about the major components of the hydrological cycle: rainfall, land use, irrigated areas, ET, and changes in groundwater.

Restoring hydrological equilibrium in the Arab world is critical for sustainability, productivity, and equity between generations. However, carrying it out will be difficult. It will require restoration of the historic linkages among *assessment of availability, bargaining, codification, delegation, and engineering (ABCDE)*. Information about availability is the foundation for this structure, and new technologies, especially RS techniques, offer powerful ways to improve knowledge for all concerned.

References

Al-Ghafri, A., T. Inoue, and T. Nagasawa. 2007. "Irrigation Scheduling of Aflaj of Oman." University of Hokkaido. www.inweh.unu.edu/inweh/drylands/Publications/AlGhafri.pdf

Allen R.G., M. Tasumi, and R. Trezza. 2007. "Satellite-Based Energy Balance for Mapping Evapotranspiration with Internalized Calibration (METRIC) Model." www.drought.gov/imageserver/NIDIS/workshops/remotesensing/abstracts/graeme_aggett.pdf

Anderson, M.C., J.M. Norman, G.R. Diak, W.P. Kustas, and J.R. Mecikalski. 1997. "A Two-Source Time-Integrated Model for Estimating Surface Fluxes Using Thermal Infrared Remote Sensing." *Remote Sensing of Environment* 60: 195–216.

Bastiaanssen, W.G. M., M. Menenti, R.A. Feddes, and A.A.M. Holtslag. 1998. "A Remote Sensing Surface Energy Balance Algorithm for Land (SEBAL). Part 1: Formulation." *Journal of Hydrology:* 212–13, 198–212.

Bates, B.C., Z.W. Kundzewicz, S. Wu, and J.P. Palutikof, eds. 2008. "Climate Change and Water." Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva.

Battisti, D.S., and R.L. Naylor. 2009. "Historical Warnings of Future Food Insecurity with Unprecedented Seasonal Heat." *Science* 323 (240).

Frederiksen, H.D., and R.J. Vissia. 1998. "Considerations in Formulating the Transfer of Services in the Water Sector." International Water Management Institute, Colombo.

Gleick, P.H. 1996. "Basic Water Requirements for Human Activities: Meeting Basic Needs." *Water International* 21: 83–92.

Perry, C.J. 2007. "Efficient Irrigation, Inefficient Communication, Flawed Recommendations." *Irrigation and Drainage*. July.

Mehraby, R. www.destinationiran.com/Kariz_(Qanat).htm)

Steduto, P., T.C. Hsiao, and E. Fereres. 2007. "On the Conservative Behaviour of Biomass Water Productivity." *Irrigation Science*. DOI 10.1007/s00271-007-0064-1.

SEI (Stockholm Environmental Institute): Stockholm 1998, 2005. Water Evaluation and Planning System. www.seib.org/weap

Trawick, P.B. 2003. *The Struggle for Water in Peru: Comedy and Tragedy in the Andean Commons*. Stanford University Press.

UNESCO. 2009. "Water Availability per Person per Year." www.unesco.org/bpi/wwdr/WWDR_chart1_eng.pdf

Ward, F.A., and M. Pulido-Velasquez. 2008. "Water Conservation in Irrigation Can Increase Water Use." "Proceedings of the National Academy of Science." Free online through the PNAS open access option. www.pnas.orgcgidoi10.1073pnas.0805554105

7

Egypt Case Study Energy Efficiency CDM Program: Irrigation and Drainage Pumping Sector

Abdulhamid Azad

In 1992 over 180 countries adopted the United Nations Convention on Climate Change (UNFCCC), a framework convention aimed at stabilizing climate-altering greenhouse gases in the atmosphere.[†] The Kyoto Protocol, which was adopted under the UNFCCC and entered into force on February 2005, commits industrialized countries to reduce their greenhouse gas (GHG) emissions by an average of 5.2 percent below their 1990 levels by 2012. To meet these commitments in the most cost-effective manner, the Protocol contains provisions allowing industrialized countries some flexibility to meet their obligations through projects generating emission reductions (ERs) elsewhere. The most important instrument permitting industrialized countries to finance emissions-avoiding projects in developing countries and receive credit for doing so is the Clean Development Mechanism (CDM) proposed under article 12 of the Kyoto Protocol. The main purpose of this mechanism is to assist host countries with sustainable development through the transfer of cleaner technology and financial resources for specific projects, while contributing to the reduction of greenhouse gas emissions.

Despite the rapid growth of global carbon finance transactions, energy efficiency improvements of irrigation and drainage pumping stations are still being bypassed due to lack of operational policy frameworks and pilot projects. Moreover, most of the pumping stations also are suffering from an overall lack of investments in the energy efficiency improvements. The result is that even the potentially most attractive,

[†] This chapter was prepared on the basis of project documents in the recently completed World-Bank-financed Egypt Pumps III Project and the preparatory work for a proposed operation with Clean Development Mechanism (CDM) engagement.

Box 7.1 Need for a New Approach to Emission Reductions

- Energy efficiency potentially could account for more than half of energy-related greenhouse gas reductions achievable over the next 20–40 years.
- Energy-efficient projects account for less than 10 percent of the current market.

low-cost carbon mitigation projects encounter significant difficulties obtaining funding (box 7.1).

This case study presents analytical issues related to CDM projects for the irrigation and drainage sector such as baseline definitions, project idea note preparation, which CDM methodology is to be used for the pumping sector, benefits, and yearly emission reductions resulting from energy savings.

Irrigation and Drainage Sector

Egypt has no significant rainfall and is dependent on its 55.5 billion cubic meters (m^3) per annum share of Nile water. The country therefore must improve returns from its available water resources in an environmentally sound and sustainable manner, which includes adopting energy-efficient technologies. The energy-intensive Egyptian irrigation and drainage sector plays a vital part in food production and in maintaining the rural economy. Agriculture accounts for 20 percent of GDP and 35 percent of the labor force. The success of irrigated agriculture depends to a large extent on the effective operation and maintenance (O&M) of the irrigation and drainage system to maintain the quality of the level of irrigation and drainage services (table 7.1).

Table 7.1 Irrigation and Drainage Service Quality Indicators

Service quality	Irrigation	Drainage
Adequacy	Ability to meet water demand for optimal plant growth	Ability to dispose excess water in minimal time to prevent damage
Reliability	Confidence in supply of water	Confidence in ability to dispose excess water
Equity	Fair distribution of share of water shortage risks and minimize the head and tail equities (poverty aspect)	Fair distribution of risks
Flexibility	Ability to choose the frequency, rate, and duration of supply	Ability to choose the time, rate, and duration of drainage water disposal

Given the very flat topography in most parts of the country, water in open conveyance channels needs to be lifted at certain critical points to provide irrigation, while drainage water needs to be pumped out. As a consequence, there are over 743 pumping stations that are of vital importance for Egypt's agriculture in the Nile Valley and Delta. By world standards, most of these pumping stations are large, with pumping capacities ranging from 2 m^3/s to 75 m^3/s. They command large irrigated and drainage areas with a high cropping intensity ranging from 180 percent–200 percent. Pumping heights range from 5 meters–50 meters. Pumping drainage water also is needed to control groundwater levels and salinity to preserve crop yields. Approximately half of these stations have very old pumping units operating inefficiently and incurring high energy costs (70 percent of total operating costs). The allocation of funds to maintenance activities is small, and the pumping stations are subject to contingency repairs. Given this system's strategic importance to the country, financing is made available from the government's budget. However, there is generally no serious questioning of either the economics or the technological choices made, such as energy efficiency aspects.

In water-scarce regions such as in Egypt, declines in reliable water supplies for irrigation will dampen the increase in cereals yield that policymakers expect as a result of improving irrigation infrastructure and techniques. By 2025, reduced reliability is expected to reduce yields in the Nile River basins by 11 percent. There is evidence that temperatures already have increased in the last two decades, and that drought episodes have intensified. International Panel on Climate Change (IPCC) climate models predict additional increases in temperature. Climate models also predict an increase in amplitude and frequency of extreme weather events such as droughts, floods, and storms. The expected rise in temperature will increase evaporation, while a rise in the seawater level will cause salt-water intrusion in coastal groundwater reservoirs. Given such scenarios in the face of growing demand, overall water availability for irrigation and other uses will decrease. At the same time, water availability will become more erratic and thus harder to manage. In the Nile Delta, drainage pumping stations will need to be redesigned to "climate-proof" the investment so that they can help to counter the effect of the expected seawater intrusion. Redesign also would enable the continuation of rice cultivation in the Nile Delta, which would help combat seawater intrusion.

In a context of increasing water scarcity, climate change will exacerbate the current supply-demand imbalance. Major investments will

Table 7.2 GHG Emissions as Reported to UNFCCC, 1990 *(million t CO_2)*

Sector	CO2 emissions *(mil, t)*	Total emissions *(%)*
All energy	82.72	71
Industry (other than energy)	10.27	9
Agriculture	17.93	15
Wastes	5.69	5
Total	116.60	100

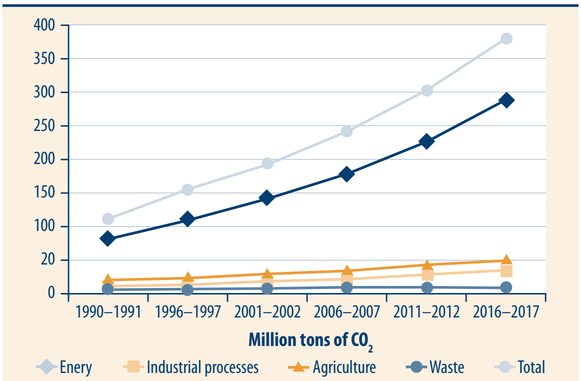
Source: Egypt National Greenhouse Gases Inventory 1990–91. www.eeaa.gov.eg

be needed to (a) modernize irrigation and drainage pumping stations and (b) improve on-farm irrigation efficiency. Adaptation may require switches in cropping patterns to new crops or varieties more tolerant of water scarcity. To avoid the harmful effects on crops of irrigation and drainage pump failures and reduce the O&M cost of the pumping stations, the government has set up a long-term program to rehabilitate the irrigation and drainage pumping network of the Nile Water Resource Management System.

GHG Emissions Characteristics

The aggregate national GHG emissions without the impacts of land-use changes were estimated at over 116 million tons of CO_2 equivalent in the baseline year 1990–91. The relative contributions of greenhouse gases in 1990–91 to the total emissions, by sector, are presented in table 7.2. The agriculture sector was the second largest GHG source, mainly from enteric fermentation and rice cultivation, followed by the non-combustion-related industrial emissions of CO_2, mainly from the steel and cement industries (EEAA 1999).

Figure 7.1 GHG Projections for All Sectors, 1990–2017



Selling Emission Reductions under the Kyoto Protocol to Support Program Implementation

To register a CDM program such as this with the CDM Executive Board, an approved methodology must exist. In this case, an approved methodology exists, namely, AM0020, "Monitoring Methodology for Water Pumping Efficiency Improvements."

In brief, how does the CDM work in the case of this project? Energy savings resulting from energy efficiency improvements reduce greenhouse gas emissions. To meet their agreed emission reductions targets, OECD countries that have agreed to reduce their emissions of GHG then can purchase these emission reductions from such projects located in developing countries, which are not obliged to reduce their GHG emissions.

Pumping stations that, in principle, are eligible to participate in this CDM program will need to meet the following criteria:

- Age of the equipment exceeds 20 years.
- Average operating hours per unit exceed 100,000.
- Capacity is inadequate, or there is no stand-by unit.
- Drainage and static head requirements have changed.
- Building is in very poor condition, including major structural deficiencies.
- There are problems with switch gear, gear boxes, and corrosion.
- New pumps will be installed if the cost of rehabilitation exceeds 70 percent of the cost of new pumps.

Most of the project investments will relate to electromechanical equipment for the pumping stations. Efforts will be directed toward establishing better linkages among the Irrigation Department, Drainage Authority, and the Ministry of Electricity and Energy. The last is implementing Energy Efficiency Programs including auditing energy consumption. These programs have had some success with domestic water supply and wastewater treatment pumping stations.

Table 7.3 Change in Energy Use

	Pumping station		
Type of intervention	**Irrigation** *(%)*	**Drainage** *(%)*	**Annual energy savings** *(US$)*
Complete rehabilitation	−22	−10	624,637
Partial replacement	−13	−5	1,376,690
Provision of spare parts	−9	−7	1,054,593
Total			**3,055,920**

The recent pumping station rehabilitation project analyzed the overall impact on energy use by rehabilitation alone (table 7.3). Rehabilitation increased the operational efficiency of motors and pumps and reduced the amount of maintenance required, resulting in immediate cost savings. Annual savings in maintenance costs were estimated at 5 percent of the capital costs of rehabilitation and 1 percent of spare parts.

CDM Program of Activities Design Document

A CDM program will be implemented through what is termed a Program of Activities, for which a Program of Activities Design Document (PoA DD) will need to be prepared and registered with the CDM Executive Board. The PoA DD will describe the overall program. The proposed CDM Program Activity Design Document (CPA) will describe all the energy efficiency measures to be implemented in a specific pumping station(s). The energy efficiency measures will be based on energy audits of the pumping stations and will include:

- Electricity demand-side management
- Power subscription adjustment
- Power factor improvement
- Changing mismatched pumps
- Impellers adjustments
- High-efficiency motors
- Preventive pump maintenance
- Energy efficiency monitoring and evaluation.

In the absence of the program activity, the pumping stations will continue to be operated at the same energy performance level or worse. The electricity consumption of the pumping stations will stay at the current order of 1,500 GWh/year or will increase. The program activity will improve the energy performance of the pumping stations and will save electricity, reducing GHG emissions. The program's emission reductions correspond to GHG emissions that would have been produced in the absence of the program activities.

The current operational conditions and performance of the pumping stations will be documented and organized in a database that will be used as a reference for the future emissions reductions evaluation. A comprehensive Management Information System (MIS) has been developed for this database.

Additionality

The program's additionality can be justified by the following barrier arguments:

a. There is no regulation or incentive scheme in place covering the program's activities.
b. The program faces significant financial barriers and possibly will have to be supported by a World Bank loan.
c. Electricity tariffs are low in Egypt so the energy bill savings are not sufficiently motivating for program implementation.

CDM Methodology to Be Used

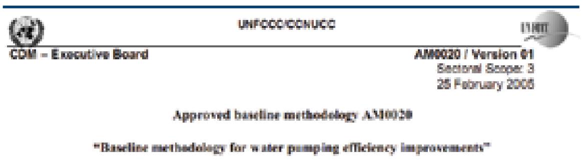
The AM0020 methodology is applicable to project activities that:

- Seek to reduce GHG emissions by explicitly reducing the amount of energy required to deliver a unit of water to end-users in municipal water utilities.
- Improve energy efficiency in overall water pumping, including reducing technical losses and leaks, as well as the energy efficiency of the pumping scheme that consumes electricity from the electricity grid, in which
  - The existing efficiency (of water and energy) *is being* improved, or
  - A new scheme is being developed to replace completely the old scheme. This methodology will apply to the new scheme only up to the measured delivery capacity (annual amount of delivered water) of the old scheme.

The AM0020 methodology is not applicable to cases in which the project activities consist of building entirely new schemes to augment existing capacity. This requirement will ensure that only emissions reductions up to the existing capacity of the system will be considered.

The CDM monitoring requirements are defined in the Approved Monitoring Methodology AM0020, "Monitoring Methodology for Water Pumping Efficiency Improvements" (figure 7.2).

Figure 7.2 AM0020, 2005


UNFCCC/CCNUCC

CDM – Executive Board

AM0020 / Version 01
Sectoral Scope: 3
25 February 2005

Approved baseline methodology AM0020

"Baseline methodology for water pumping efficiency improvements"

This methodology requires the following monitoring arrangements:

- Water from the entire scheme entering in the water system post-project must be metered and the total numbers adjusted to make sure that increases in water supply from the new scheme are not counted.
- Energy consumption in the form of kWh required to move the water within the boundaries of the system must be calculated.
- The carbon content of the electricity employed by the water system must be calculated using the combined margin approach outlined in the "Tool to Calculate the Emission Factor for an Electricity System."[1] In other words, if the water pumps are linked to the national energy grid, the CO_2 output per Mw or kW/h of electricity will need to be calculated and monitored. This information generally is made available by the authorities each year. An amendment to the methodology will be required to accommodate off-grid pumps. If the water pumps operate from off-grid sources such as diesel generators, the annual consumption of related diesel fuel will need to be calculated. Default values for the carbon content of the diesel will be used for this calculation.

The program also supports and maintains the improvement of energy efficiency of the pumping stations through energy audits, energy management programs, efficiency measurement and control, and preventive pumps maintenance. The technology employed is widely used and commercially available. Most of the program activities concern water demand management and best practices for energy efficiency improvement and pumping stations and canals maintenance. However, these activities are not widely practiced in Egypt.

GHG Emissions Reductions

Electricity savings resulting from energy efficiency improvement will reduce the emissions of GHG associated with power generation in Egypt. The main GHG targeted is CO_2. The expected emissions reductions associated with the CDM program activities are evaluated in table 7.4.

---

[1] http://cdm.unfccc.int/methodologies/Tools/EB35_repan12_Tool_grid_emission.pdf

Table 7.4 Yearly Emission Reduction Resulting from Energy Savings, 2010–18 *(%)*

Activity start date		2010
EE program implementation period		**2010–18** *(%)*
2010		6.25
2011		6.25
2012		12.5
2013		12.5
2014		12.5
2015		12.5
2016		12.5
2017		12.5
2018		12.5
Year of start of crediting period		**2012**
Emission reductions		**t CO_2**
Year 1	2012	29,070.6
Year 2	2013	58,141.3
Year 3	2014	87,211.9
Year 4	2015	116,282.5
Year 5	2016	145,353.1
Year 6	2017	174,423.8
Year 7	2018	203,494.4
Year 8	2019	232,565.0
Year 9	2020	232,565.0
Year 10	2021	232,565.0
Year 11	2022	232,565.0
Year 12	2023	232,565.0
Year 13	2024	232,565.0
Year 14	2025	232,565.0
Year 15	2026	232,565.0
Year 16	2027	232,565.0
Year 17	2028	232,565.0
Year 18	2029	232,565.0
Year 19	2030	232,565.0
Year 20	2031	232,565.0
Year 21	2032	232,565.0
Year 22	2033	203,494.4
Year 23	2034	174,423.8
Year 24	2035	145,353.1
Year 25	2036	116,282.5
Year 26	2037	87,211.9
Year 27	2038	58,141.3
Year 28	2039	29,070.6
Total	**t CO_2**	**4,883,865.4**
Average	**t CO_2/year**	**174,423.8**

They are derived from the total annual electricity bill of the pumping stations and the assumed current and target pumping station efficiencies.

CDM Implementation Cost

The estimated cost of the irrigation and drainage pumping stations modernization program will be detailed in the project concept design document. The additional CDM pre-operational development costs (feasibility assessment, project design document, registration, validation) are estimated at US$150,000, excluding the Designated Operational Entity (DNA fee). In Egypt, this fee is fixed at 3 percent of the Certified Emissions Reductions (CERs) for energy efficiency projects.

The required CDM monitoring plan will be integrated in the monitoring and reporting procedures of the pump modernization program so the additional costs for CDM monitoring will be minimal. However, an additional budget for the CDM project operational phase should be foreseen for CER verification and issuance.[2]

Benefits of the CDM Program

Besides the expected additional revenues that the CDM can generate, the implementation of a CDM program for the pumping stations modernization project offers multiple advantages:

- GOE will need to provide fewer irrigation subsidies and energy subsidies and can reallocate the reduced expenditures elsewhere.
- The program contributes to CDM development in Egypt and helps ensure the sustainable development of the country.
- It reinforces the CDM capacity of the concerned stakeholders.
- It demonstrates Egypt's efforts to reduce GHG emissions and to reinforce its sustainable development strategy.
- It helps to build a viable PPP scheme and thereby facilitates the transfer of the O&M of the pumping stations to the private sector.
- It reduces electricity consumption and helps preserve the country's fossil fuel resources.
- Training and education of pumping stations operators will create awareness of the efficient use of electricity and proper energy management's positive effect on the environment.

---

[3] Estimated at US$30,000/year.

- The project will encourage a greater investment and will provide more resources to reduce water losses through fixing leaks and faulty pumps.
- The project supports the overall financial performance by reducing the unit cost of supplying water.
- It provides employment during the implementation and monitoring phases of the project activity.

The expected revenues from the CDM program depend greatly on the commercial carbon credits selling terms and the risk-taking of transaction costs and ERs certification. The carbon price can vary from US$8–16 per ton eq. CO_2. Accordingly, the CDM program could generate US$40–100 million during its 28-year lifespan.[4]

Program Risks

As part of the pumping station modernization project, the CDM program will share in the risks of project implementation.

However, besides the intrinsic project risks, the specific CDM risks can be summarized as:

- Registration risks associated with the CDM program's additionality[5]
- Uncertainty of the future of CDM beyond 2012
- Higher transaction costs
- Relevant stakeholders' insufficient motivation and awareness of CDM benefits.

On the positive side, the program provides opportunities for policymakers to introduce, through energy efficiency measures, modernized management of this important sector.

[4] This is a rough estimate of the CDM potential revenues. In fact, their amount will depend on the project implementation and the energy performance reached and, predominantly, on the post-2012 CDM status and future market.

[5] Egypt's low electricity prices facilitate the justification of the CDM additionality of energy efficiency projects.

8

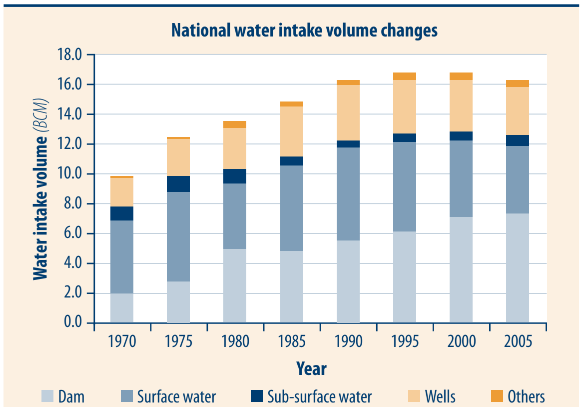
Accountable Water and Sanitation Governance: Japan's Experience

Satoru Ueda and Mohammed Benouahi

External accountability is considered a key foundation for well-functioning water and sanitation utilities. Japan has succeeded in achieving the highest standards of service through a combination of sound institutional regulations, a strong work ethic, and the use of technology. Although Japan's social and economic contexts are very different from MNA's, many aspects of Japanese water and sanitation governance would interest MNA policymakers.

Japan has adequate rainfall (1600 millimeters (mm)/year). At the opposite extreme of countries that are battling desertification, Japan is vulnerable to too much water, notably destructive typhoons and floods. As the country's rivers are short and fast flowing, a large network of reservoir storage and well-managed regulation of flows has ensured reliable water services (figure 8.1). Also, due to very high concentration of population in some major metropolitan areas, such as Tokyo, and high seasonal variation in rainfall, water resources had to be developed rapidly in the 1960s–1980s. Particularly in Tokyo in the 1960s, when economic development was booming along with the hosting of the Tokyo Olympic Games in 1964, Tokyo was called "Tokyo Desert" due to intensive and repeated water cutoff in rotation lasting for several months.

Figure 8.1 Historical Changes of Water Sources: Increasing Dam Storage Water, 1970–2005



This chapter briefly describes the institutional set-up in Japan, reviews the performance of its water and sewerage utilities, and draws some lessons for the Middle East and North Africa region. The findings are based on an August 2007 2-week study tour by the authors.

Legislative and Institutional Framework

The Japanese government operates at three levels: (1) the national government, which comprises the prime minister's office and 11 ministries; (2) 47 prefectural governments; and (3) municipalities (cities, towns, and villages). As part of the governmental system reform, the number of municipalities has been greatly decreasing, from 3,232 in March 1999 to 1,804 in September 2007.

Japan has a comprehensive system of water laws and regulations. The main water-related legislation includes:

- Public utility management: Local Public Enterprise Law (1952) and Local Government Autonomy Law
- Water resources development and management: River Law, Water Resources Development Promotion Law, specified multipurpose dam law
- Drinking water supply: Waterworks Law (1957)
- Industrial water supply: Industrial Water Supply Law
- Irrigation water: Land Improvement Law
- Sewage management: Sewerage Law (1958), City Planning Law
- Water quality and environment: Fundamental Environment Law and Water Pollution Control Law.

Water supply and sanitation (WSS) services are delegated by law to the lowest appropriate level. Thus, WSS services are principally the responsibility of local governments, such as prefectures and municipalities. Local governments can organize and delegate their functions to autonomous semigovernmental enterprises. These utility entities carry out local governmental mandates and management of daily operations, and report to mayors and/or municipal councils. In principle, all recurrent expenses of utility services are required to be fully covered by tariffs.

At the national level, multiple entities are responsible for the water supply: the Ministry of Health, Labor and Welfare; the Health Bureau; the Water Supply Division; the Ministry of Internal Affairs and

Communication (MIAC); and Local Public Financial Bureaus. For sewerage services, the Ministry of Land, Infrastructure, and Transportation, the City and Regional Development Bureau, the Sewerage Department, and MIAC are in charge. National ministries establish the regulations and guidelines for technical and service standards. They also review and approve utilities' business plans regarding their basic scope, design, and investment schedule. Finally, under the terms of the Waterworks Law and the Sewerage Law, the Ministry of Health, Labor and Welfare and the Ministry of Land, Infrastructure and Transportation subsidize prioritized infrastructure construction.

These ministries are not involved in operational aspects of water supply and sewerage utilities. They do not approve, but are merely informed of, changes in tariff levels.

Regulations for Providing Water Supply Services

From the institutional perspective, the Local Public Enterprise Law (1952) is the most important.[1] This legislation requires water utilities to supply water to improve public welfare, while operating economically as independent and autonomous business entities/public enterprises. The utilities are to collect revenues from customers to cover recurrent costs. This arrangement has required the development of a well-developed accounting system so that water supply assets can be separated from other municipal accounts and charged specifically to the water supply operation.

Most water utilities are established to serve the population/area within a single municipality, and their main offices are housed in the municipality's office buildings. An independent commissioner is appointed, usually by the mayor, as the head of the utility and approved by the municipal council. The commissioner reports to the owners/regulators, namely, municipal councils, on key business decisions, such as annual investment/operation plans, tariff increases, and auditing.

Water utilities also are required to follow the technical, operational, and service standards stipulated in the 1957 Waterworks Law, which is administered by the Ministry of Health, Labor and Welfare. The

[1] The standard translation of the Japanese law uses "Enterprise" instead of "Corporation." Therefore, when referring to water and sewerage utilities, this chapter uses "enterprise" instead of "corporation" for those that adopt corporate financing procedures according to the Local Public Enterprise Law's financial clauses.

Waterworks Law stipulates the basic management of waterworks, such as licensing for drinking-water-supply utilities establishment and operations; drinking-water quality standards; construction and administration of water supply systems; subsidies for investment schemes for planned improvement of facilities, such as major treatment plants and pipelines construction; and the responsibilities of utilities commissioners and personnel.

In 2006, 2,334 water supply utilities existed, of which 1,469 were established as statutory entities under the Local Public Enterprise Law. The remaining 885 small-scale utilities were not subject to this law. However, all of these utilities are subject to the Waterworks Law, which does not distinguish between urban and rural water.[2]

Regulations for wastewater service management

In general, sewerage management is handled separately from water supply. Some exceptions exist, such as Kyoto City. As opposed to water supply utilities, most sewerage utility offices are established as internal departments or divisions within local governments (prefectures or municipalities). Thus, almost all sewerage utility offices are accommodated within local governments' office buildings, and the heads of sewerage departments/divisions are civil servants.

The user-pays principle is also applied to wastewater collection and treatment. Thus, in principle, recurrent expenses are fully covered by user charges. The sewage tariff is billed and collected together with the water tariff by water supply utilities and transferred to the sewerage department based on prior agreement.

Regarding stormwater discharge, given its public-good nature, all construction and operating and maintenance (O&M) costs are covered by municipal general revenue. Stormwater discharge operations are clearly separated from sewage collection and treatment operations. For combined sewerage systems, local governments have established standard formulas to apportion costs, including staff costs, between sewage and stormwater operations. Costs are divided between sewage treatment and urban drainage. The former is considered a private good and is recovered through user fees, whereas the latter is considered a public good and therefore charged to general tax revenues.

---

[2] As in other parts of the world, utilities in small towns and villages are better managed by local communities.

Sewerage utilities are required to meet the technical, operational, and service standards stipulated in the Sewerage Law (1958), which is governed by the Ministry of Land, Infrastructure and Transportation. The Sewerage Law stipulates the planning, design, and operational aspects of sewerage systems (including networks and treatment plants), licensing for construction and operational plans, subsidies for investment schemes, water quality standards for outflows from treatment plants, the maximum pollution level of discharges from factories/plants, regulatory/monitoring/sanction measures, and the responsibilities of sewerage utilities' managers and staff. According to the clauses of the Fundamental Environment Law and Water Pollution Control Law, sewerage utilities/departments also are required to coordinate with the environment departments of prefectures and municipalities regarding the quality and quantity of effluent discharges into rivers and lake basins.

In 2005 the number of sewerage utilities was 3,699. Of these, 213 sewerage utilities apply the corporate accounting system under the Local Public Enterprise Law, while 3,486 utilities apply the general government accounting system. The number of the sewerage utilities under this law is still small but is increasing for large cities. Among sewerage offices visited by the authors, Tokyo, Kyoto, Fukuoka, and Sapporo adopt independent corporate accounting systems under the Local Public Enterprise Law, whereas Shiga prefecture employs a general governmental accounting system as a part of the prefectural government mandates.

Performance Assessment

Water Supply

In 2005 water supply utilities served 97.1 percent of Japan's 129 million population,[3] up from 26 percent in 1946. Water supply coverage increased significantly after the passage of the Waterworks Law in 1957. As water supply coverage expanded, waterborne diseases and infant mortality have dropped dramatically to almost nil (figure 8.2). Table 8.1 shows the main features of some major water supply utilities as well as the average data for all of Japan.

[3] Table 8.1 indicates 96.1% for water utilities, excluding small-scale utilities.

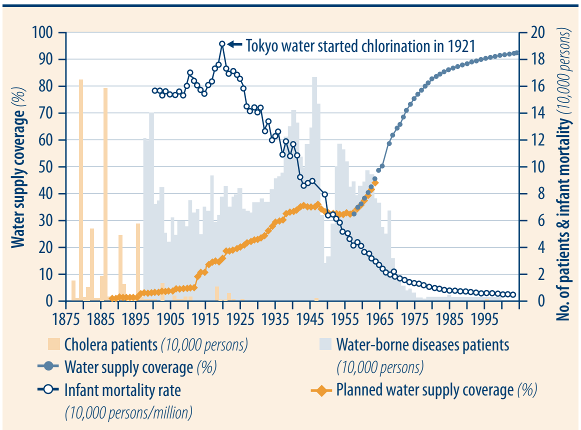
Table 8.1 Main Features of Visited Water Utilities and Japan, Average Year

	Tokyo	Sapporo	Kyoto	Fukuoka	Japan average
Population served	12,246,087	1,873,794	1,420,707	1,354,215	124,085,625[a]
Service coverage *(%)*	100.0	99.8	99.0	99.0	96.1
Average daily water supply *(m^3/day)*	4,427,100	546,925	590,151	406,393	57,644
Unaccounted for water *(%)*	5.8	9.1	13.9	5.1	8.5
No. of employees	4,563	713	909	403	58,733[a]
No. of employees per 1000 connections	0.87	0.89	1.50	0.64	1.19
Water tariff *(USD/m^3)*	1.74	1.90	1.37	2.01	1.33
Working ratio *(%)*	63	57	54	46	49

Note:
a The numbers of populations and employees are not the average of water utilities, but total in Japan.

Average daily water consumption per capita is approximately 314 liters. It increased from 169 liters in 1965 to 322 liters in 1995. However, thereafter, thanks to improved water-saving equipment and public information campaigns, consumption has been decreasing slightly to approximately 314 liters. If heavy water users such as hotels and public baths are excluded, the average per capita daily water consumption rate of households in Tokyo is estimated at 244 liters.

Figure 8.2 Urban Water Supply Progress and Benefits, 1875–1995



Wastewater Services

In 1958 expansion of coverage was accelerated by the passage of the Sewerage Law. In 1961 wastewater services coverage was only 6 percent. By 2006 coverage reached 82.4 percent of the population.[4] Table 8.2 presents the main features of the sewerage utilities studied by the authors, as well as the average of all utilities in Japan.

[4] The 82.4% represents the population coverage by the national-government-authorized schemes, of which 73.3% is covered by sewerage collection and treatment systems under the Sewerage Law. The remaining 9.1% is covered by community/individual household septic systems approved and subsidized by the Ministry of Environment. However, most of the remaining areas also are covered by individual onsite sanitation facilities, and the households are equipped with flush toilets.

Table 8.2 Main Features of Visited Sewerage Utilities and Japan Average

	Tokyo 23 wards	Sapporo	Kyoto	Fukuoka	Shiga	Enterprise national average	Nonenterprise national average
Population served	8,566,594[a]	1,858,081	1,419,262	1,359,091	1,900,358[b]	46,336,506[c]	86,726,940[d]
Population coverage *(%)*	99.9	99.5	99.3	99.4	94.9	96.6	87.4
Sewerage treatment capacity *(m^3/day)*	6,244,000	1,173,800	1,384,000	671,050	747,260	28,879,213	31,037,290
Unaccounted for sewage *(%)*	9	30	27	20	6	18	12
Sewage tariff *(\$/m^3)*	1.20	0.84	1.14	1.58	1.92	1.17	1.13
Working ratio (Maint. costs/ tariff) *(%)*	41	52	35	38	62	42	67
No. of employees	3,238	582	637	304	285	16,102	21,516
No. of employees per 1,000 connections	0.88	0.74	1.05	0.48	0.38	0.87	0.62

Notes:
a The column indicated the information only for 23 wards of Tokyo excluding Tama Wester Municipalities.
b The data of Shiga Prefecture is the average of Shiga Prefacture Government (regional integrated sewerage system) and 19 municipalities (regular sewerage) within the area of Shiga Prefecture.
c The average of sanitation utilities employing corporate accounting under the Local Public Enterprise Law.
d Represents the sanitation utilities employing general governmental accounting.

All wastewater collected by public sewers is treated at secondary-level treatment plants. Approximately 15 percent—all effluents discharged into closed water bodies, such as Biwa Lake, Tokyo Bay and Osaka Bay—are further treated to the tertiary level. Japan's discharged effluent quality, even from secondary-level treatment, is remarkably good. In general, the measured effluents' biological oxygen demand (BOD) is 3 mg/l–10 mg/l, which is well below the national effluent standard of 20 mg/l.

Lessons for MNA Water Utilities

The Japanese model is highly relevant to MNA countries. Its key features of interest for MNA are the semipublic corporate institutional framework under the Local Public Enterprise Law on the one hand, and the central regulation of operational and technical standards by the Waterworks Law and the Sewerage Law on the other. The legal framework balances the strong public ownership and oversight functions with the private sector's financial autonomy and operational economic efficiency. Thanks to their semiprivate status and obligation to recover costs, the utilities enjoy considerable autonomy for their daily operations and are relatively insulated from political issues. *Building the trust* *and confidence between the utilities and service users has been one of the bedrock principles of Japan's utility management.*

The Japanese model is thereby able to deliver :

a. Enhanced public welfare though a stable water supply and sanitation service
b. Financial autonomy achieved through tariffs and a sound management system
c. Large-scale investment in infrastructure development according to a long-term plan
d. Excellent goodwill among water customers
e. Municipality-based utilities tailored to unique local settings.

In the following sections, this chapter details key strategies and achievements of the Japanese water and sanitation system (WSS). They are:

a. Legislating and regulating for cost recovery
b. Keeping unaccounted-for water (UFW) very low in both water and sewerage utilities
c. Maintaining clarity in accounting between recurrent and capital costs
d. Making available several investment-financing options for water and sewerage utilities
e. Legislating/regulating effective governance and accountability mechanisms
f. Effectively managing human resources
g. Outsourcing wherever possible
h. Focusing on total water quality management
i. Managing river water rights and discharge permits.

Legislating and Regulating for Cost Recovery

Under the Local Public Enterprise Law, water utilities are required to make annual financial statements by processing separately (1) an income statement in the current year, (2) a balance sheet, and (3) documentation of the source and application of funds.[5]

---

[5] Some of Japan's larger urban wastewater utilities adopt the corporate financing system under the Public Enterprise Law; others adopt the governmental financial system. Except for a few (1% of total) very small ones, water utilities employ the corporate financing system.

The WSS utilities generate healthy operating surpluses. The working ratio is the relationship of operating expenses to operating revenues. Japan's national average working ratio of water and sewerage utilities ranges between 0.4 and 0.6. The higher the ratio, the less contribution margin is available to cover nonoperating costs, such as depreciation and financial charges. *The working ratio is one of the important indicators of operational efficiency and the profitability of utilities*. Table 8.3

Table 8.3 Japan's and International Water and Sewerage Utilities Working Ratios

Tokyo	Sapporo	Kyoto	Fukuoka	Japan average	Singapore	Philadelphia	Tunisia	Johannesburg	Campinas Brazil	Guanajuato Mexico
0.54	0.56	0.46	0.43	0.51	0.58	0.67	0.98	0.53 (water) 1.5 (sewage)	0.79	0.77

Sources: Local Public Enterprise Database (March 2006, Ministry of Internal Affairs and Communication, Japan), UK data on OFWAT annual report (2005), Tunisia (Country Report), Water Supply and Sanitation Working Notes No. 9, May 2006.
Note: The working ratio of the Japanese water and wastewater utilties are combined for international comparison with some assumptions.

compares the combined working ratio of water and sewerage utilities of Japanese and international cases.

Even though they cover operating and nonoperating costs, tariffs are affordable to households and compare well with those of other high-income countries. When measured against one HH's total expenditures, the combined water and sewage tariffs of US$2.50 per cubic meter ($m^3$) account for approximately 1 percent of the average HH income. This figure compares with approximately 3 percent and 2 percent for electricity and gas bills, respectively. Table 8.4 compares the combined water and sewage tariff between the Japanese and international cases.

Table 8.4 Average User Tariff (*US$/m³*)

Tokyo	Sapporo	Kyoto	Fukuoka	Japan average	Damascus	Jedda	Tunisia	Egypt
2.9	2.7	2.5	3.6	2.5	0.08	0.01	0.7	0.9

London	Brussels	Istanbul	Johannesburg	Singapore	Philadelphia	Campinas Brazil	Guanajuato Mexico
3.2	2.8	1.8	0.7	1.3	1.9	0.3	0.4

Sources: Local Public Enterprise Database (March 2006, Ministry of Internal Affairs and Communication, Japan); Tunisia, London, Berlin, Brussels, Damascus, and Jedda (counry reports); Singapore (estimate by the PUB website tariff table); Other Countries (Water Supply and Sanitation Working Notes No. 9, May 2006).
Notes: The average tariff of Singapore is estimated on the tariff structure on the PUB website. The tariffs of Japanese water and wastewater are combined for international comparison with some assumptions.

Utilities do not have the authority to raise tariffs without approval from municipal councils. However, they can put forward proposals for tariff increases based on their overall revenue requirements. As in other countries, the decision to raise tariffs sometimes gets delayed or even reversed due to political considerations. Nevertheless, most utilities have been able to achieve financial balance through periodic tariff increases (every 3–4 years). Furthermore, Japan's negative inflation rate—which changed from –0.9 percent in 2003 to –0.3 percent in 2006—also meant that, even in situations in which tariffs did not increase, the overall financial performance of water and sewerage utilities did not significantly deteriorate.

Keeping Unaccounted-for Water Very Low in Both Water and Sewerage Utilities

Water utilities and unaccounted-for water

Almost all water supply utilities have achieved very low unaccounted-for water (UFW). The national UFW average is 8.5 percent. The most competent utilities, such as Tokyo and Fukuoka, have attained approximately 5 percent. This low percentage of UFW is highly significant compared to losses in the range of 15 percent–40 percent for water utilities in many countries globally, including developed countries. Table 8.5 compares water utilities' UFW in Japan and other countries.

Table 8.5 Unaccounted-for Water *(%)*

Tokyo	Sapporo	Kyoto	Fukuoka	Japan average	Singapore	UK	Philadelphia	Tunisia	Shiraz Iran	Johannesburg	Campinas Brazil	Guanajuato Mexico
5.8	9.1	13.9	5.1	8.5	4.8	15.0	32.0	20.2	35.0	35.0	26.0	37.0

Sources: Local Public Enterprise Database (March 2006, Ministry of Internal Affairs and Communication, Japan); UK data from OFWAT Annual Report (2005); Iran (county report); Other Countries (Water Supply and Sanitation Working Notes No. 9, May 2006).

Procedures are in place to minimize physical losses. Water utilities generally repair surface leakage on the same day that a problem is detected on a 24-hour operational basis. They regularly detect potential underground leakage by electronic and correlation-type detectors. They also have been upgrading distribution pipes from cast iron to ductile iron, and service pipes from lead to stainless steel.

Thanks to Japan's high operational standards and customer service, most water utilities maintain their administrative UFW at almost nil. In

2006 the nationwide average was 1.5 percent. If required, the utilities easily can exert their authority to cut off water supply to defaulters. However, disconnection is very rarely required, because customers pay their bills. Defaulting customers are automatically disconnected.

The Tokyo Metropolitan Water Bureau is perhaps one of the best-run utilities in the world. UFW stands at approximately 5.8 percent with 100 percent coverage of a population of approximately 12 million. The average daily water supply volume is approximately 4.4 million m^3, and the total length of distribution pipes is 24,782 kilometers (km).

Sewerage utilities and unaccounted-for water

All sewerage utilities/departments measure the amount of treated wastewater and compare it to the amount of sewerage for which treatment fees are collected. They calculate the UFW using a concept similar to that used for water supply. *No collected wastewater is discharged without treatment*. The national average UFW is 17 percent and 12 percent, respectively, for enterprise utilities and nonenterprise utilities. Tokyo's UFW is approximately 9 percent, whereas Sapporo's is close to 30 percent. The higher UFW of the latter may be attributed to underground water leakage into sewer networks or erroneous connection of rain sewers to sewage sewers. Very few other countries conduct this level of UFW measurement in sewerage systems.

Clarity in Accounting for Recurrent and Capital Costs

Water supply services

Water supply utilities' accounting systems are a powerful management tool. Table 8.6 breaks down the O&M costs of several water supply utilities and the national total. The costs are clearly distinguished between (1) operational costs and (2) capital costs, including depreciation costs and bond interest costs.

The relationship between costs and revenues is immediately apparent. While Tokyo's water tariff (approximately US$2.6 billion) fully covers operational costs, the tariff of the 3 other visited cities and the national average do not fully cover capital costs (see Cost Recovery section below). The balance of approximately 5 percent is covered by the investments and subsidies from the municipalities' general accounts.

Table 8.7 shows the 2006 unit operational and capital costs of water production in comparison with the water tariff. The national average tariff

Table 8.6 Income Statement of Water Supply Utilities, March 31, 2006 *(US$ mil.)*

Cities	Tokyo	Sapporo	Kyoto	Fukuoka	National total
Personnel expenses	385	66	76	29	4,158
Energy expenses	77	3	6	4	871
Repair expenses	510	43	19	17	1,686
Chemicals/materials	66	14	10	3	519
Outsource fee	238	40	9	40	1,735
Bulk water purchase	0	0	0	19	1,415
Others	377	31	17	19	2,060
Operation costs	**1,655**	**199**	**139**	**131**	**12,444**
Bond	195	67	52	47	3,759
Depreciation costs	609	97	81	73	7,261
Capital costs for bulk water	0	0	0	42	2,440
Capital costs	**804**	**164**	**133**	**163**	**13,460**
Total	**2,458**	**363**	**272**	**294**	**25,904**
Water tariff	2,641	346	254	283	24,987
General & other accounts	213	28	19	6	1,357
Miscellaneous	93	5	1	20	1,347
Total	**2,947**	**378**	**275**	**310**	**27,691**
Surplus/deficit	**489**	**16**	**3**	**15**	**1,788**

Note: The exchange rate was US$ = JPY115 during the August 2007 mission.

Table 8.7 Water Cost Recovery: Unit Production Cost and Tariff, March 31, 2007 *(US$ per m^3)*

Cities	Tokyo	Sapporo	Kyoto	Fukuoka	Japan Average
Unit production costs	1.62	2.00	1.47	2.09	1.37
Unit operation costs	1.09	1.09	0.75	0.93	0.65
Unit capital costs	0.53	0.90	0.72	1.16	0.72
Unit average tariff	1.74	1.90	1.37	2.01	1.33

Notes: US$ = JPY 115 in August 2007.
Unit production costs = Unit operation costs + unit capital costs (depreciation and bond interests).

was US$1.33/m^3, while the average production cost was US$1.37/m^3. These figures show that the cost recovery ratio (including capital portion) was approximately 97 percent.

Sewerage services

As for water supply, sewerage utilities' accounting systems provide a powerful management tool, enabling the comparison of costs and revenues. Table 8.8 breaks down O&M costs of several water sewerage

Table 8.8 Income Statement of Sewerage Utilities, March 31, 2006 *(US$ mil.)*

	Tokyo	Sapporo	Kyoto	Fukuoka	National enterprise total
Personnel expenses	248[a]	41	50	13	1,058
Energy expenses	90	13	11	9	348
Repair expenses	211	14	6	9	481
Chemicals/materials	13	7	4	4	120
Outsource fee	238	56	36	65	1,058
Others	116	9	22	32	755
Total operation costs	**915**	**140**	**129**	**131**	**3,821**
Bond interests	700	104	158	150	3,697
Depreciation costs	989	137	163	140	4,250
Total capital costs	**1,690**	**241**	**320**	**290**	**7,947**
Grant total costs	**2,604**	**381**	**450**	**420**	**11,768**
Sewerage service tariff	1,487	176	230	233	6,280
Rain storm discharge fee[b]	1,215	187	177	148	4,073
Other operation revenue	57	2	7	6	209
General accounts subsidy	59	12	41	31	1,504
Miscellaneous	20	1	1	2	119
Total revenue	**2,837**	**378**	**456**	**420**	**12,185**
Surplus/deficit	**233**	**–3**	**6**	**0**	**417**

Notes: US$ = JPY115 in August 2006.
a Tokyo figures refer to 23 wards only.
b Rain storm discharge fee is paid by cities' general accounts.

utilities. For sewerage utilities that adopted the corporate financing system under the Local Public Enterprise Law, costs are clearly distinguished between (1) running costs and (2) capital costs, including depreciation costs and bond interest costs.

The management accounting framework makes it possible for cost-sharing schemes to be established for wastewater-and-stormwater-combined operations. While the wastewater collection and treatment portion is fully covered by the sewage tariff, the stormwater portion is covered by the municipal general budget. The sewage tariff covers on average 53 percent of sewerage running and capital costs at the national level. An additional 35 percent of the budget is supplemented by the local government general accounts.

Table 8.9 breaks down sources of investment funds for four major utilities and the national total in Japan's FY05 budget. The national average bond share was 48 percent, which was higher than that for water supply. The national average subsidy share was 38 percent for

Table 8.9 Construction and Improvement Budget Sources of Sewerage Works, March 31, 2006 *(US$ mil.)*

	Tokyo	Sapporo	Kyoto	Fukuoka	National total	Enterprise national total	Nonenterprise national total
Enterprise bonds	478[a]	106	106	139	9,950[b]	3,000	6,950
National subsidies	314	62	63	79	7,944	1,992	5,953
Other works/beneficiaries share	68	11	5	4	1,344	266	1,078
General accounts support and other revenue	317	6	11	21	2,205	894	1,310
Total investment budget	**1,177**	**185**	**185**	**243**	**21,443**	**6,152**	**15,291**

Notes: US$ = JPY115 in August 2007.
a Tokyo figures refer to 23 wards only.
b National total is the sum of (a) enterprise national total and (b) nonenterprise national total.

sewerage—also much higher than that for water supply. The balance was covered by the municipal general account. The reliance on bonds and subsidies was a result of the delayed development of the sewerage systems.

Table 8.10 shows unit sewerage running costs and capital costs, as compared with the sewage tariff. Table 8.10 deals only with wastewater collection and treatment costs, since stormwater discharge costs are fully covered by the municipal general account.

Table 8.10 Wastewater Cost Recover: Unit Operation Cost and Tariff *(US\$/m^3)*

Unit costs	Tokyo 23 wards	Sapporo	Kyoto	Fukuoka	Shiga	Enterprise national average	Nonenterprise national average
Unit production costs	1.02	0.81	1.00	1.76	3.33	1.29	2.42
Unit operation costs	0.49	0.44	0.40	0.60	1.19	0.49	0.76
Unit capital costs	0.54	0.37	0.61	1.15	2.14	0.80	1.66
Unit average tariff	1.20	0.84	1.14	1.58	1.92	1.17	1.13

Notes: US$ = JPY 115 in August 2007.
Unit production costs = Unit operation costs + unit capital costs (depreciation costs and bond interests).

The sewage tariff ranges between US\$0.8/m^3–1.9/m^3. The national average total cost is approximately US\$1.3/m^3 for enterprise utilities and US\$2.4/m^3 for nonenterprise utilities. Based on these, the national average cost recovery rate (including capital costs) is 91 percent for enterprise utilities and 47 percent for nonenterprise utilities. Recurrent costs are fully covered by all utilities. The working ratios are 0.42 and 0.67, respectively, for enterprise and nonenterprise utilities. In general, large cities, such as

Tokyo, can recover all costs, including the capital portion, through the sewage tariff. In contrast, in rural areas, such as Shiga, and many other nonenterprise areas, it is not easy to collect an adequate level of sewage tariff to fully meet costs. Their unit costs, particularly capital costs, are much higher than those of urban areas. The difference reflects the fact that these rural utilities developed their systems in much more scattered areas with smaller economies of scale and, in recent years, without a historically developed infrastructure stock.

The sewage tariff is generally set lower than the water tariff, despite the fact that sewerage system development costs are higher than those of water supply systems. This differential reflects the public's willingness to pay. *People are more willing to pay a higher tariff for drinking water than for wastewater.* In these circumstances, some rural sewerage utilities become very dependent on funds from the municipal general account. This dependency is negatively affecting municipalities' financial status and their ability to provide other public services.

Making Available Several Investment-Financing Options for Water and Sewerage Utilities

Most water supply and sewerage utilities mobilize external funds in addition to internal funds. Three major external financing sources are available.

Bonds

Utilities issue bonds with the authorization of and backed by municipal governments. Some wealthy municipalities' financial standing is very good. The Tokyo Metropolitan Office's credit rating is AAA. Although utilities do not issue bonds on their own credentials, some strong utilities would be able to secure funds on their own financial credentials if allowed to do so.

National subsidy

The national ministries subsidize investment for large-scale infrastructure. For waterworks, the Ministry of Health, Labor and Welfare subsidizes up to one-third of investment costs for large-scale systems development and renovation as well as to introduce advanced treatment systems. For sewerage works, the Ministry of Land, Infrastructure and Transportation subsidizes 55 percent of the construction of treatment plants and 50 percent of pipe-networks development. For integrated basin-level sewerage systems, which collect sewage from more than 2 municipalities, the subsidy rate increases to 60 percent of the construction of treatment plants. As noted earlier, the total allocated amount of national subsidies is much higher for sewerage systems than for water supply systems.

National tax allocation to local governments

The Ministry of Internal Affairs and Communication allocates block grants from national taxes to local governments. This national tax allocation to local governments is designed to ensure the national minimum standards of public services, particularly for smaller rural municipalities that have few other sources of revenue. Among the many parameters of the allocation criteria, the value of municipality bonds issued for infrastructure development, including water and wastewater systems, is taken into account. The grant is not allocated directly to water and sewerage utilities' accounts but to the general accounts of local governments. Nonetheless, the grant works as an incentive for local governments to issue bonds for infrastructure development.

Good Sector Governance and Accountability Mechanisms

Japanese water utilities have established accountability mechanisms that combine the merits of both private and public entities: (1) the high economic efficiency and financial autonomy of the private sector and (2) the oversight functions of the public sector. Most utilities in Japan set well-defined targets for key performance indicators. For water utilities, they typically include total revenue, water production, drinking-water quality, customer service, financial performance, water consumption, and new connections. Water supply utility commissioners are accountable to the municipal councils for achieving the targets. The directors general of sewerage utilities/departments report to the heads of municipalities, such as mayors.

Japan has a strong tradition of utilities being accountable to local elected officials and of transparent information-sharing. The municipal councils or mayors are kept informed of the utility's operations by the commissioner or director general and review its annual/quarterly operational reports. However, they do not interfere in the daily operations. Most municipalities have established strong reporting frameworks, including financial audits and annual and periodic performance status reports. All of these reports are incorporated in the annual reports and are made available at public offices and on websites.

To ensure competitive prices and flexibility in purchasing, the utilities generally follow public procurement regulations. To enhance accountability, utilities are subject to technical and operational audits, not just financial audits, and have active internal audit departments.

Use of nationwide benchmarking to ensure accountability

The Ministry of Internal Affairs and Communication administers the Local Public Enterprise Law. The ministry leads an annual standardized national benchmarking exercise for all water supply and wastewater utilities. The benchmark database of all utilities for every year is published on the website of the ministry and municipalities. The benchmarking items total more than 100. They include service quality, financial efficiency, water losses, energy costs, revenue collection, financial performance, and other operational efficiency and performance indicators.

The national benchmark exercise provides an opportunity for municipalities and utilities to monitor their own performance status as well as improvements across the country. The exercise thus makes them more accountable to their constituents because comparative results can be made regularly available to the public. This chapter has benefited from the national benchmark database in addition to the information collected directly from visited utility offices.

Customer service ingrained as a key part of utility culture

Although Japan's water supply and sewerage utilities are monopolistic service providers, they are very responsive to their customers. Important aspects of *customer orientation include friendliness of the customer billing and collection system, orientation toward seeking customers' opinions, timely information to customers on water service disruptions/changes, and response to customers' complaints*. Many utilities operate a one-stop call center for customers to take care of water service disruptions, relocation, new subscriptions, and payment. Some utilities open customer windows for extended times, for example, to 8:00 p.m. on weekdays as well as Saturday hours. The utilities also establish water repair squads to conduct emergency repair and interrupted service recovery within 24 hours.

As described earlier, water utilities usually offer multiple options by which their customers can pay their water and sewage bills. The options include electronic funds transfer and payment at commercial banks, postal offices, and convenience stores. Customers can make service requests on the utility's website.

Effective Management of Human Resources

Personnel management is highly meritocratic. The commissioners or directors general of utilities are appointed by the mayors of municipalities on the basis of expertise and experience. Some are selected from among respected in-house career officials. Staff salary and promotions are based on performance, academic credentials, and seniority reflecting overall experience. The third criterion provides incentives for staff to stay with the same utility. The average service duration of career staff of water and sewerage utilities is approximately 25 years. Staff are rotated within each organization to enable them to obtain wider experience. Those who display high potential are groomed for promotion. Staff turnover is very low and is due mostly to mandatory retirement.

Staff skills and employee innovation are regarded as critical inputs to improve performance. Most utilities provide ample career development and training opportunities to their staff, which also keep turnover low. An extensive training plan covers professional skills development and corporate culture. The utilities provide various kinds of training programs for their staff as part of their annual performance review. The emphasis is on frontline staff who come into direct contact with customers and/or contractors.

Innovation and knowledge-creation are important features of the water sector's corporate culture. Some utilities plan technology development projects on a pilot scale and even obtain patents for successful pilots. Other utilities have built their own training facilities and field stations. Furthermore, the government-affiliated agencies and associations, such as Japan Waterworks Association, Japan Sewerage Works Agency, and Japan Sewerage Association, have contributed studies for developing new technologies and disseminating technical guidelines and manuals. These publications are particularly useful for smaller utilities in rural areas that do not posses adequate numbers of technical staff.

As a result, staff productivity is high. For water supply and sewerage utilities combined, the average is 2 staff per 1,000 connections. Each utility maintains the staff level of 1 per 1,000 connections. This rate is much smaller than that of utility companies in other advanced countries. Table 8.11 compares the water utility staff level per 1,000 connections between Japan and other countries.

Table 8.11 Number of Employees per 1,000 Connections

Tokyo	Sapporo	Kyoto	Fukuoka	Japan average	Singapore	Philadelphia	Tunisia	Johannesburg	Campinas Brazil	Guanajuato Mexico
1.7	1.6	2.5	1.1	1.9	2.9	4.4	8.0	4.7	4.1	8.0

Sources: Local Public Enterprise Database (March 2006, Ministry of Internal Affairs and Communication, Japan); Tunisia (Country Report); Other Countries (Water Supply & Sanitation Working Notes No.9, May 2006).
Note: The number of Japanese water and wastewater utilities staff are combined for international comparison. The household connections are counted as 1 for both water supply and sanitation although they can physically counted as 2, i.e., one for water supply and another for wastewater. The number of outsouced workers are not included as the number of regular staff for the Japanese utilities.

Use of Outsourcing Wherever Possible

While most utilities keep core business functions in-house, they have engaged private contractors whenever necessary. Typically, outsourcing takes place for (1) routine O&M of treatment plants and network pipes, (2) checking and executing repair works, (3) engineering design and construction supervision, (4) information and telecommunication technology services, and (5) metering and billing. The average outsourcing ratio for water supply utilities is approximately 15 percent; that of sewerage utilities is approximately 30 percent. The utilities gradually are increasing the outsource percentage through natural attrition of in-house career staff. Table 8.12 compares the outsourcing percentage of operational expenditures between the Japanese and international cases.

The 1999 Private Finance Initiative Law encouraged public and semipublic entities to test private sector participation. Several utilities have begun trials of privatization and market testing. Some utilities are piloting innovative large-scale privatization schemes to build and operate specialized facilities, such as cogeneration power plants and sludge treatment and recycling plants. However, private funding of major investments remains the exception.

Table 8.12 Outsource Ratio of Operational Expenditures *(%)*

Types	Tokyo	Sapporo	Kyoto	Fukuoka	Japan average	Type	Singapore	Johannesburg	Campinas Brazil	Guanajuato Mexico
Water	14	20	7	30	14	Combined	25	10	21	20
Wastewater	26	40	28	49	28					

Sources: Local Public Enterprise Database (March 2006, Ministry of Internal Affairs and Communication, Japan); Water Supply and Sanitation Working Notes No. 9, May 2006.
Note: The Japanese average of wastewater is based on local autonomous enterprise entities by law.

Other semipublic supporting agencies and associations

Some semi-public agencies support utilities. Based on prefectural or municipal utilities' requests, the Japan Sewerage Works Agency provides technical support for construction, maintenance, and management of main facilities, such as wastewater treatment plants and pumping stations. The agency also conducts experiments, research, and training sessions. These activities are particularly important for small municipalities, as they do not have enough staff with the requisite management and technical skills.

The Japan Waterworks Association and the Japan Sewerage Works Association carry out surveys and research related to water and sewerage systems. They also help raise public awareness and disseminate information. In particular, the Japan Waterworks Association serves as the think-tank for the Ministry of Internal Affairs and Communication and municipalities by preparing technical design manuals and guidelines, and organizing technical conferences and workshops.

Focus on Total Water Quality Management

Japan's combination of central government regulation and corporate governance ensures attention to quality in all aspects of water management.

Drinking water quality management

Tap water is safe to drink anywhere in Japan. To maintain strict drinking quality standards, water utilities prepare and execute water quality examination plans. Each plan specifies the parameters to be analyzed and the frequency of analysis. The analyzed results are disclosed in the utility's annual report and/or regularly posted on the internet.

Water utilities in some areas adopt advanced water treatment methods, such as ozone treatment and biologically activated carbon-absorbing treatment, to eliminate odor, trihalomethane precursor, and other particulates that cannot be sufficiently removed by conventional treatment processes such as rapid sand filtration. Water utilities have installed automatic quality-monitoring devices at various points in water supply areas to continuously monitor residual chlorine. In addition, regular water quality analysis is conducted at rivers and reservoirs.

Water distribution optimization and leak detection

Most utilities have developed extensive water distribution pipe networks. The water supply system is monitored around the clock at the operations center to adjust to changing water demands. The utilities use operations systems, such as water distribution planning support systems, and dam inflow simulation and reservoir operation optimization systems.

Water utilities typically develop water supply operational plans that consist of a (1) water intake plan, (2) water main networks operation plan, and (3) pumps operation plan. The utilities also have developed water demand forecast programs with parameters such as weather conditions, time, day of the week, and holidays. These plans apply to both ordinary days and emergencies, accidents, and drought periods.

Some advanced utilities, such those as Fukuoka and Tokyo, have developed more advanced water distribution systems to regulate pressure and flow in distribution pipes. Such regulation promotes the effective use of water and minimizes water leaks. This system uses pressure gauges and flow meters that have been installed throughout the city. These measuring devices enable the Water Distribution Control Center to monitor conditions within the pipes on a 24-hour basis via telephone lines. Based on the information obtained from the gauges and meters, the motorized valves can be opened and closed remotely to regulate water pressure and flow. The system can automatically detect pipe bursts by checking the rate of flow and pressure changes and their correlation. If the abnormality continues above set thresholds, the system warns the operations center and site offices.

Seismic design and preparedness

Japan is prone to earthquakes. Water utilities have taken various measures to ensure the best possible water supply for citizens immediately after earthquakes. Utilities have set high antiseismic design criteria for physical infrastructure and established emergency operation systems. They also have built auxiliary power plants and emergency water supply basins and tanks to secure water supply during emergencies.

Wastewater treatment standards

The water quality of discharged effluent from sewerage treatment plants is regulated by the Sewerage Law. Among many parameters, the limit for the BOD of effluents is set at 20 mg/l. For most sewerage treatment plants, the BOD of treated effluents outflow is below 5 mg/l—much lower than the regulatory limits. The BOD of inflowing raw effluents typically ranges between 100 mg–200 mg/liter.

Basin-wide water quality control plan

The Water Pollution Control Law requires local governments to set environmental quality standards for each control point of rivers and lakes to meet the water quality requirements for the environment and human health. A comprehensive basin-wide water quality management approach is employed to reduce pollution and meet the required water quality level. Based on the required amount of pollution load reduction, local prefectural governments prepare a Comprehensive Basin-wide Sewerage System Development Plan. This plan specifies the basic parameters of sewerage collection and treatment systems in the basin. Sewerage utilities and environment departments coordinate closely to prepare the plan and monitor water quality.

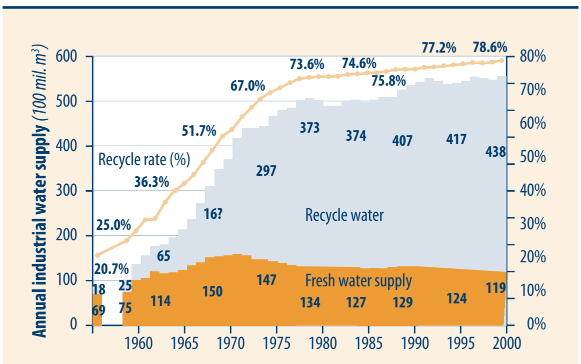
Industrial pollution control

The Sewerage Law also stipulates water quality standards for effluents discharged by specified industrial factories/plants into sewerage treatment plants. In most cases, the maximum values of BOD and suspended solid (SS) are set at 600 mg/l, and heavy metals are strictly controlled. The specified factories and other commercial facilities, such as hotels, livestock farms, and cleaning businesses, are required to install onsite pollution control facilities to meet the quality standards.

The Sewerage Law and the Water Pollution Control Law require local governments to conduct onsite inspections and compliance monitoring without notice and, if required, to provide administrative guidance and improvement orders. The owners could face imprisonment of up to 6 months and/or be fined up to $2,500 if they do not follow the improvement orders, such as installation of pollution treatment facilities at the plant. As noted earlier, local governments provide grant subsidies and interest-free loans to the owners to install required pollution control facilities/equipment.

One of the most important factors in reducing industrial pollution loads is to significantly increase the internal water recycling of plants and factories. During the past 40 years, the average internal water recycling rate increased from approximately 20 percent to 80 percent (figure

Figure 8.3 High Industrial Water Recycle Rate: Significantly Reduced Water Demands and Pollution Loads, 1960–2000



8.3). From the 1960s through the 1980s, Japan's rivers and lakes were heavily polluted by rapid economic development. Over the past 20 years, however, water quality has been significantly improved thanks to the increase in industrial water recycling and the rapid development of sewerage management systems.

Treated wastewater recycling

The direct recycling rate of sewage effluent is very low (approximately 1.4 percent), except for toilet-flushing water and environmental flow augmentation in small rivers and canals in some urban districts. However, in most urban areas, indirect recycling through river systems is quite common. Treated sewage effluent discharged to rivers is quite important for augmenting river environmental flows and thus for maintaining the ecology and scenic environment of rivers. Treated effluent is also important for supplying water to downstream water users. Historically, many cities and towns have been developed along rivers and rely on the natural water recycling system between the upstream and downstream of rivers. In some urban rivers, more than 50 percent of river water flow originates from treated effluents from sewerage treatment plants upstream.

Sludge treatment

Most sludge from treatment plants is dehydrated and incinerated to ashes, reducing the volume to approximately 1/40–1/50 of the original. In 2003, on average nationally, sludge was used for (1) landfill after incineration (approximately 40 percent), (2) construction materials after melting of incinerated ashes to sludge (approximately 40 percent), and (3) farmland improvement materials after dehydration of sludge. These operations are subsidized by government for environmental reasons.

Stormwater discharge

One of the important roles of a sewerage system is to prevent floods. A comprehensive flood-prevention master plan is prepared to define the required flood runoff and storage capacity. In some flood-prone areas, underground stormwater storage pipes and reservoirs are constructed under roads. Shield tunneling is used to build large tunnels and stormwater pipes. Permeable road pavements, onsite storage, and retarding ponds at schools and parks also are constructed to reduce flood peak volume. Technical coordination is established for urban flood control between sewerage utilities and river administrators to ensure the proper operation of drainage pumps and other flood control facilities.

The operations of treatment plants and pumping stations are based on information from rainfall radar and telemetry water-monitoring systems. Citizens can access the same information on the utilities' websites.

By March 2005, of a total of 1,896 systems, Japan had 23 combined wastewater/stormwater systems and 1,873 separate systems. Combined systems sometimes allow untreated wastewater to be discharged to public water bodies during flood periods. They therefore need to be upgraded to reduce heavy pollution loads from the first flush of flood water by building flood-storage facilities.

Electronic sewer registration database

Some advanced utilities have established computerized asset management systems. Tokyo Sewerage Utility has developed an electronic sewer mapping system at 1/500 scale indicating all sewer locations, depths, diameters, and types. All users can access this information on the Internet. This online data is useful in coordinating with other underground utility lines and assisting contractors' designs and scheduling

Water resource management

Effective coordination among institutions underpins the success of Japan's water resource management.

Despite the country's high rainfall, water resource management is an important challenge in Japan. Some Japanese regions are faced with water scarcity due to high population density. For example, the renewable water resource of the Kanto area, which includes the Tokyo metropolitan area, is only 905 m^3 per year per capita, which is equivalent to that of Egypt. In the early 1960s, Tokyo faced chronic water shortages and had to cut approximately 45 percent of water supply to up to nearly 1 million households. During the scarcity, people used to call the city the "Tokyo Desert." Moreover, because of steep terrain/river bed slope and a high fluctuation of rainfall among different seasons, river flows and water resources are difficult to regulate and manage without storage dams in the upstream reaches of rivers.

Dams thus have played an increasing role in ensuring Japan's water supply. The share of water resources from dams increased from 19 percent in 1970 to 45 percent in 2005. In 2005 the number of dams with a height of more than 15 meters was 2,897, of which 627 were dams whose functions included storing water for drinking. Other dams were used for flood control, irrigation water supply, and hydropower generation.

River Management: Water Rights and Discharge Permits

The River Bureau of the Ministry of Land, Infrastructure and Transportation plays a pivotal role in water resource management. The River Law covers (1) flood control, (2) water use, and (3) water environment. The River Law designates the ministry's regional river bureaus and river management offices as "river administrators."[6] The law requires them to issue water rights and discharge permits based on the current and future water balance of river basins. The river administrators also are responsible for issuing permits for the installment/construction of any hydraulic structures and land use in rivers.

Comprehensive water resources development

The Specified Multipurpose Dams Law and Water Resources Development Promotion Law were legislated in 1957 and 1961, respectively. The former law stipulates the procedure for the execution of multipurpose dam projects, including cost allocation among participating parties. The latter law requires the preparation of comprehensive water resources development master plans for 5 (then 6) major basins, including Tokyo, Kyoto/Osaka, Nagoya, and Fukuoka. In 1962 it also established the Public Water Resources Development Corporation to execute major multipurpose dam projects in the designated basins. In 1973 the Dam Reservoir Resettlement Area Special Measures Act was enacted to provide stronger financial and technical support for the residents in upper watersheds who were to be relocated due to dam reservoir inundation.

Conclusions and Lessons

Japan has achieved the highest standards of water and sanitation service through a combination of sound institutional regulations, a strong work ethic, and the use of technology. From the evidence presented, the

---

[6] The River Law was enacted in 1896 with an emphasis on flood control. It was amended in 1964 to fully address water use and allocation, and again in 1997 to address the environmental aspects of rivers. The 1997 amendment requires river administrators to establish multistakeholder river councils and, through the council meetings and public hearings, to develop basin management plans for all rivers.

reader can observe that the performance of Japan's utilities benchmark with the best in the world.

Does Japan's experience provide any lessons for the MNA region's utilities? There are clearly many factors that are different, notably, the homogeneous nature of Japanese society, the availability of adequate public financing in this second-largest economy in the world, and a unique work ethic.

Nevertheless, several lessons could be relevant to MNA in the sense that water supply and sanitation policies have combined sound principles of public finance with local political and cultural institutions. To summarize, these lessons are:

1. Clarity in roles and responsibilities, which leads to a very high degree of external and internal accountability (chapter 2 of this volume).
2. Clear distinction between the public good and private good aspect, so that the financing burden is shared among the national government, local governments, and users.
3. Use of standard technical and financial indicators of utility performance that creates "peer pressure" among utilities to improve their performance.
4. Completely nonideological use of public-private partnerships through outsourcing contracts.
5. Last but not least, maintaining excellent links between the service provision aspect and the resource management aspect through an integrated planning process that fully respects the ABCDE principles described in the Introduction to this volume.

9

Tunisia's Experience in Water Resource Mobilization and Management

Mohamed El Hedi Louati and Julia Bucknall

Introduction

Water is scarce, and its availability is also highly variable. In addition to its long history of earthquakes, hailstorms, and plagues of locusts, Tunisia has always suffered from droughts and floods. They are hard to predict as they do not follow any clear cyclical pattern. For more than a century (1640–1758), Tunisia had no droughts, whereas in modern times, it has had approximately 30. Over the centuries, the successive civilizations who have lived in Tunisia have developed management systems to cope with the risks of floods and droughts. They were not always successful. A series of severe droughts in the area that is now Tunisia lasted for approximately a decade from 870 CE. By the end of these droughts, the local administrator wrote that prices of wheat had increased steeply; and food had become so scarce that people had resorted to cannibalism (Talbit 1985, 112).

Managing this scarce and variable water supply is critical for Tunisia's development. The country engages in extensive political debate and strategizing, and the government has invested heavily in measuring, mobilizing, and managing resources. This chapter highlights Tunisia's progress in managing water, showing the evolution from traditional practices to large government-led investments to store and transfer water (which could be characterized as "physical engineering"). The latter led to a third stage, beginning around the turn of the millennium, which continues physical investment but increases the emphasis on water management (and therefore could be characterized as "institutional engineering"). Many aspects of Tunisia's experience could be improved, but, on the whole, this chapter suggests that *Tunisia is an example of good planning and management*.

Availability of Water Resources

Tunisia is one of the countries in the Mediterranean basin least well-endowed with water resources. The potential volume of available water, 4,836 Mm^3 per year, is less than 500 m^3 per inhabitant per year. This ratio will decline to 360 m^3 by 2030, when the population will have grown to approximately 13 million.

To manage variable supplies, Tunisia balances surface and groundwater stocks and flows within and between years. It uses dams and groundwater reserves to store surplus water in wet years and uses these stocks in dry years.

It also must distribute the water between different parts of the country. Maintaining a regional balance has been and will remain an essential element in Tunisia's water supply planning and management. The population is concentrated along the coasts, where cities, industry, and tourism are well developed. Agriculture is the largest water user and is located throughout the country except in the southern desert. However, the country's water supplies come mainly from the north and the interior of the country. Water transfers, therefore, have been a salient feature of Tunisia's long history from the Roman aqueduct at Zaghouan (built in 72 AD) to the modern-day Mejerda-Cap Bon Canal (1982), whose distribution networks go all the way to Sfax.

On a national scale, water resources are distributed unequally. Table 9.1 illustrates the geographic distribution of different categories of water in Tunisia. Eighty-one percent of the country's resources are in the north, 11 percent in the center, and only 8 percent in the south.

Table 9.1 Spatial Distribution of Water Resources in Tunisia *(Mm^3/yr)*

<table>
<tr><th></th><th>Far North</th><th>North</th><th>Center</th><th>South</th><th>Country total</th></tr>
<tr><td>Supply of surface water (Mm³/yr)</td><td>960</td><td>1230</td><td>320</td><td>190</td><td>2700</td></tr>
<tr><td>Groundwater (Mm³/yr)</td><td colspan="2">395</td><td>216</td><td>108</td><td>719</td></tr>
<tr><td>Deep groundwater (Mm³/yr)</td><td colspan="2">269</td><td>326</td><td>822</td><td>1417</td></tr>
<tr><td>Total potential resource (Mm³/yr)</td><td colspan="2">2854</td><td>862</td><td>1120</td><td>4836</td></tr>
<tr><td>%</td><td colspan="2">59</td><td>18</td><td>23</td><td>100</td></tr>
</table>

Source: DGRE 1995.

Tunisia shares *international surface water* in the form of some rivers along the western border with Algeria. The two countries have reached agreements on how to mobilize and use this water, including agreeing the annual volume available in the relevant basins and how to distribute it between the two countries. These countries also have established a monitoring system, which enables both countries to track pollution as well as water volumes for the main international river, the Mejerda.

In addition, the country has a considerable volume of international groundwater, located in the Djeffara coastal basin shared between Libya and Tunisia and, most importantly, in the Northwest Saharan Aquifer System, shared between Algeria, Libya, and Tunisia. The latter has more than one Mkm^3 of water with very limited recharge, of which some 80,000 km^3 are in Tunisia. Three countries have established a commission to monitor this aquifer and have agreed to cooperate on its management to minimize cross-border impacts. This is 1 of only 2 such agreements in the world. Tunisia uses water from this aquifer to irrigate greenhouse vegetables and dates (figure 9.1).

Figure 9.1 Cooling Tower Bringing Geothermal Water from the Sahara Down to a Temperature Usable in Irrigation

Photo: Julia Bucknall.

Tunisia's water policy aims to contribute to sustainable socioeconomic development while balancing two conflicting facts:

1. Limited water supplies and increasing cost to generate or store and transfer additional resources
2. Growing demand for water.

The variability in water availability between years is huge. During the past few decades, the maximum potential volume of surface water was 11 billion m^3 in 1969–70, and the minimum was 780 Mm^3 in 1993–94. Variability is high everywhere but much higher in the South. In the North, the wettest year was nine times wetter than the driest year. In the South, 180 times more water was available in the wettest year than in the driest.

This highly irregular supply affects the country in the form of floods and shortages of varying seriousness. However, the infrastructure available in recent decades has enabled Tunisia to store and transfer water, thus reducing the impacts of both flood and drought.

As monitoring has improved, and particularly as hydrogeologists have discovered larger volumes of groundwater available, the estimates of the amount of water potentially available in Tunisia grew substantially between 1968 and 2007 (table 9.2).

Table 9.2 Tunisia: Estimates of Potential Water Supplies, 1968–2007 *(Mm³/yr)*

	1968	1972	1980	1985	1990	1996	2000	2005	2007
Surface water	2000	2000	2580	2630	2700	2700	2700	2700	2700
Groundwater	160	230	490	590	670	720	737	745	745
Deep groundwater	600	900	1030	1100	1170	1250	1399	1419	1419
Total	2760	3130	4100	4320	4540	4670	4836	4864	4864

Sources: DGRE-MARH.

Despite the increase in known resources, estimated water availability per capita is declining (table 9.3). For groundwater, the calculation of water available refers to the maximum volume of water that can be extracted annually from the country's groundwater resources under prevailing technical and economic conditions without leading to the long-term exhaustion of the underground resource base. For surface water resources, the calculation takes into account resources available for annual extraction in 95 percent of years.

Table 9.3 Tunisia: Change in Estimated Per Capita Long-term Water Availability, 1995–2005 *(Mm³/yr)*

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Surface water *(Mm³/yr)*	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100	2200
Groundwater *(Mm³/yr)*	720	720	720	720	720	737	737	737	737	737	745
Deep groundwater *(Mm³/yr)*	1211	1217	1217	1225	1377	1399	1403	1403	1397	1411	1420
Total resources *(Mm³/yr)*	4031	4037	4037	4045	4197	4236	4240	4240	4234	4248	4365
Population *(mil.)*	8.957	9.089	9.215	9.333	9.456	9.563	9.65	9.75	9.84	9.93	10.03
Availability by inhabitant *(m³/inhabitant/year)*	450	444	438	433	444	443	439	435	430	428	435

Source: INS and MARH.

Tunisia has water quality problems in addition. Less than half of the country's resources have less than 1.5 g/l of salt and therefore meet health and agronomic standards. Of this water with reasonable salinity levels, 72 percent is surface water, 20 percent deep groundwater, and scarcely 8 percent groundwater (tables 9.4 and 9.5). Surface water thus is used both for direct consumption and to improve the quality of other categories of water.

Table 9.4 Breakdown of Salinity of Water Resources *(%)*

	Salinity<1,5g/l	1,5<Salinity>3g/l	Salinity>3g/l	Total
Surface water	72	22	6	100
Groundwater	8	32	60	100
Deep groundwater	20	57	23	100
Total	47	34	19	100

Source: Mamou 1993.

Table 9.5 Breakdown of Water Resources Regarding Salinity in Relation to Total Potential Resources *(Mm^3)*

	Salinity<1,5g/l	1,5<Salinity>3g/l	Salinity>3g/l	Total
Surface water	1944	594	162	2700
Groundwater	58	230	431	719
Deep groundwater	283	808	326	1417
Total	2285	1632	919	4836
%	47	34	19	100

Source: Mamou 1993.

As difficult as it is to manage Tunisia's water resources now, the job will only get harder in the future. Studies show that Tunisia can expect an increase in average annual temperature (2 degrees C on average), a modest fall in average precipitation (approximately 5 percent by 2030), and increased variability.[1] In particular, extreme phenomena (droughts, floods, and strong winds) will increase in both frequency and intensity, with very dry years likely to occur more often. These changes will have serious consequences for water resources, ecosystems, and agriculture; for urban dwellers; and therefore for the entire economy and society.

Investments to Store and Transfer Water in Tunisia

For the past three decades, Tunisia's water resource management policy has been based on mobilizing water resources. Thematic strategies

[1] MInistry of Agriculture and Water Resources 2006.

have been drawn up for agricultural water, rural and urban drinking water, urban sanitation, and the reuse of treated wastewater for agricultural purposes.

The Tunisian Ministry of Agriculture and Water Resources (MARH) has developed a model to help operate the country's water systems and manage the risks associated with both droughts and floods. It compares available resources with expected needs under various planning scenarios including estimates of when different major infrastructure investments will begin operation. This model simulates all foreseeable demands to enable the government to ensure that needs are met and to plan infrastructure needs well in advance. The tools used to create the simulations are constantly updated and enhanced to account for variables related to demand levels, the performance of modern technology, and perverse effects of reality.

The MARH's model consists of a number of separate information systems:

The first is the Optimal Water Resource Management model (known by its French acronym, G.E.O.R.E.) The idea of developing integrated water information systems was first proposed in a study that the government had developed over 1990–95. This study, "Water Economy 2000," was intended to enable the country to respond to water demand on a national level over the coming decades (first to 2010, then 2030). It collected, analyzed, and synthesized a wealth of data and information pertaining to water resources and requirements, both qualitative and quantitative. In this way, relational databases covering resources and supply were established. All the country's water resources (conventional and nonconventional) were identified at both the regional and national levels. For the first time in this type of study in Tunisia, a geographic information system (GIS) was used to identify where water resources were located and used. The GIS was connected to numerical databases and simulation and optimization models. Thus, it enabled a review of the water management system under diverse planning scenarios and over different geographic areas. The optimization models, based on dynamic stochastic programming, enabled the assessment of the performance of the existing and projected future water system. The models calculated fluctuations in both resources and consumption at varying scales and using various assumptions. By combining the relational database with the GIS assessments of the supply/demand balance, models were drawn up to determine the likely instances of over- and undersupply going forward in time and on a regional basis. Based on these results and on statistical analysis, a critical load scenario was developed to serve as the basis for determining future measures to be taken. From there, measures were defined that would enable identified shortfalls to be made up or reduced and their economic costs and environmental impacts to be evaluated. The specified measures were organized by timing and location in the form of a set of alternative strategies from which a national water management strategy could be derived.

The second information system is the agricultural map of the country, completed in 2004. This map is in fact a series of regional maps. They give an overview of the agricultural area of each governorate, its resources, development potential, strengths, and weaknesses. The agricultural database was compiled into a GIS, comprising close to 50 layers of geographic data. The maps have the following objectives:

- To ascertain in a reliable and dynamic manner the status of a particular location regarding natural resources (land, water, forests), basic infrastructure (water, transport), and economics (processing, refining, and harvesting facilities for agricultural products)
- To ascertain the land allocation status
- To identify the gap between current and optimal land use by comparing the land use map with the agro-economic potential map
- To simulate and spatially visualize decisionmaking scenarios based on the modification of specific parameters, such as cost of entry, production prices, yields, and incentives.

The third information system is the National Water Information System, known by its French acronym as SINEAU. It is being completed and is expected to be publicly available. It combines three different water information systems: one on ground and surface water, one on water pollution. and one on soil quality. The SINEAU links these three using a horizontal system of reference and unified spatial references. It will establish standards for describing data and sharing it with different stakeholders as well as a system for managing and referencing the relevant data.

Over the past three decades, Tunisia has developed significant water infrastructure aimed at meeting its ever-increasing demand. This infrastructure network had two purposes: to respond to different usage priorities and to enable flexible management. Decisions regarding the type and size of these storage and transfer facilities and the manner of their use were guided by a number of key constraints:

- *Geological nature of the landscape*. This constraint led decisionmakers to deploy different types of facilities (multiple-arch concrete dams, buttressed dams, single-arch dams, gravity dams, compressed rolled concrete dams).
- *Lithology of the landscape* through which the water flows naturally guided the design of certain facilities and the way in which they are managed. In the Mejerda Basin (the largest basin in northern Tunisia), several Triassic outcrops are largely responsible for the water's increased salinity. These outcrops exist exactly on the sites chosen for the dams (which have the best topographical features). Thus, the outcrops have influenced decisions regarding the height of the dam and, as a result, the volume of water held behind it. (Sidi Salem is a case in point.)
- *Location of demand*. Most water consumption is far from the source of supply, making transfer systems inevitable.
- *Hydrological analysis*. Hydrological analysis of the country's different catchment areas shows a high level of heterogeneity from the point of view of both water quality and regularity of natural supply.

To ensure that water quantity is available in the place and at the time required, and to improve water quality through dilution, the infrastructure was planned using three guiding principles:

1. Allowing inter-annual storage to enable supplies to be regularized from year to year, taking into account the historical frequency of drought (including repeated droughts)
2. Creating interconnected dams situated in the same catchment areas so that the system can capture any overflows of the dams in wet years
3. Allowing water to be transferred from dams in one catchment to dams in another both to balance stock levels in periods of regional drought and to improve water quality in particular reservoirs.

From a hydrological point of view, the initial design of the detailed Northern Water Plan was based on 34 years of monthly supply observations. The average supply figure served as a reference point for deciding the size of the facilities.

After these water facilities had been in operation for a number of years, several complementary steps presented themselves as potentially useful for improving the system's performance:

- *Minimize the effect of cyclical droughts*. To take advantage of the years of excess rainfall, 11 other sites for medium-sized dams were identified and earmarked for construction in the medium term. These facilities will fill up primarily during rainy years. These medium-sized structures also will safeguard the large dams from excessive silting. The water supply from these 11 dams was taken into account when the earlier dams were designed,
- *Raise the height of specific existing facilities* to increase their storage capacity and to offset the effects of silting.
- *Create local water subsystems*, as part of a national strategy of water mobilization via hillside dams (structures fewer than 10 meters high with a storage capacity of fewer than 5 Mm^3). These facilities lengthen the active life of the major water facilities and enable the creation of smaller local development centers. Currently, 225 such units are in place, providing approximately 200 Mm^3 of water.
- *Extend the geographic range of the transfer systems*. This extension was a key component of the second phase of the national water usage strategy. It enabled the establishment of an integrated WRM structure (covering the use of both surface and groundwater resources).

The hydraulic system for surface water in Tunisia was conceived essentially for the northern part of the country. In the system, 13 linked dams already are in place, and an additional 14 should be online by 2015, for a total of 27 interconnected dams. Their configuration is based on the fact that water demand can be divided into two basic demand categories, depending on the number and type of reservoirs that supply it: "local" or "shared." Local demand sources its water from one specific reservoir, whereas shared demand is supplied by more than one reservoir. Tables 9.6, 9.7, and 9.8 give details of the reservoirs and the areas that use the water from them as well as of the transfer schemes. Dams that serve more than one area are shown in table 9.6.

Table 9.6 Tunisia's Reservoirs and Number of Areas Served

Dam	Bou-heurtma	Ben Metir	Joumine	Kasseb	Lakhmess	Mellegue	Rmil	Sidi El Barrak	Sejnane	Siliana	Sidi Salem	Zerga	Zouitina
No. of areas served	5	3	7	1	1	3	1	2	6	1	18	1	2

Source: Louati 2005.

Table 9.7 Tunisia's Reservoirs that Serve Multiple Uses

	Sejnane	Joumine	Ben Metir	Mellegue	Bouheurtma	Kasseb	Sidi Salem
Ben Arous and Nabeul (irrigation)	X	X					X
Bizerte (drinking water)	X	X					
AG02				X	X		
Grand Tunis (drinking water)	X	X	X			X	X
Cap Bon (drinking water)	X	X	X				X
Sahel and Sfax (drinking water)	X	X					X

Source: Louati 2005.

Table 9.8 Tunisia's Main Water Transfer Systems and Their Characteristics

Name of structure	Length *(km)*	Flow *(m^3/s)*	Diameter *(mm)*
Pipelines from Sidi El Barrak-Sejnane	18 km over 2 lines	4–4.6 m^3/s per line	1800 mm
Pipelines from Sejnane to Taref station	13 km over 2 lines	12 m^3/s	1800 mm
Pipelines from Taref station to Sidi M'barek	23 km over 3 lines	12 m^3/s	1800 mm
Piplelines M'barek-Bejaoua	47 km over 3 lines	12 m^3/s	1800 mm
Mejerda Cap Bon canal	120 Km	16–8.8 m^3/s	
Ben Metir pipeline	135 km	1.3–1.1 m^3/s	1250 mm
Kasseb pipeline	121 km	1.1–09 m^3/s	1190–1250 mm
Belly-Sahel pipeline:			
Belly-Sousse	96 km (2 files)	1.5–2.3 m^3/s (1st file)	1400–1200 mm
		3.6 m^3/s (2nd file)	1600 mm
Sousse-Sfax	118 km	1.35 m^3/s	1400–1000 mm
Jilma-Sfax pipeline	151 km	0.73 m^3/s	1100–600 mm
Sbeitla-Sfax pipeline	148 km	0.3 m^3/s	600–325 mm
Pipelines from Kairouanais			
Sidi Saad dam			
	18 km right bank	1.935–1.5 m^3/s	1600–1250 mm
El Haoureb dam	10 km left bank	0.5–0.335 m^3/s	600–400 mm
El Houareb	12 km	1.0 m^3/s	1000–300 mm
S.Saad (projected)	24.8 km	1.0 m^3/s	1100 mm
Nebhana pipeline	126 km	2.1–0.350	1400–600 mm

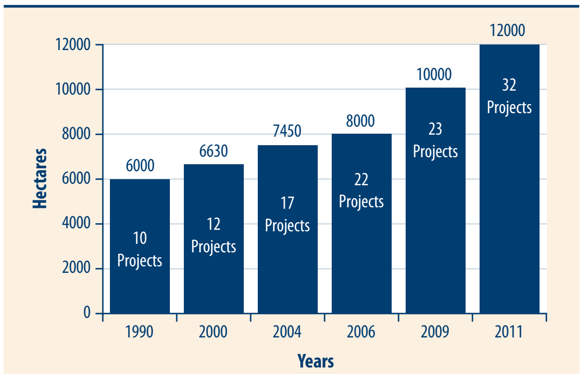
Source: Ministry of Agriculture and Water Resources 2000.

To supplement its scarce natural supplies, *Tunisia has a long experience of generating nonconventional water and of innovative investments*. Its experience in reuse of treated wastewater, desalination of salt and brackish water, and artificial recharge of aquifers is instructive and indicates a concern for integrated management of the water cycle.

Since the 1970s, Tunisia has been formally *reusing treated wastewater in agriculture* and now has one of the world's highest rates of reuse. Almost all of Tunisia's 194 Mm^3 per year urban wastewater generated is treated to adequate standards (ONAS 2004). Approximately 30 percent of it is reused in agriculture supplying approximately 7,000 ha of fruit trees and fodder, following strict sanitary standards. The country plans to invest in significantly increasing that share over the next decade (figure 9.2). Experience indicates difficulties ensuring cost-recovery for wastewater reuse. At present, the service is subsidized. In addition, Tunisia uses treated wastewater for environmental purposes, in one case, to ensure flows to an ecologically important wetland.

Despite being a country not endowed with energy resources, Tunisia has experience with *desalination of brackish and saline water*. Desalination began in 1983 in Tunisia. The national agency responsible for drinking water, SONEDE, has capacity of 58,800 m^3 per day (table 9.9). Private operators have an additional capacity of 44.000 m^3/day, mostly for tourism, although with some capacity in industrial

Figure 9.2 Growth in Treated Wastewater Used in Agriculture, Tunisia, 1990–2001 *(ha)*



Source: Ministry of Agriculture.

Table 9.9 Desalination Capacity in Tunisia, 1983–2000

Station	Capacity *(m^3/day)*	Year operation started	Technology	Feed water salinity *(g/l)*	Number of membranes
Kerkenah	3300	1983	Reverse osmosis	3.6	144
Gabes	25500	1995	Reverse osmosis	3.2	1188
Zarzis	15000	1999	Reverse osmosis	3.2	1188
Jerba	15000	2000	Reverse osmosis	6.0	756
Total	58800				2844

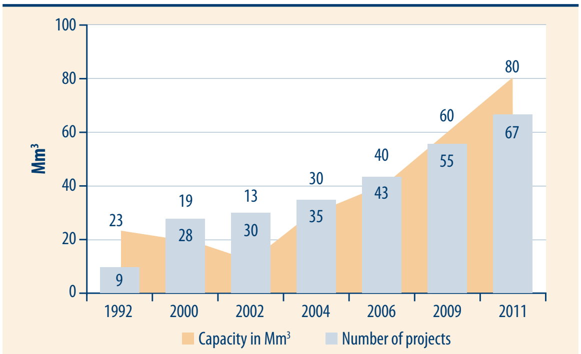
Source: SONEDE, MARH 2004.

enterprises and high-value agriculture. In the South, the authorities have been able to use reverse osmosis technology to convert brackish groundwater into drinking water.

The government subsidizes the private sector to invest in desalination and considers this technology a key part of the long-term water management strategy for the country. It plans to increase public sector installed capacity to 50 Mm^3 day by 2030.

In addition, the country has long experience of *artificial groundwater recharge*. This is a way of storing surplus water from one season for use during dry periods. The program of construction of small dams described above also included spate irrigation infrastructure to channel flood water. In addition to helping manage surface water flows, these two types of investment had a major impact on aquifer recharge (figure 9.3). Furthermore, Tunisia has projects using quarries, old wells, and direct injection to increase aquifer recharge, in some cases including recharge with treated wastewater. To avoid potential contamination, these schemes usually are toward the mouth of the aquifers. One trial scheme uses treated wastewater at the mouth of the aquifer to protect against saline intrusion. The government plans to increase the volumes of artificial aquifer recharge to more than 200 Mm^3 per year in 2030 through small dams, check dams, and soil and water conservation investments in upper watersheds.

Figure 9.3 Growth in Volumes and Schemes for Artificial Aquifer Recharge in Tunisia



Source: Louati 2008.

Use of Water Resources

The irrigation sector consumes close to 80 percent of Tunisia's extracted water. Tunisia has approximately 420,000 ha of land that could be irrigated through both public and private schemes. Of this, 400,000 ha are actually irrigated. The government's strategy aims to serve these lands with water, assuming that water is available, by 2010. The sector now uses approximately 2 billion m^3 per year. Demand should stabilize at 2.1 billion m^3 by 2010.

Groundwater extraction has increased continuously since 1997, rising from 2,161 Mm^3 to 2,638 Mm^3 in 2006—an increase of approximately 26 percent over 15 years (table 9.10). Yet, withdrawals are becoming unsustainable, while exploitation of deep groundwater is increasing slowly. On the positive side, there is potential for more or better use of surface water. In the last decade, overall usage rates of surface water have been low.

Table 9.10 Tunisia's Evolution of Water Consumption, 1997–2005 *(Mm^3)*

	1997	1998	1999	2000	2001	2002	2003	2004	2005
Surface water	399	361	445	499	248	561	510	464	688
Groundwater	757	764	771	778	778	778	778	778	807
Deep groundwater	1005	1014	1031	1078	1119	1135	1109	1127	1143
Total	2161	2139	2247	2355	2145	2474	2397	2369	2638

Sources: DGRE 2007a, 2007b.

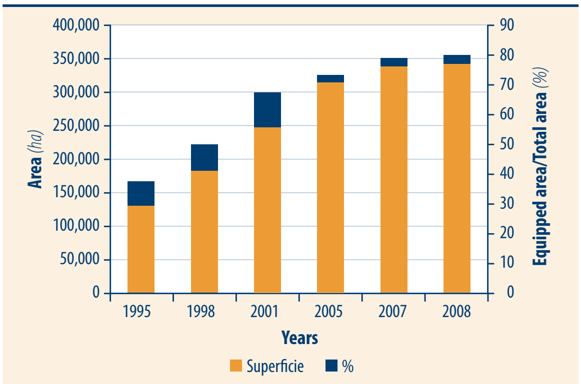
The lack of good-quality water is becoming increasingly acute in the wake of unpredictable climate patterns. Thus, the country needs to find a way to improve the value-added from the water allocated to the agricultural sector. A technical, economic, organizational, institutional, and legislative framework has been set up to maximize the country's irrigation potential as efficiently as possible. Water conservation constitutes a key component of this strategy. Since the end of the 1980s, with the introduction of conservation measures in irrigated areas, consumption per ha has begun to decline sharply, falling from 6,200 m^3/ha in 1990 to approximately 5,500 m^3/ha in 2005.

In 1995 Tunisia's water administration adopted a National Program of Irrigation Water Conservation (PNEEI). Its purpose was to rationalize the use of water to ensure that the maximum economic value is derived from irrigation and to keep water demand at a sustainable level. The PNEEI has the following broad goals:

- Strengthen knowledge of appropriate technologies to ensure optimal water use
- Ensure that regional departments have a better grasp of techniques and methods to conserve irrigation water suited to local conditions
- Encourage consumers to adopt water conservation techniques

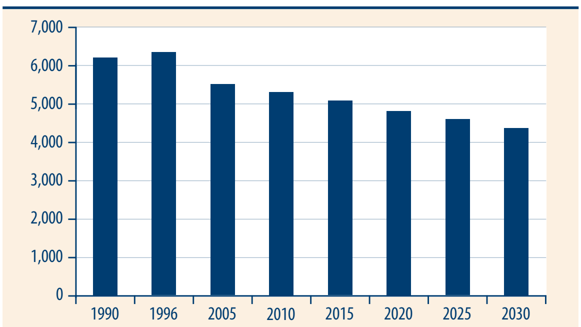
- Make available to citizens the knowledge and technical support required for them to put these techniques into practice
- Rapidly extend the introduction of on-farm water-saving equipment; transfer public irrigated areas (PPI) to agricultural development groups (GDA) under appropriate operating conditions.

Figure 9.4 Tunisia Irrigated Area Equipped with Efficient On-farm Irrigation Systems, 1995–2008 *(%)*



Source: DGGREE-MAHR 2007.

Figure 9.5 Evolution of Mean Water Allocations per Irrigated Hectare, 1990–2030 *(m^3/ha)*



Source: DGGREE-MAHR 2007.

The program provides a 40 percent–60 percent subsidy for efficient on-farm irrigation equipment, (upgraded gravity irrigation, sprinkler irrigation, and drip systems) with the exact rate depending on the category of agriculture. The program aimed to install efficient on-farm irrigation equipment on 90 percent of Tunisia's 400,000 ha of irrigated land by 2006 and to improve irrigation efficiency to a level of at least 75 percent by the end of 2006. As of June 2006, the irrigated area with qualifying conservation systems in place covered close to 310,000 ha, or 75 percent of the irrigated area. The implementation rate has been running at 15,000–25,000 ha per year. Figure 9.4 shows the take-up of the irrigation systems. Figure 9.5 shows how water allocations per ha have been changing.

The breakdown of the area under irrigation is:

- 98,000 ha of drip irrigation (or 21.6 percent of the total irrigable area)
- 106,000 ha of sprinkler irrigation (26.7 percent)
- 106,000 ha of upgraded gravity irrigation (25 percent).

Drip irrigation accounts for close to 25 percent of the total irrigable area, whereas it accounted for just 3 percent in 1995.

Regional action plans have been put in place by the Regional Agricultural Development Commissions with a goal of covering 100 percent of the irrigated area by 2009. The implementation of the water conservation program in irrigated areas is expected to bring water consumption per hectare down to approximately 4,000 m^3/ha by 2030.

The National Authority for Water Exploitation and Distribution (SONEDE), the body tasked with producing and distributing drinking water, has set up a strategy to ensure efficient water use. The changes in water allocated to SONEDE are shown in table 9.11 below.

Table 9.11 Trends in Production and Consumption of Drinking Water, 1996–2007 *(Mm^3)*

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Production of drinking water	309	317	326	337	346	373	373	394	403	420	439	453
Consumption of drinking water	230	247	258	272	285	301	297	306	315	339	340	348
Specific consumption (liters consumed and billed/day/ inhabitant connected to the system)	65	68	69	71	73	75	75	75	76	78	80	82

Source: SONEDE 2008: Statistics on SONEDE's water production since 1994, databases.

Irrigation water tariffs cover some O&M costs, but not the costs of capital investment, operation of bulk infrastructure, or value of the water itself. Tariffs for drinking water gradually are moving to a point at which they will completely cover running and financing costs, plus a significant portion of equipment costs. The current coverage is approximately 87 percent.

Policy Measures

Regulatory Measures

Water sector legislation related to water conservation covers investment incentives, investment regulation, and the rationalization of the water management system. The Water Code was promulgated in 1975. Its articles 12, 15, 16, 86, 102, 106, 90, and 96 relating to resources, planning and development, tariff rates, and the reuse and conservation of water were modified and completed by new laws in 1987, 1988, and 2001.

Technical Measures

Initiatives to improve the efficiency of communal irrigation and drinking water networks have been set in motion. The main results of these initiatives are:

1. *Water conservation project in small- and medium-sized water-consuming areas in central Tunisia*. It aims to restore and modernize public networks, promote on-farm water-saving equipment, and transfer the management of these operations to farmer groups (known by their French acronym as GICs). This project covers 11,000 ha of irrigated land at a cost of 24 Mdinars.
2. *Project to improve irrigated areas in the southern oases, covering 23,000 ha*. Project aims to make the distribution system more watertight by constructing concrete canals or laying underground PVC piping, and to install a drainage system to remove excess water and leach salts.
3. *Modernization project in the old irrigated areas of the Lower Mejerda Valley*. Underway, this. project aims to modernize a 4,300-ha portion of the old irrigated areas, which cover 27,000 ha in total.
4. *Water conservation program for public drinking water networks and facilities*. Its components include installing new equipment for metering and regulation, tracing leaks, renovating old meters and connections, and regulating pressure in the system.

Measuring the volume of water produced and distributed plays a key role in water management. The government's strategy is to equip every water system with an appropriate means of measurement and to divide networks into sections through the installation of local metering systems. This thorough deployment of meters will ensure an effective mechanism for tracing leaks. As of 2007, all of the reservoirs producing drinking water were equipped with either meters or other means of measuring outflows.

The government intends to equip all drinking water supply systems with appropriate regulation equipment. By 2007, 96.6 percent of supply systems (gravity and reverse-flow) had been fitted.

Metering policy is centered on three key initiatives:

1. Replacing jammed meters to reduce or eliminate the need to issue pro-rata bills; then replacing unclassified meters.

2. Rehabilitating worn-out connections and networks by replacing pipes and fittings to reduce leaks. In 1998 SONEDE began inventorying these connections (329,000 in total) and scheduled their replacement within 10 years. The proportion of water consumers served by worn-out connections fell from 24 percent in 1998 to 6 percent in 2007.
3. Resizing meters to bring them up to the necessary capacity. Regulation at the water system level consists of equipping drinking water supply systems (gravitational or reversed-flow) with appropriate means of regulation (cut-off valves, ballcocks, altimetric water gates, and pilot lines, radios) to avoid wasting water through overflows and leaks. Leak detection uses either correlation or the acoustic method. Part of this detection work is done in-house; part is subcontracted. During 2007, some 8,300 km of the distribution network were inspected, and 2,011 leaks or broken pipes were detected—equivalent to 1 leak or breakage every 3.3 km. Table 9.12 shows the scale of investments in improving leak detection and metering for drinking water.

Table 9.12 Number of Water Supply Meters Replaced or Improved, 2004–2007 *(m)*

Year	2004	2005	2006	2007
Number of jammed meters repaired or replaced	41,134	37,586	34,267	51,082
Number of worn-out meters replaced	71,232	40,727	16,349	9,611
Number of meters resized	1,419	1,671	578	316

Institutional Measures

Tunisia's experience of self-managed communal water systems goes back to the early 1900s, when user-owner associations were created. Among these associations were the irrigation syndicates created between 1901 and 1906 to use the water of the wadis in central Tunisia. Examples are the irrigation syndicate at the Sbiba Wadi, created in 1901, and the irrigation syndicates at the Zroud and Marguellil Wadis, which were created in 1906.

Between 1912 and 1919, associations were created to develop the southern Tunisian oases. In 1987 these associations were converted into communal interest groups. Their function was to develop public water resources; construct, maintain, and use public water works;

irrigate and decontaminate farmland; and develop drinking water supply systems.

Regional committees to assess and ensure the implementation of the water conservation program were set up in March 1992 at the regional administrative level (Regional Offices for Agriculture Development, known by their French acronyms as CRDAs). The inauguration of the committees coincided with the launch of a program of training and promotion of water conservation in the irrigation sector. Regional strategies and a water conservation assessment and implementation system at a national level have been in place since 1993.

In 1987 the management of all drinking water supply systems and borehole irrigation on public land was transferred to the GICs. In 1988 the GIC program was extended to large dam irrigation systems on public land. The purpose was to ensure that areas irrigated by boreholes and large dams were under the same management arrangements. By the end of 2005, 75,000 ha of public land serviced by large dams were under GIC management.

In 2001 the PISEAU (Water Sector Investment Project) began to transfer the management of irrigation land to farmer groups (whose name had changed to agricultural development groups, known by their French acronym as GDAs). The project financed 10 technical assistance initiatives in 8 governorates to transfer management of 31,000 ha irrigated by large dams to GDAs and to reinforce GDAs' capacity where they were already in place (16,000 ha).

Separately, a technical assistance project for the GDAs in areas irrigated by boreholes was implemented, again to encourage water conservation in Tunisia's small and medium-sized irrigated areas. This 7-year project (1999–2006) involved approximately 60 GDAs and cost roughly €1 million. Two additional TA projects were put in place to strengthen the technical capacity of the regional departments and GDAs involved in the supply of drinking water. The first to be launched began in 1997 and ended in 2008. It covered approximately 800 drinking water GICs in 8 governorates. The second initiative (2006–10) aims to boost the technical capacity of 160 drinking water GICs located in an additional 17 governorates.

Performance Indicators

Indicators have been adopted to evaluate water resource mobilization and management programs.

Table 9.13 Evolution of Effectiveness of Dams at Regulating Irregular Flows, 1997–2006 *(Mm^3)*

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Average annual irregular flows *(Mm^3)*	2,100	2,100	2,100	2,100	2,100	2,100	2,100	2,100	2,100	2,100
Regularizable irregular flows *(Mm^3)*	1,342	1,342	1,342	1,647	1,647	1,647	1,647	1,652	1,660	1,682
Regularized irregular flows *(Mm^3)*	1,030	1,228	1,221	1,316	1,292	1,300	1,465	1,521	1,601	1,587
Regulation index *(%)*	49.05	58.48	58.14	62.67	61.52	61.90	69.76	72.43	76.24	75.57

Source: Ministry of Environment and Sustainable Development 2007.

The effectiveness of dams in regulating flow is measured by a Regulation Index (table 9.13). This indicator is defined for any specific year as the ratio between the volume of regularized flows in that year and the average annual irregular water flow.

The development of water resources is evaluated according to an index that measures the ratio between annual withdrawals of water and conventional, renewable, natural freshwater resources (table 9.14). Annual withdrawals of conventional, renewable natural water include losses incurred when the water is transported.

Table 9.14 Evolution of Rate of Exploitation of Water Resources in Tunisia, 1997–2004

	1997	1998	1999	2000	2001	2002	2003	2004
Withdrawals of renewable underground water *(Mm^3)*	1,098	1,117	1,137	1,184	1,206	1,230	1,207	1,216
Withdrawals of surface water *(Mm^3)*	399	361	445	499	248	561	510	464
Available renewable underground resources *(Mm^3)*	1,273	1,284	1,432	1,423	1,408	1,408	1,430	1,498
Available surface resources *(Mm^3)*	1,030	1,228	1,221	1,316	1,292	1,300	1,465	1,521
Index of total exploitation of renewable resources *(%)*	65.00	58.84	59.63	61.45	53.85	66.14	59.31	55.65

Sources: National Statistics Institute and Ministry of Agriculture and Water Resources.

The rate of groundwater exploitation is consistently above 100 percent. For deep groundwater, exploitation also is on the increase, and is at approximately 80 percent.

The system for evaluating and monitoring water conservation, along with a land survey carried out in 2001, has enabled a mid-term assessment of the National Water Conservation Program. The results confirmed that the program was both effective and economically viable in the agricultural sector. In particular, the evaluation shows that an extremely dynamic response from stakeholders led to a significant increase in the area of land equipped with water conservation systems. Promotional campaigns using a variety of means of communication have contributed greatly to water conservation in irrigation.

Table 9.15 tracks the evolution of average yields for drinking water systems between 1997 and 2007, calculated as the ratio of consumed volume, plant volume, and briny water volume to plant entry volume. The overall network yield slipped from 78.2 percent in 2006 to 77.3 percent in 2007. This fall resulted from a 0.5-point drop in yields from conveyance (92.2 percent in 2007 and 92.7 percent in 2006) and a 0.6-point drop in yields from distribution networks (83.4 percent in 2007 vs. 84 percent in 2006).

Table 9.15 Evolution of Average Yields for Drinking Water Systems in Tunisia, 1997–2007 *(Mm^3)*

Designation	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Volume consumed	246.7	256.9	271.6	285.1	301.3	297.4	305.8	313.9	327.3	340.1	348.1
Service plant volume (VSS)	0.8	0.169	0.705	1.665	1.65	1.537	1.142	1.062	1.785	2.486	3.492
Conveyance plant volume (VSA)										1.6	0.026
Volume of briny water (VSM)	1.9	2.324	3.597	5.328	5.08	5.058	5.561	5.9186	5.3	5.9	6.9196
Plant entry volume (VES)	321.7	329.67	342.95	357.25	380.13	380.01	400.52	410.03	427.1	447.59	463.78
Overall network yield (Rg) *(%)*	77.5	78.7	80.4	81.7	81.0	80.0	78.0	78.3	78.3	78.2	77.3

Source: SONEDE 2008: Statistics on SONEDE's water production since 1994, databases.

To gauge the efficiency of transfer networks, the transfer network yield is calculated. In 2007 this yield figure reached 99.5, compared to 92.2 for the conveyance networks and 83.4 for distribution networks.

Conclusions and Recommendations

The unavoidable reality facing Tunisia is the necessity to conserve and derive maximum benefit from its limited water resources. *Conservation* *will be far more productive than looking for ways to secure new reserves*. The substantial future savings that are needed will have to come from the major water-using sectors, especially agriculture, which consumes almost 80 percent of Tunisia's available water resources.

Tunisia must expect a future of water shortages exacerbated by more frequent droughts and climate change. Water supply management therefore must improve the operation of water infrastructure and harness technology to make optimal use of existing resources. The rationale for creating new irrigated areas should be examined in light of future water demands. *Implementing a demand-based water management strategy will strengthen the case for a realignment of water sector institutions*.

Studies of Tunisia's water management system often highlight gaps or weak points in the system, particularly in the relationship with private water users. The political trend is toward *participatory management*. Thus, all levels of the administration have made great efforts to help local organizations (GICs/GDAs) to take control of operating and maintaining their water distribution facilities. It is important that regulatory texts reflect this trend toward greater participation by the beneficiaries/stakeholders. With increased involvement of users, water planning and implementation will see improved performance.

In this regard, serious thought needs to be given to the ways in which these water users can be brought in to participate in defining Tunisia's water management policy and strategy. *New mechanisms need to be created to institutionalize the participation of different users at key stages of planning and operation*.

Increasing users' participation in the water management system should enable projects to be planned and managed based on genuine knowledge of the needs and constraints of both parties—the state, which holds the resources and guarantees their continuity; and user groups, who are responsible for the viability and sustainability of their own activities.

References

Blue Plan (Plan Bleu)-UNEP. 2000. "Vision of the Mediterranean Regarding Water, Population and the Environment in the 21st Century." Sophia-Antipolis/Marseille. www.planbleu.org/publications.

____. 2002. "Analysis of Strategies and Prospects for Water in Tunisia." Sophia-Antipolis/Marseille. www.planbleu.org/publications.

____. 2005. "Mediterranean, Blue Plan Perspectives on the Environment and Development." Sophia-Antipolis/Marseille. www.planbleu.org/publications.

____. 2006. Methodological documents of the 34 key indicators for the monitoring of the Mediterranean strategy for sustainable development. Sophia-Antipolis/Marseille. www.planbleu.org/publications.

DGGREE-MARH (Ministry of Agriculture and Water Resources). 2007. "Report on the Preparation of the Investment Project in the Water Sector."

DGGREE/DGPRDIA-MARH (Ministry of Agriculture and Water Resources). 2001. "Financial and Economic Evaluation of the Water Conservation Program in Irrigation."

DGRE (Directorate General of Water Resources)-MARH (Ministry of Agriculture and Water Resources). 2007a." Directory of Exploitation of Deep Aquifers."

____. 2007b. "Directory of Exploitation of Shallow Aquifers."

DGREE- MARH (Ministry of Agriculture and Water Resources). 2001–06.

____. 2001–06. Report analyzing communal interest groups in irrigation.

____. 2001–06. Statistics concerning communal interest groups in the irrigation sector and drinking water in rural areas.

____. 2001. Study assessing the national water conservation program in Tunisia.

German Development Institute. 2003. "Reuse of Treated Wastewater in Tunisia."

Hamdane, A. 2002. "National Strategy for Water Conservation in Irrigation: The Case of Tunisia." Forum: Advances in the Management of Water Demand. Blue Plan, Rome.

Hamdane, A.-UNEP. 2006. "Monitoring of Progress in the Water Sector and Promotion of Demand-Management Policies. National Report on Tunisia." Blue-Mediterranean Sustainable Development Commission.

Louati, M.H. 2005. "Optimization of Management Rules for Multiples Reservoirs Considering Risk."

____. 2008. "Blue Plan, Efficiency of Water Utilization, National Studies: The Case of Tunisia."

Louati, M.H., and others. 1998. "Long-Term Strategy for the Water Sector in Tunisia, 2030." Water XXI.

Louati, M.H., and others. 1999. "Practical Guide to Drought Management in Tunisia: Methodological Approach."

Louati, M.H., and G. Keser, 2000. "Optimized System for Water Management."

Mamou, A. 1993. "Principal Outline of National Planning, Environmental Limits 1996."

Mediterranean Action Plan (MAP), Program of Priority Actions, UNEP. 1998. "Directives for an Integrated Approach to the Development, Management and Utilization of Water Resources."

Ministry of Agriculture and Water Resources (MARH). 1998. "Studies on the Water Sector."

____. 2000. "Water Conservation 2000": Resource Assessments, Requirements and Strategy for Water Management."

____. 2006. "National Strategy for the Adaptation of Tunisia's Agriculture and Ecosystems to Climate Change."

Ministry of Agriculture and Water Resources (MARH)-GTZ. 2004. "Guide Plan Concerning the Implementation of Real-Time Water Resource Management: Project to Optimize Management of Water Resources."

Ministry of Environment and Sustainable Development. 1993–2005. "National Reports on the State of the Environment in Tunisia. "Tunisian Research Institute for the Environment and Sustainable Development,

____. 2007. "Sustainable Management of Water Resources in Tunisia."

____. 2008: "Indicators for a Sustainable Development, Tunisia."

Ministry of the Environment and Sustainable Development-DHV. 2005. "Updated Inventory of Sources of Water Pollution in Tunisia."

National Institute of Rural Engineering, Water and Forests-Thameur Chaibi. 2003. "An Integrated Approach to the Sustainable Management of Water Resources in the Mediterranean Basin: The Case of Cap Bon, Tunisia."

National Institute of Statistics. 2000 and 2004. "Tunisian Statistical Yearbooks." Tunis.

____. 2005. "Annual Report on Infrastructure Indicators." Tunis.

ONAS (National Sanitation Office). 2004. Data. Tunis.

Sahara and Sahel Observatory (OSS). 2004. www.oss-online.org

SONEDE (National Water Supply Authority). 2005. Water Statistics in Tunisia. Tunis.

____. 2008: Statistics on SONEDE's water production since 1994, databases.

____. 2008. "Water Conservation Report 2007."

Talbit, M., ed. 1985. L'Emirat Aglabite, Dar Gharb Islami Beyrout.

UNEP. 2000. "Blue Plan: 130 Indicators for Sustainable Development in the Mediterranean."

World Bank. 2003. "Analysis of Environmental Performance in Tunisia."

Zaara M. 2004. "Desalination in Tunisia: Reality and Perspectives." Seminar in Almeria, Spain, November 23.

10

Lessons from the Rehabilitation of the Water Supply and Sanitation Sector in Post-War Iraq

Sana Agha Al Nimer

This chapter describes Iraq's current water supply issues, government strategy, and key lessons for post-conflict countries

In post-conflict countries, societies face distinctive challenges. They are immediate and urgent recovery along with the long-term objective of economic recovery, as well as social and political cohesion. One of the key challenges facing Iraqis is to develop credible and inclusive institutions that will lead to stability and sustainable economic prosperity. In the post-conflict context, rehabilitating and improving basic services such as water supply and sanitation are essential for improving the living conditions of the people. International experience in reconstruction efforts in post-conflict countries has shown that well-targeted expenditures on municipal services, especially water supply and sanitation (WSS), are especially important to alleviate suffering and to reduce the risk of further conflict.

Sector Background

Before the 1991 Gulf War, the population of Iraq enjoyed a relatively high level of water supply and sanitation services. The sector operated efficiently and utilized then-current technologies. Over 95 percent of the urban population and over 75 percent of the rural population had access to safe potable water. Water quality was satisfactory. Approximately 218 water treatment plants and approximately 1200 compact water treatment units were operating throughout the country. Sanitation services covered approximately 75 percent of the urban communities. Twenty-five percent of these communities were connected to sewerage systems, and 50 percent had on-site septic tanks.

Since 1991, the WSS sector has experienced a steady decline. Aging infrastructure, poorly maintained equipment, leaking water and sewer networks, and low technical capacity and morale are key problems of the sector. Today, most Iraqis have limited access to WSS, and to other basic services such as electricity and solid waste collection.

The level of water supply coverage is approximately 73 percent for urban areas and 43 percent in rural areas. A high percentage of water produced does not meet the World Health Organization's (WHO) water quality standards. In addition, the efficiency of service delivery is low due to the deteriorating condition of the water supply and wastewater facilities and electrical power cuts of up to 16 hours per day.

Wastewater collection and treatment facilities are available in only few large cities. These facilities are in dire need of rehabilitation. Wastewater treatment covers approximately only 8 percent of the population in the 15 governorates. The remaining waste from more than 20 million people is discharged directly into the environment (river system or on-site septic tanks).

Serious environmental and health risks associated with lack of basic services, contaminated water supplies, and poor disposal of sewage overburden the already stressed health system. Diseases associated with poor sanitation, unsafe water, and unhygienic practices have increased to alarming rates. These conditions have accounted for an estimated one-quarter of recent child mortalities. It is estimated that 40 percent of children who visit health centers suffer from gastrointestinal diseases due to the lack of safe drinking water.

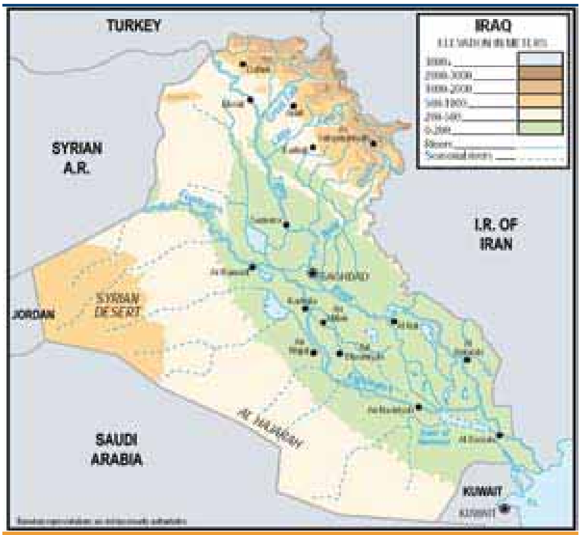
In the capital city of Baghdad, water supply and sewerage systems have fallen into disrepair from years of neglect and lack of maintenance, recent war damage, subsequent looting, and disruptions in electricity supply. Water production capacity is approximately 2.1 million cubic meters (m^3) per day, which is far below the country's basic demand of approximately 3.4 million m^3 per day. The situation is exacerbated by a water loss rate of 50 percent–60 percent from leaking distribution networks and frequent pipe ruptures. Newly developed areas in city suburbs are not served with any potable water. The population depends entirely on raw water of low quality provided by private vendors. In addition, Baghdad's three sewage treatment plants are inoperative. They discharge partially or untreated effluent into the Tigris River, the city's main water source.

One reason that operations and maintenance (O&M) are underfunded is the lack of cost recovery. Water tariffs for all Iraqi governorates, excluding the northern region, range from 0.0013US$/$m^3$

to 0.0133US$/m^3 per month for domestic customers.[1] In most governorates, the level of metering is low. Nonrevenue water (NRW) has increased due to 20 years of wars and sanctions. Lack of maintenance as well as damaged networks and infrastructure explain the NRW level of approximately 57 percent. Accurate estimates are difficult, because fewer than 10 percent of the connections are metered.

Financial management systems are weak. Cash accounting is still used. The accounting makes no clear separation between operational and capital expenditures, and cash-flow statements are not prepared. Generally, the recorded water revenues are not the amounts billed but the revenue collected. Unpaid billings are not recorded separately from formal accounts. Depreciation is charged, but the assets are not periodically re-valued in line with inflation.

Figure 10.1 Map of Iraq



Iraq also faces the renegotiation of the allocation and distribution of the resource with its upstream states, Syria and Turkey (figure 10.1). Since the majority of Iraq's water originates outside of its international borders, these negotiations add a level of complexity and urgency to the management of the sector.

Government Strategy

WSS is one of the key priorities of the Government of Iraq. The government's immediate strategy is to ensure the safe provision of services, increase coverage through rehabilitation and reconstruction, and allocate sufficient resources for O&M.

The strategy includes:

[1] Substantially lower than the costs of production in well run water utilities with full cost recovery (see Ueda and Benouahi's description of Japanese water utilities in this volume).

- Continued rehabilitation and construction of water supply and sewerage infrastructure
- Improvements to the quality of water supply services
- Capacity building and training of sector staff
- Provision of sufficient water resources for all regions in Iraq
- Crash maintenance programs of the existing infrastructure, that is, pumping stations and water supply and sewerage networks
- Appropriate monitoring of environmental issues
- Development of realistic timetables for project implementation
- Critical review of present subsidy policies and development of a plan for the gradual increase in tariffs and elimination of cross-subsidies
- Public-private partnerships for water demand management.

Water Supply and Sanitation Investment Program

Iraq's Ministry of Municipalities and Public Works (MMPW) has developed a Water and Sanitation Investment Program (2007–20). It identifies approximately 575 projects consisting of 85 technical assistance (TA), 309 water supply, and 181 wastewater projects. The total cost for the investment program is an estimated US$30 billion.

Due to the extensive needs in the sector, priority projects for the investment plan were identified based on six selection criteria. They were (1) additional population served by the project, (2) present water deficit, (3) environment and public health, (4) capital cost per capita, (5) project completion time, and (6) economic rate of return (ERR).

Donor coordination

Duplication of efforts is a risk as more donors become active in Iraq. A significant number of projects remain unfinanced.

Pilot private sector involvement

The private sector has not played a key role in financing large investments. However, some projects may be attractive to the private sector in the long term. With the prevailing set of political, economic, and security risks, a feasible option is to pilot management contracts (in addition to ongoing service contracts for construction, operations, and maintenance).

Capacity building

MMPW has received extensive support from the World Bank and other institutions for capacity building for all aspects of its work.

Key Lessons for Post-Conflict Countries

The Iraq experience reveals valuable lessons for other post-conflict situations. These lessons are summarized in a set of priority steps:

1. Actively coordinate donors
2. Identify urgent investments
3. Restore water supply
4. Identify upgrades or replacement of critical equipment
5. Develop an implementation strategy
6. Ensure security in work and living areas
7. Involve the private sector at the appropriate time
8. Follow adequate implementation and procurement procedures.

Donor Coordination

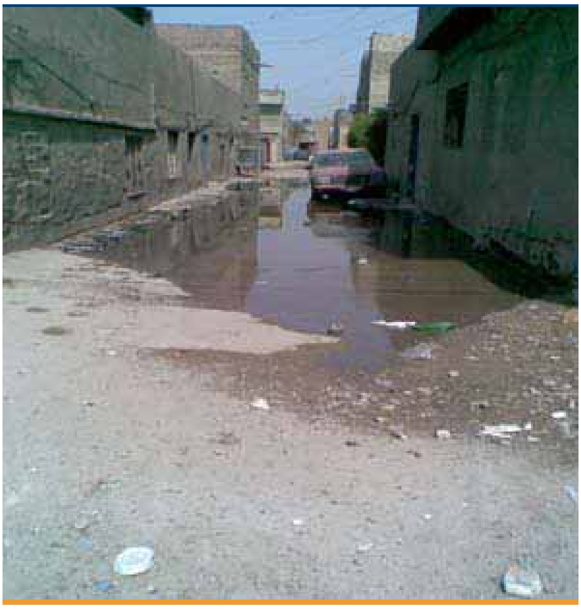
Donors active in Iraq include USAID, United Nations, World Bank, and bilateral donors. They have financed a total of approximately US$750 million targeting 33 identified projects, which has been disbursed since 2003.

In the immediate post-conflict environment, speed of response and thoroughness of initial assessment are essential. Donor coordination is critical to avoid duplication and maximize the impact of scarce resources. A key goal is to ensure that financing and assistance are targeted equitably throughout the country. Equity requires a damage assessment as well as awareness of the ethnic sensitivities of a post-conflict country. It is important to identify all relevant stakeholders, including community and civil society structures, and to include them in reconciliation and reconstruction.

Following the 2003 conflict, the international community was quick to recognize the need for a multilateral approach to Iraq's reconstruction and development. At the request of the international community, the World Bank and the United Nations Development Group worked closely to assess Iraq's reconstruction needs.

In October 2003, the United Nations/World Bank Joint Iraq Needs Assessment estimated the total needs for 2004–07 to be US$55 billion. This amount comprised US$35.8 billion for the 14 sectors covered by the Needs Assessment, and US$19.4 billion estimated by the Coalition Provisional Authority (CPA) for other sectors, including security and oil. The joint needs assessment served as a basis for various international donors' conferences. The World Bank and the UN designed

Figure 10.2 Drainage Problems in Sadr City



an International Reconstruction Fund Facility for Iraq.

As a result, the distribution of projects has been reasonably balanced throughout the country. The Baghdad Governorate has the most projects followed by Mayoralty of Baghdad, Maysan, Muthana, Erbil, Kerbala, Qadissiyah, and Dhi Qar.

Identification of Urgent Investments

It is essential to identify areas that most urgently need assistance. Key investment projects, even if small, can be crucial in restoring services. It is important to note that not all infrastructure destroyed by conflict is suitable for restoration or is critical to the immediate needs of the population. Some areas in Iraq faced neglect from years of lack of services, and had high population densities. The World Bank Iraq Trust Fund project financing targeted a number of these areas, including Sadr City in Baghdad and Badawa in Erbil (figures 10.2–10.4). The impact on the population was significant.

Figure 10.3 Badawa: A Polluted Urban Environment

It is important to identify the local technicians and sector staff who are the best equipped to identify priority projects. Unfortunately, most Iraqi technicians have either migrated, are reluctant to work in the public sector, or perished in the conflict.

External staff will also play a part in local recovery and reconstruction of infrastructure. To address issues more sensitively, these staff should be briefed adequately and have sufficient understanding of local conditions, history, geography, and culture of the country.

Figure 10.4 Badawa after Completion of Rehabilitation Works

Source: Authors from Quarterly Progress Reports.

Timely Rehabilitation of Water Supply Service

Water supply systems are often damaged in war, and sometimes deliberately targeted. *Rehabilitation of water supply systems offers one of the greatest levels of development impact in a post-conflict setting.* Emergency water supply systems consist of temporary tanks used to store clean water, which is transported by tankers. In spite of the evidence, these systems generally are overlooked in favor of treatment works and pumping stations.

In Iraq, water supply comes mainly from surface water. Therefore, to tackle the existing drinking water crises in major cities, temporary water treatments using unsophisticated technologies have been widely used as stop-gaps. These technologies include flocculation, chlorination, and possibly simple sand filters (compact units with a life span of five years). Regarding the restoration of urban public supplies, issues to be considered include cross-contamination between sewers and water distributors, and lack of O&M and spare parts.

Where they existed, sewerage systems in Iraq were less likely to have been targeted during the war. However, given the long period of inadequate maintenance and failure of power supplies, their conditions are generally very poor. Malfunctioning sewer systems are likely to pose health hazards by contaminating potable water supplies. Cleaning sewers requires costly equipment and usually is a priority that gets addressed after clean water supplies have been restored. Until then, public authorities need to prioritize disseminating appropriate public education so that the public will take the essential health measures, such as boiling or chlorinating drinking water.

Identify Upgrades or Replace Critical Equipment

Post-conflict states often have under-resourced, poorly maintained, and out-of-date services infrastructure. Rehabilitation involves updating the system, catching up on maintenance, refurbishing plants, and carrying out much needed repairs.

After identifying the immediate needs as well as budgeting for the medium and long-term needs, the government has to prepare a budget to identify and estimate required costs. Generally, funds are limited, so prioritization becomes necessary. To avoid prejudice against any particular group, determining the priorities should involve as many local stakeholders as possible. Locals will have very high expectations, so addressing unrealistic local aspirations should be discussed openly by the complement of various stakeholders.

Develop an Implementation Strategy

An implementation strategy should be developed that reflects the needs of service users, local skills, construction security, the mix of local and external inputs, budget flows, and overall program management capacity. Local participation must be engaged. Early involvement of local people who are familiar with the technical and system backgrounds can help in setting realistic investment and implementation targets.

The re-establishment of local contractors should be encouraged by developing small contracts, with external support to strengthen management skills where necessary. The skills mix of local and expatriate staff and contractors in rebuilding has two benefits. It results in local employment and income. It also ensures a project's sustainability through community buy-in and creating a culture of maintenance for the project. In scheduling, lengthy or overly bureaucratic procurement methods need to be anticipated.

If possible, funding should be managed independently from government systems. One option is to use a separate local bank account. The project management team would countersign payment checks with the local government officers.

Payment currencies and systems for local contractors/suppliers/consultants also must be planned ahead to prevent stoppages. When payments for salaries and goods are delayed, so is implementation. In Iraq, payments in US dollars are far easier to process than those in the local currency, which involve a particularly cumbersome process in the local banking system.

Security in Work and Living Areas

Even after a conflict, insecurity and danger may continue. It still is not safe enough for the international community to visit Iraq. Infrastructure contractors may be reluctant to undertake development work in insecure areas, which are often the very areas that most require development. The inability of international workers to work in the country increases the frustration of the local population toward external donors, contractors, and other outsiders. In the absence of a strong economy or currency, payments to local contractors may involve the added risks of storing and transporting cash payments.

In prioritizing tasks and activities, donors and service providers should consider improving security as a key priority. In some areas, security services provision adds 30 percent to 50 percent to investment costs.

Involve the Private Sector at Appropriate Time

Major private investment is likely to be appropriate only after a period of some stability, or where appropriate guarantees can be made that offset the risks. Private investors are likely to be wary of investing before the conflict is fully resolved. Even then, investors may be discouraged by the weakness of government's administrative capacity and the difficulty of enforcing payment for services.

However, some private organizations may come forward to fill important gaps for which the entry cost is relatively low and returns are rapid. An example is the provision of telecommunications immediately after conflict. The use of donor-funded guarantees and co-financing can facilitate private/public partnerships.

Phased arrangements may be considered, including a planned progression from modest forms of private participation in infrastructure, such as service or management contracts, to leases or long-term concessions. In Iraq, for the foreseeable future, pilot management contracts will be the most appropriate, with the government owning major assets and assuming a large proportion of the commercial risks.

Appropriate Implementation and Procurement Procedures

Post-conflict situations usually result in immediate and large financing needs on emergency projects. Procurement in a post-conflict situation raises the risk of corruption and conflict over access to contracts, employment, and services. It is critical to have a strategy in place for managing this risk. Sufficient training in procurement for all levels of government is very important and should be provided as soon as possible. Through their requirements for procuring goods and equipment, the government benefits from advice from the donor agencies in the timely and transparent delivery of services.[2]

References

Government of Iraq. 2005. National Development Strategy (NDS) of the Transitional Government. Baghdad.

United Nations/World Bank. 2003. United Nations/World Bank Joint Iraq Needs Assessment. Washington, DC. October.

[2] See Calkins and Abu-Taleb in this volume for a discussion on governance and anticorruption problems and how to address them.

11

Governance in Yemen's Water Sector: Lessons from the Design of an Anticorruption Action Plan

Maher Abu-Taleb and Richard Calkins

This chapter summarizes the key lessons learned while dealing with governance and corruption (GAC) issues in Yemen, and is based on the recent design of a water sector operation. Specifically, the chapter presents a diagnostic of governance and corruption issues in Yemen's water sector, the application of "smart project design" to improve governance at the sector level, and the development of an Anticorruption Action Plan (ACAP) to help ensure that the water sector project funds are used for the intended purposes.

While the World Bank has been working on the broader issues of good governance at the country level for many years, with a few exceptions, the focus on sector- and project-related governance and corruption issues is relatively recent. In 2007–08, a team of World Bank and Yemeni government sector specialists were presented with the opportunity to design a water sector investment operation as part of a Sector-Wide Approach (SWAp). At that time, a strategic decision was made to make resources available to diagnose the governance issues in the sector, identify the vulnerabilities and potentials of ongoing reforms, and build consensus around a sector governance program.

The project under discussion supports the Yemeni government's US$1.5 billion 5-year National Water Sector Strategy and Investment Program (NWSSIP). More specifically, this project will support the Yemeni Government's US$381 million Water Sector Support Program. It comprises US$141 million in counterpart financing from the government budget and the remainder from other development partners.[1] The

[1] Details available in World Bank, Yemen Water Sector Support Project Appraisal Document, 2009.

SWAp framework builds on country-level governance and anticorruption initiatives. The framework has piloted the design of the first specific Anticorruption Action Plan in the Middle East North Africa Region (MNA), to be implemented for the entire water sector as part of the Water Sector Support Programme (WSSP).

The chapter is organized as follows. First, the brief overview gives the context for this work along with definitions to acquaint the reader with the relevant concepts. The overview is followed by a summary of the governance agenda at the country level. Next, an assessment of governance and corruption risks is presented along with the planned mitigation measures and the details of the Anticorruption Action Plan. Finally, a monitoring and evaluation (M&E) framework is outlined. As with any new initiative, the plan needs to be implementable to work as intended and ensure that benefits of enhanced development effectiveness actually exceed the costs.

Context

By world standards, Yemen is a country poorly endowed with water resources. Groundwater is being over-exploited. Consequently, the large part of the rural economy dependent on groundwater is under threat. In addition, both urban and rural settlements are poorly provided with safe water and sanitation services. Government has been aware of these reform challenges for decades and, over the last 15 years, has taken significant institutional steps.

The government's decision to prepare an update of its national water strategy that would run from 2009–15 provided an opportunity to incorporate institutional design elements that would improve governance. The strategy update's objective was to incorporate changes in light of the experiences of the past five years and to provide a basis for a sector-wide approach (SWaP) to financing. Under the supervision of an Inter-Ministerial Steering Committee of five ministers, a highly participatory process was adopted to evaluate experience to date and to prepare the updated national water strategy.

The water sector project supports implementation of Yemen's National Water Sector Strategy and Investment Program (NWSSIP). The strategy is intended to (1) strengthen institutions for sustainable water resource management, (2) improve community-based water resource management, (3) increase access to water supply and sanitation services, (4) increase returns to agricultural water use, and

(5) stabilize and reduce groundwater abstraction for agricultural use from critical water basins.

The project is being prepared based on fundamental reforms related to implementation efficiency, coordinated donor harmonization, and improved water sector governance. All three of these bases are prerequisites for poverty alleviation and agricultural income growth. Some major water sector donors in Yemen (the World Bank and aid agencies of the governments of Germany, the Netherlands, and United Kingdom) have provided technical assistance to the government to harmonize and align efforts to support its national water strategy. Meanwhile, they are building local institutional capacity by progressively entrusting implementation to mandated national agencies. The project design includes a draft Memorandum of Understanding (MOU) that defines the obligations of the partners under a SWAp with common rules for coordinated support. In addition to the governance improvement built into the project design, specific anticorruption measures have been incorporated in the Anticorruption Action Plan, which will be implemented as part of the project.

Before continuing, some definitions are presented below:

Good governance is the exercise of power in the management of a country's economic and social resources for development. Good governance is associated with faster, private sector-led growth and with pro-poor development outcomes. Poor governance has the opposite effects and provides greater latitude for corruption. The World Bank's new strategy to address governance and corruption issues emphasizes three key principles—referred to as the TAP Framework:

1. Transparency
2. Accountability,
3. Participation (TAP) (box 11.1).

Corruption involves the use of public office for private gain. It occurs at all levels, from petty corruption to administrative corruption to grand corruption (including "state capture"). It is a symptom of poor governance and reduces development effectiveness.

Smart Project Design is intended to help ensure that development objectives are achieved and that Bank/IDA funds are protected. It is country specific and reflects what has been learned about risks and risk mitigation in a particular country. While the definition of Smart

Box 11.1 Three Key Principles of Good Governance

A review of the literature on good governance suggests that practitioners should pay particular attention to three highly complementary and mutually reinforcing principles: ***transparency, accountability,*** and ***participation*** (TAP).

1. ***Transparency*** implies openness and visibility, which should apply to almost all aspects of the conduct of governmental affairs. It is the foundation on which both accountability and participation are built. Information in the public domain is the "currency" of transparency and, together with open and visible decisionmaking processes, signals that there is really nothing to hide. Transparency facilitates good governance. Its absence provides cover for conflicts of interest, self-serving deals, bribery, and other forms of corruption.
2. ***Accountability*** has many dimensions, both internal and external. Internal accountability implies proper management of resources. External accountability refers to the responsiveness of political leaders to the needs and aspirations of the citizens. Accountability, of course, implies that the institutions—including the civil service—have the capacity to be responsive to the demands of the citizens and that salary levels and other incentives are consistent with those expectations.
3. ***Participation***—or, as some have referred to it, **inclusion—**is important not just on principle but in practical terms. It represents the "demand side" of good governance. The benefits of participation are well documented on a global scale in most aspects of public governance. Participation of civil society organizations (CSOs), consumer groups, project beneficiaries, and affected communities in all stages of Bank-financed projects simultaneously can improve development outcomes and reduce opportunities for fraud and corruption.

Project Design is evolving, experience suggests six relatively standard elements:

1. Pursuit of sector-level governance issues through a combination of project-specific and "parallel track" initiatives
2. Focus project design on reducing the negative impact of governance and corruption on successful development outcomes
3. Strengthen internal accountability and the project's "control environment" (procurement, financial management, auditing, information availability)
4. Strengthen external accountability—responsiveness to the "demand side" (consultations with affected communities, participation of beneficiaries in project design and implementation, and strengthened community voice)

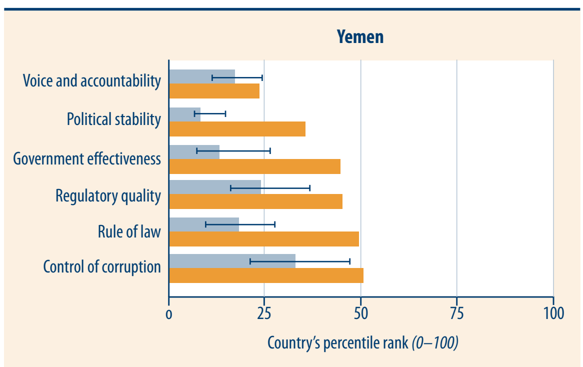
5. Ensure that project design builds in effective oversight by implementing agencies (possibly involving third-party oversight) and allows for effective supervision by the Bank/IDA
6. Develop and implement a well-thought-out communications plan designed to consistently send the right signals to all parties concerned.

Anticorruption Action Plans (ACAPs) may be used to formalize some or all of the elements of Smart Project Design. ACAPs generally are not required for Bank/IDA projects. However, they have been mandated in some situations, such as when lessons from findings of the World Bank's Department of Institutional Integrity (INT) investigations and Detailed Implementation Reviews (DIRs) appear applicable.[2] In other cases, ACAPs have been at the initiative of the relevant ministry as a way to increase the visibility and impact of its governance and anticorruption efforts. The latter is the case for the Yemen Water Sector Support Project.

Governance Agenda at the Country Level

Over the past two years, Yemen has made significant progress in several areas of governance. While it continues to lag the MNA Region and other low-income economies, the country appears to have strengthened its rankings in areas such as control of corruption, regulatory quality, and rule of law (figure 11.1). The main challenges remain low government effectiveness and accountability as well as very low political stability. Despite improvements in its control institutions, perceptions about corruption in Yemen remain unfavorable. Regarding voice and accountability, however, Yemen

Figure 11.1 Comparison with Regional Average (Middle East & North Africa) *(lower bar)*



Sources: D. Kaufmann, A. Kraay, and M. Mastruzzi 2008: Governance Matters VII: Governance Indicators for 1996–2007.

[2] DIRs, or Detailed Implementation Reviews, are carried out by INT (the Bank's Department of Institutional Integrity) in response to multiple allegations of fraud and corruption in Bank/IDA projects in a given country, or at the request of the country team concerned—generally in connection with a review of corruption concerns within a given sector or country.

scores better than other more developed nations of the region: Egypt, Iran, Iraq, Libya, Saudi Arabia, Syria, and Tunisia.

Recent Governance Accomplishments

With strong support from the donor community, Yemen has made progress on its governance agenda in a number of critical areas. Examples are the new procurement law, development of the High Tender Board policies and capacity, completion of the procurement laws implementing regulations, development of the proposed procurement database in key agencies, and staff training and development.

In addition, progress has been achieved in the Cabinet-approved comprehensive financial management reform strategy. Areas of improvement include budget execution; cash management and internal controls; internal and external auditing; financial reporting; and the role of oversight bodies such as the supreme audit agency, the Central Organization for Control and Auditing (COCA).

In 2007 the Government of Yemen (GOY) also finalized the Anticorruption Law. It will support enhanced information disclosure as a part of greater transparency and accountability, and as a prerequisite for the wider participation of civil society, especially project beneficiaries.

On a parallel track, the Bank and other donors have supported civil service reform and capacity building intended to help GOY achieve a more professional, competent, and merit-based government service. Others in the donor community have supported legal and judicial reforms—critical to strengthen the rule of law.

As part of the 2007 Anticorruption Law, the Supreme National Agency for the Control of Corruption (SNACC) was created. The Bank is supporting the development of this new anticorruption agency through a program of technical assistance (TA).

Governance and Corruption Issues in the Water Sector and Mitigation Measures in WSSP

Water Challenges in Yemen

Yemen has one of the lowest rates of per capita freshwater availability in the world (135 m^3/cap/year), compared to the almost 10 times higher regional average, 1,250 m^3/cap/year. The country has no perennial rivers. Its water comes from rainfall, springs, seasonal spate flows, runoff, and groundwater. In the last decades, a massive and persistent problem of unsustainable groundwater extraction in both highland and coastal areas has arisen, threatening the agricultural economy, urban growth, and industrial development. In urban areas, approximately only 56 percent of the population has access to network water supply and only 31 percent to sewerage. In rural areas, approximately 45 percent of the population has access to safe water and only 21 percent to adequate sanitation. *Water scarcity has created competing demands for its services, and these have greatly complicated the challenges of governance.*

GOY created the National Water Resources Authority (NWRA) to implement an integrated approach to water management. In 2002 a water law was enacted, and in 2003 the Ministry of Water and Environment (MWE) was established. Thereafter, MWE prepared a consolidated strategy, action plan, and investment program for the water sector as a whole. The *National Water Sector Strategy and Investment Program 2005–09 (NWSSIP*) was adopted and published by GOY in 2004.

NWSSIP aimed at recovering control of the groundwater resource and moving Yemen toward the Millennium Development Goal (MDG) targets for water supply and sanitation. In late 2007, GOY decided to prepare an update of NWSSIP to run from 2009–15. The objective was to incorporate changes in the light of experiences and to provide a basis for a sector-wide approach (SWAp) to financing.

Overall, the NWSSIP process has brought significant advantages to water sector management: (1) a common framework for planning, financing, implementation, and monitoring; (2) a point of reference and a forum for stakeholders to maintain continuous dialogue through the Joint Annual Reviews; (3) a basis for an integrated intersectoral approach to water resource management through pooled/joint financing; and (4) benchmarks to measure performance.

Governance and Corruption Risks in the Water Sector

Table 11.1 lists the 4 major issues identified in the assessment of governance and corruption risks in the water sector. Corresponding mitigation measures also are presented and are elaborated below, as part of the Anticorruption Action Plan.

Table 11.1 Key GAC Issues and Mitigation Measures

	Mitigation measures	
Issue	**Sector-level**	**Project-level**
Nonoptimality in selection of investment projects	NWSSIP, MTEF	Development of NWSSIP with clarified investment policies, elaboration of MTEF for water sector, development of specific investment criteria by subsector
Lack of transparency in procurement process	Adoption of new procurement law and enforcement of reforms	Development of standard bidding documents, MIS system, e-procurement pilot, and Anticorruption Hot Line
Short-changing investment projects by contractors, suppliers, and consultants during implementation	Enhanced public disclosure	Anticorruption Hot Line, expanded use of technical and/or "value for money" audits
"Elite capture" of project benefits after completion of project	Stakeholder participation in project design and implementation	Improved information disclosure and Anticorruption Hot Line program

Issue 1

Nonoptimality in selection of specific investment projects, including interference by "influential persons" in decisionmaking at the national level, in some instances combined with an absence of feasibility studies and inflated cost estimates, which provide opportunities for excess profits and/or payment of bribes and kickbacks.

Mitigation measures. Development of the National Water Sector Strategy and Investment Plan (NWSSIP), which clarifies the policies for achieving sustainable use of water as a natural resource and specifies the corresponding investment priorities. NWISSIP will be supplemented by the elaboration of a Medium-Term Expenditure Framework (MTEF) for the water sector—a three-year rolling public sector budget document.[3] In addition, under WSSP, investments to be supported by the pooled donor funding mechanism must meet specific investment criteria. These criteria will vary by subsector. They will include minimum internal rate of return (IRRs), maximum unit costs per capita or per hectare (ha), or financial rates of return (as for local utility companies).

---

[3] An MTEF is a consolidated financial document that links (1) public expenditures; (2) financing plan for those expenditures; and (3) outputs or "deliverables" that will be produced. The Water MTEF is timely because government and donors have decided to bring most financing of the water sector within a "SWAp" framework. The Water MTEF will provide the medium-term expenditure and financing framework within which the WSSP will be integrated

Issue 2

Lack of transparency in the procurement process, lack of good practices in public sector procurement, and shortages of experienced procurement professionals within implementation agencies. These three factors provide opportunities for interference by "influential persons," conflicts of interest, collusion among bidders, and irregular payments by bidders to influence outcomes.

Mitigation measures. Adoption of the new national Procurement Law, which incorporates global "best practice" in processes and procedures; reform of the High Tender Board—including greater independence in decisionmaking and development of standard bidding documents for the procurement of goods, civil works, and consultant services. These reforms will be supplemented by the development of implementing regulations, staff training and development, and establishment of a MIS to support the new procurement procedures. In addition, ACAP includes a provision to improve information disclosure, pilot "e-procurement," and develop an Anticorruption Hot Line Program to increase the probability that inappropriate interference in procurement will be reported.

Issue 3

Short-changing investment projects by contractors, suppliers, and consultants during implementation. Means include irregular payments to supervisors to "look the other way," submission and acceptance of fraudulent documentation (certificates of delivery or completion of work that do not accord with contract specifications), and irregular payments for the release of project funds or to secure the payment of invoices.

*Mitigation measures***.** Under WSSP, ACAP provides for enhanced disclosure of information about investment plans in the water sector, and participation of project beneficiaries and affected communities in project design and implementation. These initiatives will help communities to understand what should be done under WSSP projects, thus enabling them to monitor ongoing implementation activities. The Anticorruption Hot Line will provide a mechanism for community members to report suspicious activities. In addition, under the financial management component of ACAP, WSSP will expand the use of technical and/or "value for money" audits that will help to identify any shortcomings in the performance of contractors and suppliers, and inconsistencies between certificates of delivery and completion and what actually exists "on the ground." The communications program under ACAP will alert the contractors, suppliers, and consultants to these initiatives, putting them on notice that short-changing projects during implementation is more likely to be discovered.

Issue 4

"Elite capture" of project benefits after completion of the project. This term refers to diverting the benefits to groups other than the intended beneficiaries or for unintended purposes (for example, qat production).[4]

Mitigation measures. The emphasis given by WSSP to participation by beneficiaries and affected communities in project design and implementation significantly reduces the opportunities for subsequent "elite capture." In addition, the ACAP Anticorruption Hot Line will provide a channel for citizens to report any diversion of project benefits.

Anticorruption Action Plan

The Anticorruption Action Plan (ACAP), developed as part of project design, is an innovative step in MNA operations, building on the progress achieved in the country-level governance and anticorruption agenda. It also complements the reform program of the water sector.

The components of ACAP respond to the assessment of GAC risks in development projects in the water sector. Broader applicability to other sectors is being considered by the government.

ACAP includes both "supply-side" components, which focus on strengthening country systems and the associated control environment within which investment projects are implemented; and "demand-side" components, which focus on enhancing external accountability through community voice and participation—including project oversight. A summary is presented in box 11.2, and details of each component follow.

Detailed Elements of an Anticorruption Action Plan

Procurement reform and capacity development

This element builds on the work done at the country level in procurement reform, described earlier. While the procurement component of the project focuses on the implementation of those reforms, ACAP provides additional funding to pilot special initiatives—such as the

[4] Qat is a locally produced plant, the leaves of which are chewed as a stimulant. Consumption in Yemen is widespread and extensive. Excessive qat consumption at the national level accelerates drawing on water resources.

Box 11.2 Overview of Anticorruption Action Plan

Supply-side components include:

- Procurement reform and capacity development, supporting the implementation of the new (international best practice) procurement law through training programs and innovative pilot initiatives at the sector and project levels
- Financial management reform and capacity development, supporting the implementation of the Cabinet-approved comprehensive public financial reform strategy covering budget preparation and execution, internal controls and audits, financial reporting, and improved oversight by the supreme audit agency
- Enhanced information disclosure, building on the 2007 Anticorruption Law, and taking full advantage of new technology to put information into the public domain and to support the scaling up of "best practice" cases of information disclosure within the water sector.

Demand-side components include:

- Community participation and consultation, building on "best practice" models already being implemented in some water sector projects
- Education and awareness program, to be carried out in cooperation with Supreme National Agency for Combating Corruption (SNACC), as part of the water sector SWAp Program's communications program
- Anticorruption Hot Line Program, to be implemented within the water sector, as part of the "detection" program.

introduction of e-procurement. Progress in implementing the reform program will be critical to achieve the longer-term vision of the WSSP in moving toward reliance on country systems.

Financial management reform and capacity development

As in the case of procurement reforms, this element builds on the work done at the country level in the area of financial management and audit reform. Here also, the financial management component of the project will support the implementation of these reforms, including the introduction of an internal audit function. As part of the ACAP, particular attention will be given to the use of technical and/or performance audits to ensure that contractors, suppliers, and consultants are delivering on their contractual obligations. These special audits will be carried out in collaboration with the new internal audit function. Progress in these areas also is critical in moving toward reliance on country systems.

Enhanced information disclosure

This element builds on the information disclosure provisions of the 2007 Anticorruption Law. The intention is to take full advantage of new technology (web pages, public terminal displays) to put information into the public domain and to support the expansion of "best practice" disclosure.[5] In addition to annual investment and procurement plans, tender opportunities and outcomes, status of project implementation, and results, Yemen is looking at capturing and publishing relevant unit cost factors, results of various audits, and outcomes of "consumer surveys"/citizen report cards.

Community participation and consultation

To enhance the demand for greater transparency, accountability, and fairness, ACAP will pay particular attention to the use of consumer surveys. Examples are those completed recently in the rural water supply subsector and Poverty and Social Impact Assessments (PSIAs), such as in the urban subsector. Support also will be given to follow up consultations in selected localities; and, for urban centers, with the local corporations.

Education and awareness

This element, in cooperation with SNACC, is an education and awareness program. The intention is to pilot communications initiatives in the water sector toward applying them to other sectors in future. The target audiences are government staff in implementing agencies; private sector firms and individuals (contractors, suppliers, and consultants); and civil society, especially project beneficiaries in affected communities. The key messages are that GOY is giving new priority to reducing corruption and that all will have a role to play in this effort. Those involved will be reminded of their obligation to perform with professional integrity and the consequences of failing to do so. They also will be informed of the ACAP initiatives being introduced to prevent, detect, and deter fraud and corruption in water sector projects.

Anticorruption hot line program

This element supports the design and development of a Hot Line Program to increase the probability that fraud and corruption will be

---

[5] Such as those developed by the General Authority for Rural Water Supply Projects (GARWSP).

detected. To be operated by an independent third party, this program will include a hot line phone staffed every day of the year, fax line, web page, email address, and post office box—all for the receipt of complaints and allegations of fraud and corruption. After a preliminary screening to sort out irrelevant complaints, the valid cases will be forwarded to the ACAP Advisor for referral to the appropriate authorities (SNACC, COCA, the implementing agency if more information is needed).

Monitoring and Evaluation

Given ACAP's innovative nature, monitoring how it is doing is essential, so as to learn from experience and adjust its approach accordingly. Features of the monitoring system include:

- Adopting a "learning by doing" approach that recognizes the experimental nature of many of the activities that will be attempted in this new area.
- For whatever initiatives are undertaken, defining clear objectives for desired improvements in development outcomes or reductions in fraud and corruption.
- Selecting a limited number of monitorable indicators that will enable tracking progress toward these objectives over time.
- Establishing baseline numbers for these indicators, wherever feasible, and setting up monitoring systems that will report regularly on the direction of progress.
- Monitoring and evaluating the results and assessing the factors that aided or hindered the effectiveness of the activities that were undertaken.
- Where the evaluation indicates that the activities were successful, consider scaling up, as appropriate—in that sector at a minimum, and possibly in other sectors in the country.
- Where the evaluation indicates that the activities have not been successful, suspending them until the conditions needed for success are attained. If total suspension is not practical, discontinue the activities and try a new approach.
- Using the mid-term review and end-of-project impact assessment to evaluate all of the activities, and extract the lessons learned for future reference.

While all of the above sound simple, the unfortunate reality is that they are far more complicated than they sound. Some indicators of development outcomes are relatively straightforward; others are not. The results chain—from objectives to inputs, activities, outputs, and outcomes—may not lend itself to precise measurement, especially when the objective involves reducing fraud and corruption. For example, there is not likely to be a meaningful "baseline" number for fraud and corruption. Moreover, the number of cases of fraud or corruption actually should increase with improvements in detection measures such as expanded audits and the availability of complaints lines.

For these reasons, a special effort will be required to define meaningful progress indicators—even if these are surrogates for what cannot be measured directly. It also will be necessary to develop M&E systems that will enable GOY and the Bank to track progress of key indicators at the country, sector, and project levels. For the reasons cited above, these indicators are foreseen to be reviewed in the initial phases of the project.

Summary and Lessons Learned

ACAP as a Learning Exercise

The process of designing and implementing ACAP should be seen as a learning process for everyone involved, especially since this is the first such initiative in Yemen at the sector and project levels. Many of the components involve pilot projects to test the effectiveness of a particular approach. Every component will need to be monitored and evaluated carefully during implementation. If a particular element is not working as intended, it should be fixed or dropped and alternative approaches tried. If a particular element is working especially well, consideration should be given to adopting it on a wider scale, as appropriate.

Supervising the Anticorruption Action Plan

Overall, for projects that include an ACAP, it is vital to pay close attention to how well this plan is being implemented and the extent to which it is meeting its objectives. Some of the key components of the plan are likely to involve new or pilot activities. These pilots should be approached with high hopes but modest expectations. The plan itself should be seen as a "work in progress" that is subject to review and modification as needed, and as a learning experience for everyone involved. The plan should be treated as an important component of the overall project. It will be important to ensure adequate funding for supervision, availability of the right skills and experience to guide the effort, and careful planning to optimize the use of supervision resources overall.

The four key steps in the supervision process of ACAP are to:

1. Establish a regular review of progress for each component, including an assessment of what is going well, what is not going well, and why.
2. Discuss and agree with government on adjustments needed to enhance effectiveness.
3. Record findings and required follow-up in supervision documents, both to keep management informed of progress and as an aid to subsequent "lessons learned."
4. Include an impact assessment as part of the mid-term review of the project and as part of the final evaluation of project outcomes.

Appendix A1. Improving Governance and Reducing Corruption through Public Disclosure of Information

The World Bank desired to support the development of an Anticorruption Action Plan (ACAP) for the Yemen Water Sector Sector-Wide Approach (SWAp) Program. To do so, the Bank examined the role of public disclosure of information and the prospects for improving governance and reducing corruption by enhancing the amount and type of information available to the public. One of the conclusions reached is that measures can and should be taken to collect and disseminate a variety of information about activities in the water sector and that these measures should feature prominently in the Anticorruption Action Plan.

This conclusion is consistent with the three basic and interrelated principles of good governance: *transparency, accountability,* and *participation* (TAP). *Transparency has to do with both more open decisionmaking processes and greater availability of information in the public domain; and is the foundation for both accountability and participation*. Fortunately, a number of initiatives to improve transparency by improving the availability of information already are underway in Yemen's water sector. The Bank's intention is to build on these initiatives by supporting the spread of "best practice" disclosure methods in a number of critical areas.

This appendix provides an overview of the kinds of information that should be disclosed, target audiences for different types of information, various methods to disclose information, and benefits expected from these initiatives.

Information to Be Disclosed

The current water sector strategy and investment plan have been updated. The next step will be the development of the Medium-Term Expenditure Framework (MTEF). The details of the updated investment program, MTEF (when it is available), and annual budget allocations then should be published to make them available to the public. These disclosures should occur for each of the four key subsectors: urban water and sanitation, rural water and sanitation, irrigation, and integrated water resource management at the basin level.

Similarly, at the project level, annual procurement plans should be published, followed by advertisement of specific tender opportunities.

Within the procurement process, information should be disclosed consistent with international best practice, including the announcement of winning bidders and prices. The ACAP for the SWAp Program also proposes piloting e-procurement for some of the largest contracts. In addition, ACAP will support the collection and publishing of pricing data from each of the four subsectors on selected, comparable unit costs. Unit costs will include pumps of various standard sizes, pipes of various composition and sizes, concrete storage tanks of various sizes, and trenching for various types of soil and terrain conditions. The data will be collected and published quarterly.

Under the financial management component of ACAP, the proposals include strengthening the capacity of internal and external audits and the extension of audit terms of reference (TOR) to include, on a selective basis, performance and/or technical audits. The Bank also will encourage implementing authorities to publish the audit reports.

Engaging the community in project identification and design and establishing WUGs (water user groups)/WUAs obviously require an information campaign by project management to inform potential beneficiaries of the existence of the project, eligibility rules, procedures for application submission and approval, and the requirements for establishing WUGs and WUAs.

A related "demand-side" initiative under the ACAP is the proposal for consumer satisfaction surveys and citizen report cards. The intention is to disclose how well service providers are actually delivering their services.

Given all of these areas in which information disclosure is critical for improved governance, ACAP includes a separate component focused specifically on enhancing information disclosure. Funding will be provided for the launch of new pilot initiatives (such as e-procurement), identification of existing "best practice" disclosure activities, and scaling up "best practice" wherever feasible.

Relevant Target Audiences

Obviously, the target audience for information disclosure depends on the nature and purpose of the information. Given the critical nature of the water sector and the unsustainable water use practices in the country, the sector strategy and investment plans should be of interest to a fairly wide audience. The MTEF will be of interest to oversight agencies (including Parliament), those working in the sector agencies, local governments, and civil society. Annual budgets, annual procurement plans, and specific tendering opportunities will be of primary interest to those engaged in program and project implementation, including private sector contractors, suppliers, and consultants.

Unit cost data should be of interest to both implementing and oversight agencies, as well as to the business community. The results of internal and external audits— especially the results of performance and technical audits—will be particularly interesting to oversight agencies, but also to civil society, including the increasing number of CSOs that are focusing on governance and anticorruption.

Information about project opportunities and eligibility criteria will be of obvious interest to potential project beneficiaries. Reports of consumer satisfaction and citizen report cards will be of interest to consumers, service providers, and relevant levels of government—particularly the oversight and regulatory agencies.

Methods of Information Disclosure

The most appropriate methods of disclosure depend on both the nature of the information or data to be disclosed and the characteristics of the target audience. At one end of the spectrum, "high-tech" disclosure methods may be appropriate, including through web pages and internet links (as for e-procurement). Of particular interest is the procurement MIS system that has been developed in the rural water supply and sanitation (WSS) sector under GARWSP with financial support from the Netherlands. This system is computer based, with terminals available in the lobby of GARWSP headquarters and branch offices, and makes available information on all stages of the project cycle. These ongoing updates enable project beneficiaries, contractors, suppliers and consultants, and GARWSP management and staff to see at a glance the status of project approval, procurement processes, and status of implementation (including the tracking of invoice submission, review, approval, and payment). These running updates are one of the "best practice" disclosure models that will be considered for "scaling up" under ACAP.

In the mid-range of the spectrum, newspaper advertisements may be appropriate for notifying potential bidders of a tender opportunity. However, at the community level, printed word literacy cannot be assumed, let alone technical literacy. Consequently, radio and television may be the more appropriate channels for information dissemination.

These could be supported by community meetings and/or focus groups in which information is presented by project sponsors and discussed in a public forum. At the village level, community meetings may be supplemented by simple written materials posted on bulletin boards.

Expected Benefits of Enhanced Information Disclosure

Greater transparency and information disclosure in public procurement are important to reduce corruption and control costs. A key element of ACAP will be the analysis of unit costs across projects, subsectors, and areas of the country. In addition to publishing the data quarterly, the availability of these data will (a) enable the analysis of possible anomalies or unexplained differences in prices for comparable items and (b) provide a base-line (which does not now exist) to track movements in unit costs over time. Ideally, if other elements of ACAP are successful, there even could be a reduction in unit costs as a result of greater attention being paid to those costs.

Regarding development effectiveness and the sustainability of project investments, the evidence is clear and compelling. *Projects initiated without community participation (1) are less likely to meet the needs of the intended beneficiaries and (2) are unlikely to be maintained.* The second is due to both the lack of ownership by the affected community and the absence of a community-based organization (CBO) tasked with managing and maintaining the relevant assets. In fact, *many of the projects in the current water sector portfolio involve rehabilitation of earlier projects that failed due to a lack of participation.*

Finally, carrying out consumer surveys and citizen report card exercises and publicly disclosing the results should go a long way to strengthen the community demand for accountability and responsiveness by service providers.

Taken together, the proposed enhancements to the availability of information in the public domain should have a noticeable and positive impact on development effectiveness in Yemen's water sector.

Bargaining

12

Water Allocation Conflict Management: Case Study of Bitit, Morocco

Rachid Abdellaoui

The Bitit irrigation perimeter is a small-scale irrigation system built in Morocco at the start of the twentieth century by farmers and managed by them.† The system lies at the foot of the Atlas Mountains at an average altitude of 600 meters above sea level, midway between the cities of Fes and Meknes. As farmers have put land and water to productive use, there naturally have been conflictual situations. An interesting dimension has been the emergence of markets for water rights as a means to bring transparency to bargaining for water. Water rights have mitigated conflicts over water for two constituencies:

- Among Bitit irrigation water users
- Between these irrigators and the water utility, RADEM, which supplies water to Meknes.

The Irrigation System and Its Evolution

State of Water Resources

The Bitit irrigation perimeter is fed by three perennial springs (table 12.1).

In the early 1980s, Morocco experienced a series of severe drought years. The government created 3 boreholes in the Bitit area to extract approximately 120 liters of water per second (l/s) to serve potable water needs. As a result, the perennial springs have witnessed lowered discharges.

† Adapted by the editors from a background paper prepared for the "MNA Development Report on Water: Water Conflicts and Their Management Mechanisms in Morocco," CEDARE Cairo, 2005.

Table 12.1 Three Perennial Springs That Feed Bitit *(l/s)*

Spring name	Estimated discharge during summer , 1974–79 *(l/s)*	Estimated discharge during summer, 2005 *(l/s)*
Sidi Tahar	1850	1450
Si L'Mir	120	0
Sbâa	600	400
Total	**2570**	**1850**

Appropriation of Land and Water

At the start of the last century, land and water were exploited collectively by the Bitit area's population, mainly as rangeland. The resources were plentiful, and each household had more land than it could exploit. Excess water discharges from the springs fed into the adjoining marshlands, causing malaria to become a common health problem in the Bitit community.

However, by the 1920s, through both natural population growth and the growth of commercialization, pressures on land and water resources began to increase. The French colonial administration had two goals. On the political side, it intended to keep the peasants from joining the nationalists, who had become very active in both Fes and Meknes. On the economic side, the French meant to encourage market linkages for these rural communities.

In the mid-1910s, the French had promulgated laws to place water resources in the public domain unless they had been regulated by specific pre-existing water rights. Regarding Bitit, these laws established equal sharing of water between upstream (politically active Ait Ouallal) and downstream (less politically active Ait Ayach) communities. Later, group and individual water rights were recognized and recorded. Both land and water then became private property that could be sold to both nationals and French private settlers.

However, the nearby city of Meknes had growing demand for water and the local farmers resisted attempts to expropriate their rights. In 1949 a special decree fixed the share of the Public Domain of Bitit waters at 60 percent of availability, leaving only 40 percent of the water to the farmers. There was strong opposition from the latter. As compensation, the French offered to construct the main canal of Bitit, to reduce infiltration rates in the existing earthen canals (thus "justifying" the 60 percent reduction in water rights), and to improve public health by reducing malarial mosquitoes. The canal was constructed by 1954, after which 400 l/s were diverted for the potable water needs of Meknes.

By the 1970s, Morocco was an independent country, but government decisions continued to respond to urban needs. Meknes needed more water, and water available in the public domain was estimated to be 1800 l/s (in peak irrigation season). However, there was still a need to avoid social unrest in the countryside. To justify the diversion of just an additional 400 l/s, the government undertook a rehabilitation project by which many more kilometers of earthen irrigation canals (*seguias*) were lined to reduce water infiltration losses, and thus compensate beneficiaries for the additional water diversion. By August 2005, although the municipal water demand had drastically increased, the overall water sharing had not changed. Meknes continues to divert 800 l/s, leaving the rest of the water resources with the farmers for three reasons, one political and two technical:

1. On the political side, farmers' opposition to further diversion of water to which they considered they had water rights
2. On the technical side, (a) the Office National de l'Eau Potable's (ONEP) using better drilling technology to enhance Meknes' water supply with approximately 1200 l/s, and (b) higher treatment costs for the spring waters during the rainy season when they had high quantities of suspended matter.

Table 12.2 summarizes this evolution of water allocations.

Irrigation Canal Network and Water Shares

The main canal, constructed in 1953, starts at the spring of Sidi Tahar. The canal feeds five large main seguias and several smaller ones before discharging downstream in Ait Ayach lands. All main seguias were lined in the 1980s. The subsequent rehabilitation of the irrigation network necessitated two developments:

1. Construction of proper diversion and discharge partitioning structures
2. Fixation of the seguia on which individual water rights could be exercised led to the computation of the design discharge of the seguias.

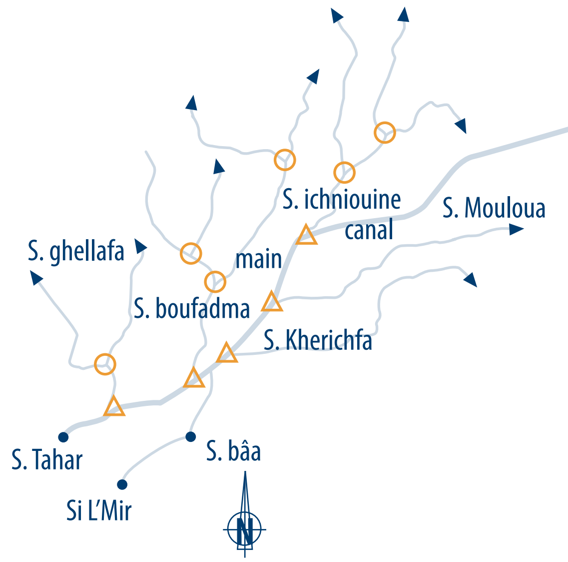
Table 12.2 Evolution of Water Allocations in Morocco, 1920s–2005

Period	Groups of shareholders	No. of shares	Total discharge *(%)*	Water right discharge *(l/s)*	Discharge actually diverted *(l/s)*	Important event/comments
Early 1920's	Béni M'tir (Ait Ouallal)	48		2,420	2,420	Start of appropriation (by peasants) of waters and land previously collective
	Chorfa et Regraga	8		403	403	Intensive pressure on land and water by French settlers
	Caid	3.5		176	176	
	Total	59.5	100	3,000	3,000	
Around 1925	Ait Ouallal	24		1,210	1,210	Laws of 1919 and 1924 related to water and definition of water domain
	Ait Ayache	24		1,210	1,210	Ait Aiyache—downstream users of Béni M'tir
	Chorfa et Regraga	8		403	403	Individual appropriation of land and water
	Caid	3.5		176	176	
	Total	59.5	100	3,000	3,000	
1949	Ait Ouallal	24		484	1,210	
	Ait Ayache	24		484	1,210	Ait Ayache being downstream, they are probably not diverting all their right
	Chorfa et Regraga	8		161	403	
	Caid	3.5		71	176	
	Total	59.5	40	1,200	3,000	
	Public domain		60	1,800	0	Vizirial decree of November 23, 1994 (Official Bulletin of 30 December 1949)
1953–54	Ait Ouallal	24		484	1,049	Construction of main canal to compensate for the water appropriated by the public domain
	Ait Ayache	24		484	1,049	
	Chorfa et Regraga	8		161	350	
	Caid	3.5		71	153	
	Total	59.5	40	1,200	2,600	
	Public domain		60	1,800	400	Water is effectively diverted to Meknes
1983–88	Ait Ouallal	24		415	714	Rehabilitation of irrigation system consisting essentially of lining main seguias to compensate for additional 400 l/s diversion
	Ait Ayache	24		415	714	With creation of modern discharge partitioning structures
	Chorfa et Regraga	8		138	238	Small reduction of spring discharge
	Caid	3.5		60	104	
	Total	59.5	40	1,028	1,770	
	Public domain		60	1,542	800	Diversion to Meknes of an additional discharge of 400 l/s
2005	Ait Ouallal	24		298	424	Large reduction of discharge of various springs
	Ait Ayache	24		298	424	
	Chorfa et Regraga	8		99	141	3 tube wells with total discharge of 120 l/s are created.
	Caid	3.5		44	62	
	Total	59.5	40	740	1,050	
	Public domain		60	1,110	800	

Actual measurements conducted after the rehabilitation project showed that water losses in irrigation canals effectively dropped from approximately 1.21 l/s/100 meters to 0.9 l/s/100 meters of the seguia. The farmers immediately recognized the benefits of lining the seguias, particularly as the overall network was very long. They also recognized the importance of concrete diversion structures that prevent water theft.

Figure 12.1 is an approximate drawing of the irrigation network with seguia names.

Figure 12.1 Bitit Irrigation Network with Seguia Names



Source: Author.
Note: Scale = 1: 70,000.

Table 12.3 gives the breakdown of shareholders' water rights by group of shareholders and by main seguia. The shares indicated in table 12.3 assume continuous water discharge of a water modulus.[1] The modulus varies depending on the spring discharge and thus the season.

Field measurements conducted in 1987 indicated a variation of the water modulus ranging from 25 l/s to 35 l/s with an average of 30 l/s depending on the seguia and the precision of the flow-partitioning device on the main canal. Presently, farmers estimate that the water modulus is only approximately 20 l/s, which correlates perfectly with the reduction in spring discharge since then. In 1987 the total available discharge to peasants was approximately 1770 l/s, which, divided by 59.5 shares, equaled a water modulus of 29.75 l/s. In 2005 the figures were 1050 l/s and 17.65 l/s, respectively (table 12.2). For example, Seguia Boufadma carries 9 water modulus (which summed to approximately 270 l/s in 1987, but now sums to only 160 l/s in peak-use periods) (table 12.3).

[1] The bulk elastic properties of a material determine how much it will compress under a given amount of external pressure. The ratio of the change in pressure to the fractional volume compression is called the bulk modulus of the material. http://hyperphysics.phy-astr.gsu.edu/hbase/permot3.html

Table 12.3 Water Shareholder Groups and Shares of Ait Ouallal by Main Seguia

Group of shareholders	No. of shares	Guellafa	Boufadma	Kherichfa	Moulouya	Tichniouine	Roz	Batbatia	Taoujdate	Tighza	Total
Ait Moussa Hammi + Ait Akka	8		4			3	1				8
Ait Rbaa	4		2			2					4
Ait Ali Boubker	4	4									4
Ait Brahim	4			1	2					1	4
Ait Ammar	4			2	2						4
Chorfa et Regraga	8	4	1					2	1		8
Caid	3.5	1.5	2								3.5
Total shares (water modulus)	35.5	9.5	9	3	4	5	1	2	1	1	35.5

The irrigation turn duration originally was computed for each shareholder to receive the total water discharge of the seguia during a full day. For example, the households of Ait Moussa Hammi and Ait Akka villages originally numbered 52. Thus, their irrigation rotation on Boufadma followed a 52-day cycle, and each household received a 4 water modulus, totaling a discharge of 120 l/s every 52 days. As the water rights process fragmented due to population growth and demand grew because of crop intensification (as with the introduction of summer vegetable crops), the irrigation frequency had to be increased. Consequently, over time, the water turn duration was reduced (table 12.4).

To avoid having 6.5 days of irrigation turn and facilitate water distribution by making the rotation weekly, in 1990 rights were recomputed proportionally. Presently, farmers' water rights are expressed in

Table 12.4 Evolution of Irrigation Turn Duration over Time (Ait Moussa Hammi and Ait Hakka), 1940s–1990s

Period	Length of irrigation turn *(days)*
Until late 1940s	52
Until late 1960s	26
Until late 1980s	13
Since early 1990s	7

hours: In 2005 a farmer who owned 1 hour of water actually possessed 3600 seconds * 20 liters/second, that is, 72 m^3 every irrigation turn (= rotation) of 7 days.

Cropping Pattern

In the early 1980s, the total useful area of the Bitit irrigation system was estimated at 5000 hectares (ha). Of these, approximately 2000 ha were irrigable (900 ha during the summer + 1100 ha during winter). Since then, following many stone-clearing operations, the arable land has greatly increased.

The preferred winter crops are cereals (primarily wheat planted in November and harvested in June), which receive supplemental irrigation if necessary. Ninety percent of summer crops are vegetables and tobacco. Orchards (mainly apples) have been abandoned due to low water availability.

Tobacco acreage has decreased, and tobacco is kept only as an alternative crop to reduce farmers' risk. Potato acreage also has decreased. Some farmers switched from summer production of potatoes (planting in March, harvesting in August) to seed production of F1 and F2 generations (planting by mid-August, harvesting in January at the latest).[2] Onions are a popular crop. They are planted in March and harvested by mid-August, followed by seed potatoes. These crops appear to be the best combination that matches seasonal demand for water with existing market conditions.

Irrigation System Management

Traditional organization to manage conflicting interests

Bitit's irrigation system is managed by traditional organizations at the main seguia level. Before the start of each cropping season, after Friday prayers (which time was chosen to ensure maximum attendance), the shareholders of the seguia gather in a general assembly to take decisions to reduce potential conflicts among members:

a. Shareholders elect a certain number of *waqqaf* (type of ditch rider) members. This task has the highest priority.

[2] F1 and F2 refer to foundation seeds for potatoes of good quality.

b. After this vote, and with the expert assistance of the waqqaf, shareholders establish the *Jrida* of the seguia. This is a full list of the individual shareholders and their irrigation time durations, together with the exact location of the fields that each shareholder would like to irrigate in the forthcoming season.
c. Last, the shareholders agree on the water distribution sequence during each irrigation turn.

The number of waqqafs will depend on the number of shareholders, the length of the seguia, and the degree to which irrigation land is dispersed along the seguia. In 1987, 5 waqqafs were elected to manage Seguia Boufadma (270 l/s at that time).

The waqqaf members are required to live in the village, have an extensive knowledge of field locations and water rights, and fully understand the spatial and temporal water distribution logic of the seguia. These persons therefore allocate their time to irrigation management and also are available at any time day or night. An implication is that waqqaf members tend to own little land and usually have either none or very few water rights. In 1987 each irrigator in the villages paid each waqqaf 300 DH/year for 24 hours of water rights, which corresponds to 12.5 DH/year/hour of water right.

The first task of the waqqaf is to help to establish the Jrida during the general assembly and to work on it later until it is complete and exact. This process usually takes time as:

a. The number of shareholders is very large. Therefore, it is not feasible to list all of them during one two-hour general assembly.
b. Many of the small shareholding farmers often are not at the assembly, requiring the waqqaf to contact them later at their homes.
c. Some transactions on water rights are not resolved immediately. Additional time is needed to make sure that no mistakes are made.

The *Jrida* is of paramount importance because it is the *basic management framework* through which water allocation and distribution rules are established. Although the process of establishing/operationalizing the Jrida may seem to be and is challenging, the waqqaf usually is able to complete the process before irrigation season begins.

The waqqaf uses local knowledge to simplify the Jrida. Irrigation quarters of variable acreage and limits are defined, to which one irrigation modulus (*fess*, literally "a hand of water") is allocated. Usually, this process requires defining turns among the various field intakes. Topography, water rights, cropping patterns, and conflict reduction are the key criteria in determining the rules.

The Jrida system is very flexible. It fully incorporates irrigators' concerns by ensuring that allocation rules for each quarter are transparent for that irrigation season, including after crops are progressively harvested. Once the Jrida is established and the first irrigation turn is executed, the waqqaf's responsibilities are reduced. The waqqaf has made every farmer aware of who his predecessors and successors are in the rotation process. Because the irrigation turn is exactly one week in length, the rotation is perfectly fixed. Each field receives the water on a given day at a given time for a given duration.

However, problems do arise during the irrigation process that require waqqaf intervention. For example, while transplanting onions, farmers need low discharges (half of the water modulus) and can irrigate only during daylight hours. They often seek the waqqaf's help with these specifics. Besides the irrigation management responsibilities, the waqqaf must manage conflicts among irrigators, particularly accusations of water stealing by irrigators.

Modern WUAs continue to work according to traditional norms

In December 1990, Law 2/84 (published in May 1992) established the rules by which water user associations (WUAs) (Associations des Usagers des Eaux Agricoles, or AUEA) are to be created and managed. The law also listed the benefits that WUAs could be expected to receive from government policies aimed at irrigation system rehabilitation/improvement.

In 2005, there were 5 WUAs in Bitit (1 for each of the 5 main seguias). All of them were created under the framework of Law 2/84. Nevertheless, old practices of the traditional organizations continue to dominate. While previously the waqqaf was earning 13 x 24 x 12.5 DH = 3900 DH/year, it now earns 7 x 24 x 30 DH = 5040 DH/year. When adjusted for inflation, the amount probably is very similar. Moreover, if the rotations are more frequent, they also are shorter.

Conflicts over Water

Conflicts over water among farmers

Water conflicts are very rare because both traditional and legal water allocation and distribution rules are perfectly clear and well established in writing. In addition, concrete discharge partitioning structures leave very little space for arguments.

According to Ait Ouallal farmers, conflicts arise primarily when irrigators resort to water theft. For example, at the start of an irrigation season, water is relatively abundant, and farmers may overestimate the acreage of summer crops that they may be able to irrigate satisfactorily. Later, climatic conditions change, particularly when very hot and dry easterly winds known as *chergui* raise temperatures for several consecutive days during the peak growing months of July and August. Under these circumstances, to save their crops, irrigators may resort to water theft. The role of the waqqaf is to watch for such transgressions and enforce penalties on these irrigators.

Tubewells play an important role in supplementary irrigation. Through tube wells, irrigators can meet any unexpected demand for irrigation water during the peak crop demand period without resorting to water theft. The farmers usually buy tubewell water on a volumetric basis.

A recent proposal by a mineral water bottling company to purchase water rights (see further developments in this text) has caused disagreement among farmers. They all want to sell their water to the bottling company but cannot agree on how much water each one would be allowed to sell.

Conflicts over water between farmers and the municipal water agency of Meknes

The Régie Autonome de Distribution d'Eau de Meknes (RADEM) is the municipal water management agency of Meknes. Ait Ouallal farmers complain about the way that RADEM handles the diversion of the 800 l/s directly from the Sidi Taher Spring. The spring is protected by a concrete structure with a metallic door that has a single key kept by 2 guards hired by RADEM. Farmers are forbidden from verifying the discharge that is effectively diverted. The diversion takes place literally behind closed doors, and no flow measuring device is installed other than an imprecise concrete weir with a height that can easily be modified.

Ait Ouallal farmers allege that RADEM is diverting more than its share, particularly during the peak summer season. Ait Ouallal farmers insist they will not accept further diversion of "their" water, whether or not authorities consider it part of the public domain. The farmers are adamant that RADEM should purchase water from them.

Effects of Water Markets on Women

In Morocco, women can inherit property rights. The fact that water is a marketable good has been a factor in promoting the status of female household heads, because women without access to enough labor for irrigated farming can sell their water. Farmers sell the usage of water for one irrigation season if they need money or if they do not have the resources (labor and/or money) to grow irrigated crops themselves. While property owners are attached to land and sell it only as a last resort, there is much greater willingness to sell water rights, because they are a renewable resource.

Water market in Bitit

In Bitit, water has been a freely marketable good since the early 1930s. More importantly, water rights can be sold independently of land. Farmers like to say that water is "single," that is, it is not "married" to the land it irrigates. Water is a free good that can travel to any field provided it does not move to a main seguia other than that on which the water right is registered. In other words, water rights are tied to a given main seguia. This customary law does not pose a constraint because there is much more land than water, and seguias are designed to transport their full discharge over their total length. As discussed below, water prices become a good mechanism to allocate resources efficiently and minimize conflicts.

Water prices

The price of water can give a good idea of the efficiency of its use.

Annual rights

In 1987 the price of 24 hours of water right was 5000 dirhams (DH)/ year. In 2005 the price of 1 hour of water right skyrocketed to 1400 DH/year. Water is valuable only from mid-March to mid-October

Table 12.5 Price of Water, 1987 and 2005 *(DH/m³)*

Year	Price of 1 hr of water *(DH)*	Actual water modulus *(l/s)*	Corresponding vol. every irrigation turn *(m³)*	Turn duration *(days)*	Length of irrigation season *(days)*	Total seasonal volume *(m³)*	Price of water *(DH/m³)*
1987	208	30	108	13	210	1745	0.12
2005	1400	20	72	7	210	2160	0.65

(7 months). The prices of a cubic meter (m^3) of water in 1987 and 2005 have been computed in table 12.5.

The price of water over the past 18 years thus has been multiplied by a factor of 5.4. The computations in table 12.5 assume that water is plentiful during the winter season (mid-October to mid-March). If, however, the rains have become less plentiful—as they have—and the irrigation season longer, then the increase in the price of water is not as great as shown in table 12.5.

The official average annual inflation rate in Morocco during the last 18 years has been approximately 3 percent. Accordingly, prices should have increased by a factor of approximately 1.7 during the period 1987–2004/05. In comparison, from 1969–2005, the water tariff in the Tadla large-scale irrigation system varied as shown in table 12.6.

Table 12.6 Comparison of Water Tariff in Tadla Irrigation System, 1969–2004 *(DH/m^3)*

Year	1969	1972	1980	1984	1985	1987	1988	1990	1991	1992	1995	1996	1997	1998	1999	2000	2001	2004
DH/m^3	0.024	0.024	0.048	0.079	0.090	0.100	0.100	0.120	0.120	0.150	0.160	0.170	0.180	0.180	0.180	0.180	0.200	0.220

While the water prices in Tadla and Bitit were similar in 1987 (0.1 DH/m^3 and 0.12 DH/m^3, respectively), in 2004–05 they differed substantially (0.22 DH/m^3 and 0.65 DH/m^3, respectively). The price increase in Tadla from 1987 to 2004 was substantially below the increase observed in Bitit. One could conclude that the free water market of Bitit enabled taking into account the greater scarcity of water over time and consequently its higher value.

Tubewell water also can be purchased from AUEA for 40 DH/h of 20 l/s. The corresponding price is thus 0.55 DH/m^3, slightly less than the surface water price.

Who sells/buys water?

Annual rights

Farmers think that the water right they own is never sufficient because this resource, rather than the land, is the binding constraint on production. Usually, those who possess 2–4 hours sell their water. Those who possess more than 4 hours either sell their water or buy more water to extend their farming operations. Thus, *selling and buying water is very common practice.*

Permanent rights

Selling permanent water rights is still quite rare. Each year, only 50–60 hours of permanent water rights are sold, and usually by those who own very small time shares—so small (usually 10–30 minutes) that it is not profitable to retain the right. Rarely does anyone owning more than 3 hours sells his/her water right.

Few shareholders buy water rights. Their strategy is to look for small shareholders and progressively concentrate water property by hourly purchases. The advantages of concentrating water property are reflected in prices; the smaller the share, the lower the price per hour. Ten minutes can be purchased at less than 7000 DH/h (half the normal price). Thirty minutes costs 10,000 DH/h.

In this way, one powerful farmer has accumulated 100 hours of water rights. To ensure a reliable cash flow, he can profitably sell 50 hours for 70,000 DH/season. He himself can use the remaining 50 hours.

Net benefits from a cubic meter of irrigation water to grow onions

According to Ait Ouallal farmers, 1 ha of onions necessitates a water right of 10 hours for at least 4 months (April–July). This purchase amounts to 10 h * 3600 s/h * 20 l/s / 1000 l/m^3 = 720 m^3 every irrigation turn of 7 days. Over 4 months (17 turns), the crop water requirement is 12,340 m^3. Apart from irrigated water, it costs on average of 30,000 DH/ha to produce onions. The average yield is 50 metric tons/ha.

The onion selling price is highly variable (table 12.7). Farmers remember an exceptionally good year (1992) when onions sold for 5 DH/kg!

One bad selling year, the farmers had to feed onions to their cattle because the price was too low. The milk ended up smelling of onions! With the benefit of irrigation, farmers estimate that, on average, the net benefit (receipts minus expenses) from onions is 30,000 DH/ha. This net profit corresponds to a water productivity of 30,000/12,340 = 2.43 DH/m^3 of water, and a profit of 2.34-0.65 = 1.78 DH/m^3 net of the price of water. Farmers remark that 1.78 DH/m^3 is higher than the lowest price that potable water is sold for in Meknes.

If risk were not an issue, Bitit farmers should plant as many onions as possible because they look very profitable on average. However, in case of over-production, farmers risk losing profitability. In addition, the quantity of water used to produce

Table 12.7 Onion Price, 2000–05

Year	DH/kg
2005	2.5
2004	0.2
2003	3.0
2002	3.5
2001	1.5
2000	1.5

onions is very high. Logically, farmers should switch to a more efficient, on-farm water application type of irrigation, that is, from surface to drip irrigation. Farmers recognize that, under drip irrigation, onion yields double, while water consumption is almost halved. The water saved could be either sold or used to increase the irrigated acreage.

These arguments are not convincing to farmers because they are particularly afraid of onion over-production. They prefer to cope with price variability by reducing risks and balancing their cropping pattern. Farmers have developed specific strategies such as, "If March is dry, the onion season will be good."

It would be very interesting to further study this question. Nevertheless, the price of water at 0.65 DH/m^3 appears affordable compared to its productivity (2.43 DH/m^3).

Alternative Markets for Water

Municipal water

The municipal water market is one alternative. According to farmers, so far the municipal water agency of Meknes (RADEM) does not appear interested in buying water from them as long as its water needs (approximately 120,000 m^3/day) are covered by the 800 l/s of spring water plus the additional tubewell water it buys from the Office National de l'Eau Potable (ONEP) at approximately 3 DH/m^3. However, population growth is expanding demand for municipal water. Moreover, supply alternatives are becoming limited. Finally, aquifer levels fall every year while pumping costs increase. Farmers think this ever-growing demand may influence RADEM to enter into negotiations with them.

To date, the balance of power is with RADEM. Farmers accuse RADEM of inefficient management, specifically, of having very low water efficiency in its conveyance and distribution to urban consumers. According to the farmers, a large water leak can be observed close to the municipal water intake from Si Tahar spring. Farmers believe that RADEM does not sell municipal water in Meknes at a high enough price to create incentives for efficient use.

Farmers' feelings are a mix, first, of apprehension of RADEM trying to appropriate more water from the springs, and, second, of hope that RADEM will buy water from them at a market price. If the Vizirial decree of November 23, 1924 is invoked, their apprehension of additional water diversion by RADEM is not unwarranted.

Mineral water

Recently, in 2004, a mineral water bottling company proposed to buy water from Bitit farmers at 40 DH/m^3. In the first stage, the factory would treat 40 l/s, which will be doubled in a later stage. This deal is seen as exceptionally good since a 1-hour water right corresponds to a monthly revenue of approximately 7,000 DH. However, farmers face two challenges.

1. Securing the authorization from the Sebou River Basin Agency to finalize the deal. Securing this authorization is not straightforward. Article 9 of the Law 10-95 of August 16, 1995 indicates that

   > "…irrigation water rights can be sold with, and for the benefit, of the land it irrigates, or independently from the land but only under the express condition that the buyer owns land to which the water rights will be linked."

   Bitit farmers believe that their water rights are not linked to any agricultural use of waters and that they are free to sell their water to consumers willing to pay the acceptable price. From their point of view, Law 10-95 is prohibiting maximization of water productivity and should be revised or better interpreted.
2. Securing an agreement among farmers on how to work out a group contract since every shareholder wants to sell his or her water right to the company.

At present, farmers have almost stopped selling irrigation water rights among themselves because they believe that much better prices could be obtained from RADEM, or perhaps a mineral water company

Conclusions

Three important lessons from the Bitit irrigation system are of relevance to those who manage large-scale irrigation systems and to others who are in charge of water resource management in Morocco and even throughout the MNA Region:

1. A *clear water allocation rule*, internalized at the *farmer level*, is the basis for any good water management practice. *Transparency* in as-

signing water appropriation rights to farmers is the simplest water allocation rule to reduce conflicts.

2. The *free water market* of Bitit has contributed to *keep water rights updated*. Small water shares could be sold or hired, and consequently put to their highest economic use. Similarly, a free water market is the most effective way of keeping a clear water allocation rule *updated*. This rule is the cement that links the water users and keeping their association alive and active. What might have happened over time if water rights were not a marketable good?
3. Free water market is certainly equally contributing to the search for *increasing productivity of water.* A water price of 0.65 DH/m^3 is a good indicator. It is as much as 3 times the tariff of water in large-scale systems (Tadla, for instance). A net benefit of approximately 2.63 DH/m^3 also is higher than the more modest values encountered in large-scale systems. However, application efficiency of water remains very low in Bitit. Why farmers are not improving their water application efficiency is a question that remains to be tackled. One would expect a rapid development of trickle systems, especially because they are heavily subsidized by government.

13

How Did a Small, Poor, and Remote Rural Village in Djibouti Recently Become a Government Priority to Receive Water Supply and Sanitation?

Sarah Houssein, in collaboration with Julia Bucknall and Nathalie Abu-Ata

The case of Goubeto village in rural Djibouti illustrates the important role of local and traditional authorities, in the absence of state intervention, in solving conflicts through negotiations over the allocation of scarce water resources among community members.[†] Moreover, as a consequence of the severe and worsening water supply and sanitation crisis, progressive loss of traditional values, and rise of the previously marginalized voices of youth and women, an inclusive and participatory new structure was able to emerge and make water for their village a priority for the central government.

Goubeto was established in 1910, first as a maintenance facility for the railway under construction between Djibouti and Ethiopia, and later as a train station depot. The village is not connected to the national road network and, except for Djibouti city, is far from any major cities. Goubeto is 71 km from the city of Ali-Sabieh, which is the district capital. Primarily former railway workers and their families, along with settled nomads, inhabit Goubeto. The climate is arid and hot, and the village is poorly endowed with water resources. Goubeto's water reservoir has a maximum storage capacity of 200m^3 per month. The reservoir's capacity is dependent on the regular provision of fuel for pumping, which is subject to a quota and is delivered from Ali-Sabieh.

Until the early 1980s, villagers received potable water from Djibouti city, and trucks supplied the precious resource twice a week. Accord-

---

[†] Background Paper for 2007 "MNA Development Report on Water."

ing to the villagers, at that time, there were no major conflicts over the allocation of water. Attracted by the reliable water supply and the availability of basic social infrastructure, nomads, who had lost their livestock as a result of severe and frequent droughts, progressively settled in the village. The settlement of nomads was further encouraged by the construction of a well in 1980, which supplied Goubeto with a certain amount of bulk water once a month. Water thus played a critical role in the growth and expansion of the village.

However, beginning in the mid-1980s, water supply in Goubeto became erratic and scarce, in particular during the hot summer seasons, due to population growth and the lack of proper maintenance of water infrastructure. As a result, conflicts over water allocation flared on occasion between the settled populations and the nomads as well as among settlers themselves. For example, nomads would tamper with the water reservoirs and canals and collect the water without prior agreement with local villagers.

Traditional authorities, such as the village chief or the community of elders (*Conseil des Sages*), played a critical role in efforts to mediate and solve these conflicts. The Conseil des Sages also oversaw repairs of tampered water infrastructure and made decisions on water allocation. However, because of its physical remoteness, the village of Goubeto was never a priority for the central government. Technicians were rarely sent from the central government to Goubeto to perform routine maintenance on water infrastructure. In spite of the involvement of traditional authorities in solving conflicts over the use of water, the community of Goubeto lacked the knowledge, financial capacity, and political connections to find a long-term solution to its intermittent water supply.

In the late 1990s, as a result of worsening water quality, poor sanitation and hygiene, recurrent droughts, and malnutrition, an epidemic of diarrhea broke out, killing 12 people. The deteriorating water quality clearly posed a serious environmental threat to the residents. Some of the villagers decided to take action and lobby the central government to obtain public assistance and funding to improve the water supply and sanitation systems. The fact that the villagers supported the political opposition provided another incentive for the government to react quickly to the rapidly deteriorating environmental health situation in Goubeto.

As a result of the above developments, a water association was created in 2004. It serves as the interface between the central government and the various communities in the village. The association

includes a broad representation of local stakeholders, including elders and delegates from youth and women groups. A project to drill a new well 1 km from Goubeto is underway, and it will be powered by a solar energy system.

Goubeto offers a useful case study that illustrates how traditional authorities can play a critical role in providing water to local communities. However, because of the physical remoteness and political seclusion of the village vis-à-vis the central government, the traditional authorities were unable to significantly influence decisionmakers, nor could they count on the availability of decentralized local water institutions. This dynamic changed with the lobbying pressure imposed by the villagers and with the consequent establishment of a new village water association. Empowered by an externally funded project on environmental health, the villagers were successful in initiating the necessary links between the communities and the State.

14

Water Conflict in Yemen: The Case for Strengthening Local Resolution Mechanisms

Christopher Ward

Yemen has one of the world's lowest rates of per capita freshwater availability (135 m^3/cap/year) in the world.[†1] The climate is largely semi-arid or arid. Rainfall is abundant only in the southern uplands. Rainfed agriculture is also possible in the central highlands and escarpments, usually with supplementary water management techniques. Annual rainfall is as low as 100 mm–300 mm in most of the north and east and in the coastal plains. There are no perennial rivers. Water comes from springs, seasonal spate flows, runoff, and groundwater.

Historically, Yemenis have been adept at managing their water. They have used elaborate systems of terracing and runoff management, spate diversion, and shallow groundwater management, according to the nature of the resource and the local social organization. Elaborately negotiated systems of rules and organization accompanied the development and management of each water resource. Even so, frequent disputes arose. These were resolved by force of arms, local reconciliation procedures, or traditional judgment.

---

† Background paper prepared for the "MNA Development Report on Water," 2007.

1 This chapter draws on a background chapter prepared by Said Al-Shaybani and Abdul Salaam Al-Zubayri, "Water Conflicts: Taiz and Tuban Case Study," as well as on previous work of, and conversations with, numerous colleagues including Said Al-Shaybani, Gerhard Lichtenthaler, H.E. Professor Mohammad Al-Eryani (Minster of Water and Environment, Republic of Yemen), Daniel Varisco, Nina Scherg (GTZ), and Robin Madrid (NDI). Thanks are also due to Jonathan Puddifoot, Gareth Richards, and Adam Taylor-Awny of CARE. The author is grateful for the guidance and comments of Khaled Abu Zeid and Amr Abdel-Megeed of CEDARE, Cairo; and of Julia Bucknall, Nathalie Abu-Ata, and Mesky Brhane of the World Bank, Washington, DC.

In the latter half of the twentieth century, outside forces began to influence these water management customs. These included supply-side forces such as innovations in spate irrigation technology and the irruption of the diesel-powered tubewell. New demand-side forces included the rapid development of market-driven agriculture, an increased consumption of water by households and industry, and a very fast rate of population growth.

For years, government policies encouraged development of the resource. Now, virtually all of Yemen's water resources are in use. This rapid development has brought considerable growth to Yemen, particularly to the agricultural sector (box 14.1), which uses some 90 percent of the total available water resource. However, water demand is still rising; nonrenewable groundwater is being mined; and competition is intensifying among users at the local level and between town and country. Yemen's central governmental structures are weak and uncertain. The decentralized traditional governance frameworks are facing novel problems. For these reasons, competition has translated into conflict. This chapter examines the nature of this conflict and investigates the ability of Yemeni society to contain it (Ward 2000; World Bank 2005).

Supply and Demand

Societies developing their water resource have a range of supply and demand management solutions that can be deployed. In Yemen, the supply-side solutions have been largely exhausted, and the only additional developments being made are of meager and marginal resources. For example, wastewater reuse is locally important for periurban production around the few towns that have sewerage plants. However, quantities of wastewater are very small so it is unlikely to be a major source of additional usable water. Numerous small dams are being built with government money to control seasonal wadi flows. However, this program is socially contentious because of the inevitable redistribution of water among communities within the basin. Moreover, this program is of uncertain economic benefit due to its high evaporation rates and sometimes little evidence of improvement in water availability and control, or of incomes (Iskander and Ueda 1999; Lichtenthaler 1999, 10).

As water becomes scarcer, the economics of water harvesting have improved slightly. For example, restoration of terraces can be profitable if *qat* is grown. Other examples are the revival of runoff and cistern and tank systems, often for potable water, as groundwater sources dwindle. Some communities are resorting to increasingly marginal systems such as fog harvesting. On the supply side, interbasin water transfer, extraction of very deep groundwater (over 1 mile down), and desalination are the last—and hugely costly—solutions available. However, in such a poor country, these are a planner's pipe dream.

Despite being faced with growing water constraints, Yemen has done little to contain demand. In recent years, the government has reduced the economic incentives for water development. However,

Box 14.1 Scarcity, Conflict, and Adaptation in the Sa'ada Basin

Over the past 30 years, the already very dry Sa'ada Basin in Northern Yemen has experienced a huge population explosion. In 1975, 40,000 people lived n the basin; by 1997 there were 180,000. The population increase was due to natural growth, returning migrant workers, and internal in-migration in response to economic opportunity

Much of this opportunity has been in agriculture. Interest in it initially was sharpened by the government crackdown on smuggling (previously a major income source) after the unification of the country. Returnees from the Gulf[1] brought capital in search of investment opportunities, and investment in the land suited the traditional values of this tribal region. Government improved agricultural profitability with a fruit import ban, so that orange and pomegranate farming looked to be an attractive investment. More recently, soaring qat demand has made this crop very attractive to farmers.[2]

Profitable growth of agriculture was based on the rapid development of groundwater. In Sa'ada, until the 1970s, most land was communally owned grazing land. However, the runoff rights from this land belonged to individual proprietors in the bottom lands. Agriculture was not allowed on the grazing lands because it would impair the runoff. Therefore, tubewell irrigation could not develop on the slopes. However, a deal was negotiated that allowed the tribal owners of the pasture rights to convert half of the slope land to agriculture on condition that the owner of the runoff rights was compensated with the same right on the other half. In 1976 a local cleric promulgated this as a *fatwa*, and the rule change has been followed ever since.

With the growing profitability of agriculture and the availability of remittance capital, this proposition was attractive. Many tribal communities privatized their common lands and distributed these lands to each household. Private tubewell development took off.

These changes in the economic incentives and institutional framework for farming have driven very rapid economic and social change in the Sa'ada area. A new elite of commercial farmers has emerged. Land and water resources have been widely redistributed by market forces. Qat (previously scorned by proud tribesmen as "the tree of the devil") is being planted on a wide scale.

Continued on next page

Box 14.1 Scarcity, Conflict, and Adaptation in the Sa'ada Basin *(continued)*

As a result, the water table has plummeted, and springs have dried up. Conflicts over water and land have become more bitter. These tensions may be spilling over into the growing fundamentalist sectarianism and civil strife in the region.

The Sa'ada story is a remarkable example of economic growth, aided by the capacity to adapt to market opportunities by changing the rules about farming the slopes. However, communities in the region have not yet shown a comparable "downside" capacity to adapt to scarcity. There is growing awareness of the problem but little expectation of equitable or tribal solutions. "Tribal communities and villages are not yet addressing the groundwater problem cooperatively." (Lichtenthaler)

Source: Lichtenthaler 1999.

Notes:

1. "The potential effects of the expulsion of over a million Yemeni workers from Gulf Cooperation Council states in retribution for Yemen's support of Iraq during the 1991 Gulf War immediately increased Yemen's population by 9 percent" (Millich and Al-Sabbry 1995, 1).

2. "Because the qat (*Catha edulis*) plant produces alkaloid stimulants, perhaps 75 percent of Yemeni adults chew qat leaves each afternoon, for a period lasting at least five hours. People spend about 25 percent–34 percent of their cash income on qat (Weir 1985). …The wealth generated by qat for its cultivators has undoubtedly stabilized the rate of rural-to-urban migration at around a 7 percent annual growth rate since 1970 (World Bank 1993)" (Milich and Al-Sabbry 1995, 1).

the government has shied away from strict application of economic measures to manage demand, such as energy and water pricing or the development of water markets. The 2003 Water Law introduced a range of regulatory demand management measures, such as water rights, licensing, and regulatory control.[2] However, for the present, these are generally beyond the capability of the Yemeni administration to implement.

Technical solutions to reduce demand also are available. Some, such as PVC piping, have attained wide currency through the market. Government is promoting others, such as drip and bubbler micro-irrigation, through cost-sharing programs. Farmers have eagerly switched to higher value crops, including citrus, mangoes, and qat. Further intensification, for example, through greenhouse technology, is possible, but market profitability is not assured. In some areas, only qat provides high enough returns to justify additional investment in expensive water saving (Bazza 1999; Katariya 1999).

[2] For details on water laws and regulations in Yemen, see chapter on comparative water laws in this volume.

Scarcity

Not surprisingly, Yemen shows proof of water scarcity. The rapid depletion of groundwater is well documented. Many wells have dried up, and groundwater salinization and pollution are worsening as aquifers are exhausted. In many areas, drawing down groundwater dried up the springs.

Changes in water and land use have affected historical patterns of wadi flows and groundwater recharge. Many downstream communities now have less spate flow and groundwater than they had a few years ago.

With less water available, many farmers and communities feel the pain. The economic and social impacts of scarcity are unevenly distributed. The process of "resource capture" involved in uncontrolled drilling and extraction of groundwater and in the "race to the bottom" of the aquifer has led to the economic marginalization of those unable to compete in power and money. Small farmers, poor downstream communities, and women and children bear the brunt of scarcity (Lichtenthaler 1999, 7; Al-Shaybani 2005, 10).

Some farmers' responses to scarcity were mentioned above. Economizing through intensification is their typical first response (Moench 1997, 10). Some farmers turn to purchasing water or return to traditional water harvesting, as in the Sana'a Basin (Lichtenthaler 2003, 54). At a certain point, leaving the farm is the only option. In the Sa'ada Basin, many farmers who lived where groundwater levels had fallen more than 50 m have abandoned their farms. Some have sold the rights to the sand under their farms to building contractors (Lichtenthaler 1999, 10). Sometimes whole communities have disappeared: a village in Jabal Eial Yazeed district was abandoned due to lack of water. There are reports of villages in Abyan and Lahej disappearing and of a steady rhythm of depopulation in Hajja (Al-Zubayri 2005a).

Conflict and Adaptation

Managing conflict is crucial for Yemen. Conflict, the subject of this chapter, is only one of a range of responses to water scarcity and the most disruptive. With increasing reports of conflict (Ward 2005), water scarcity in Yemen is reaching a critical point at which it might not only constrain economic development but also threaten social stability. Thus, an examination of how conflicts are resolved is important.

However, conflict is a symptom, not the issue. Finding long-run economic and institutional solutions to the underlying problems is the key to both avoiding and resolving conflicts.

Turton (1999) sees responses to scarcity and conflictual situations as a test of "adaptive capacity": the ability of a society to accommodate change by adjusting rules. Some observers have traced evidence of adaptive capacity in Yemen. Turton and Lichtenthaler (2002) found that

> "…there is a vibrant indigenous culture (in Yemen) embracing a traditional value system…. . …adaptive capacity [may be] present in a form…capable of resisting resource capture if correctly harnessed."

Certainly, Yemen has a long history of conflict and of subsequent accommodation of change. In 1970, the early period of modern groundwater development, the tubewell was bursting into the finely balanced water economy of Wadi Dahr close to Sana'a. Wadi Dahr had a long, well-documented history of managing its water resource (box 14.2). A downstream community in the wadi complained to the court that upstream motor pumps had reduced the stream flow and disturbed "laws and customs…by which we have been guided for thousands of years" (Mundy 1995).

However, this rhetoric was disingenuous. As Mundy (1995) amply records, the history of water management in the Wadi Dahr has been marked by conflict and contentious judgments, which have progressively crystallized into "established tradition" (Mundy 1995, 110). Wadi Dahl's conflict also got resolved—but not by the courts. The rich and

Box 14.2 For Centuries, Strict Rules Have Governed Water Management in Yemen's Wadi Dahr

In the tenth century CE, the geographer al-Hamden wrote:

> "In the irrigation system of Wadi Dahr, the fields are irrigated one after the other. Once, some of the guards of the Sultan diverted the stream to the Sultan's vineyards without the knowledge of the irrigation turn keeper (*daily*). The *daily* then destroyed all the vines, but the damage to the property of the Sultan did not dishonor the *daily*. Indeed, if the *da'il* was not just in his duties, he was hanged."

Source: Mundy 1989, 99.

influential downstream farmers simply invested in the new pump technology themselves. "The stream dwindled and died, but no one with influence any longer cared." A new equilibrium emerged: assets were rebalanced and concentrated a little more in the hands of the richer. The conflict was resolved—even if not fairly—and a new "established tradition" emerged (Mundy 1995, 116).

Rules Governing Water

Government as a Rule Maker

The capacity of the Yemeni government to affect outcomes in the water sector is restricted by its weak technical, administrative, and enforcement capacity. Nevertheless, the government has played a critical role in setting the economic rules for water development and management. These economic rules have changed over time.

During the early period of the modern state (up to 1990), government was able to promote development of water supply by setting the price of diesel, credit, and other inputs low; and by directing public and donor investment into rapid development of the water resource. A permissive attitude toward qat and the ban on fruit and vegetable imports increased farming profitability. Government thus was able to achieve three major objectives: expanding irrigation and thereby legitimizing itself, raising farmer incomes, and consolidating its alliances with many important power groups. By contrast, these same public policies penalized the traditional water harvesting and rainfed systems of the poor.

In a second period (to 2000), signs of water scarcity were beginning to emerge. Government responded to these with at least five demand management measures: increases in the diesel price (that rapidly were overtaken by inflation); elimination of credit subsidies for agriculture; modification of the fruit and vegetable import ban; regulation and taxation of groundwater equipment; and projects to support increased water productivity in agriculture.

Since 2000, it has been clear that measures taken to date are inadequate to deal with the problem of water scarcity. Reluctant to use the levers such as diesel pricing[3] that could really influence out-

[3] In the 4th quarter of 2007, before the fuel price increases of 2008, the domestic price of diesel in Yemen was 20% of the free market benchmark price (World Bank 2009).

comes, government increasingly has turned to promoting water use efficiency through projects and to regulatory approaches. The 2003 Water Law defined water rights and instituted a system of licensing. The National Water Resources Authority (NWRA) was empowered to work with basin committees, local authorities, and local communities on regulatory and self-regulation approaches. So far, the impact of both the projects and NWRA's outreach programs has been limited. One bright spot is that the case studies discussed below show that in some areas, particularly nontribal areas, NWRA may be called in to arbitrate disputes.

Local Rules for Water Management

Over millennia, every community in Yemen has evolved rules for water management. Archaeology attests to rules for spate management in the pre-Islamic period that are recognizable today. Some water rules of today were documented in medieval times (Breton 1999, Al-Eryani and others 1998). These customary rules—*'urf*—are generally consistent with the *Shari'a*. Al-Shaybani (2003, 23) records a *Document of Seventy Rules* drafted and signed by sheikhs three centuries ago to codify common understanding of customary rules. Historically (but much less so today), religious authorities were important in setting rules and determining disputes. Some principles of the *Shari'a* affecting water are generally accepted throughout Yemen:

- Water is *mubah*, or "the property of no one." However, the usufruct can be appropriated by those who develop it.
- Upstream riparians have priority: *al 'ala fa al 'ala*.
- Water may not be alienated from the land.
- Wells must be spaced a certain distance apart, outside a "protection zone," or *harim* (Rule 58 in the *Document of Seventy Rules*).
- No one can deny a person drinking water—"the right of thirst."

The specific rules attached to each water source vary across the country. In *spate irrigation*, priority is given to upstream diversion structures. In most systems, the water channeled off at the diversion structure flows down from field to field. The water is released from the higher field when that field has "drunk"—this may be when the water has filled the field up to the height of a man's knee or higher (Maktari 1971). In subsequent floods, the round may start with the last field left unwatered previously, as in Wadi Zabid (box 14.3). In some schemes, canals may carry the water to farther fields. When the canal crosses the fields of others, a fee is payable. Additional diversion structures downstream may receive water only when the upstream structure is breached, which in the case of traditional structures is a regular occurrence. Alternatively, there may be rules that a proportion of each flood must pass down (Al-Shaybani 2005), or that the water in different periods is allocated to downstream diversion structures (as at Wadi Zabid, box 14.3). In Wadi al Jawf, the spring spate is allocated to one bank and the summer spate to the other.

Box 14.3 Wadi Zabid Downstream Farmers Conflict with Upstreamers

Water in Wadi Zabid's spate system is managed according to rules devised over six centuries ago by the Moslem scholar, Sheikh Gebrati. The rules are based on "upstream first": *al 'ala fa al 'ala*. The rules divide the waters among three "regions." In the dry season, there are base flows only. They go to the upper region. In the rainy season, when the floods come, the spate is divided among:

- Upper region: First 97 days
- Middle region: Next 20 days
- Lower region: Last 35 days.

The channel master allocates water to plots and decides which plot will get irrigated first by the next flow. The rule is: "Not twice in 14 days." The channel master collects charges proportional to the irrigated area. The rate is lower in the middle area, and negligible in the lower area.

Prior to 1973, many conflicts over water distribution were recorded. The conflicts claimed several lives each year. When a World-Bank-financed project modernized the system in 1973, the situation became better for all. Water control improved, and the state enforced water discipline.

After 1985, matters deteriorated. The fruit import ban changed incentives, and the upstream farmers planted bananas, which needed irrigation every five days. There was also some expansion of the irrigated area upstream. Even some lands in the upper region no longer got base flow due to the demands of the bananas and to illegal diversions by big landowners. "Daily conflicts over water" were reported. Small farmers lower down were forced to sell and to become sharecroppers.

Source: Al-Eryani and others 1998.

Box 14.4 Bloody Conflict between Traditional Wadi Al Jawf Spate Rules and Modernization

In the 1980s, the World Bank financed a project to develop farming in wadi al Jawf, a border province with an historical centrifugal tendency and characterized by strong tribal values.

The major component was to improve spate irrigation in the wadi. Traditionally, the first spate season (*seif*) was allocated to the tribe on one bank, and the second season (*kharif*) to the tribe on the other bank. However, maintaining this distribution would have made for a very expensive project, as very large canals would have been needed on either bank. Instead, an agreement was made with the relevant tribes that, in future, each spate flow would be divided 60:40, roughly the historic ratios of the spring to the summer flood. The World Bank appraisal mission got confirmation of this agreement from the tribal sheikhs, and the project went ahead. A contract was let and the contractor mobilized.

However, the tribe that was to receive the lesser share changed its mind. The first night after the contractor had mobilized, the tribe brought up guns and shelled the contractor's camp. The contractor demobilized at once; the contract was cancelled; and the project quickly ended with minimal disbursement.

Source: Ward 1994.

Clearly, the rules for spate are highly evolved and locally differentiated. Al-Shaybani (2005, 25) lists 18 different rules that may govern spate water distribution in different systems. However, it also is clear that the unpredictability of spate events, progressive changes in wadi morphology, and information asymmetry between upstream and downstream rightholders create a rich arena for misunderstanding and dispute (box 14.4) (Dresch 1993; Maktari 1971; Varisco and others 2005).

In *springs,* which have more stable flow regimes, rights normally are attached to the land. The rights are denominated in time-shares, for example, a certain number of hours once a fortnight. In Wadi Dahr, rights to spring water were divided exactly between lower and upper communities: 15 days each (until the springs dried up). These block allocations then were further divided within each community according to time-share ownership rights. These rights could be exchanged with other users to suit farming needs. Water distribution was overseen by local irrigation supervisors, not sheikhs, although sheikhs ruled in disputes (box 14.5) (Mundy 1995, 23, 62).

Box 14.5 Sheikhs Adjudicate a Water Dispute in Wadi Dahr

A farmer was accused of moving a stone and deflecting the water flow of the spate course. The case was solved by traditional judicial means. Guarantors for each side agreed to hold their parties to any agreement. The sheikhs, assisted by the *amin* (legal clerk) and a surveyor, found that the claimant was in the right. The settlement was accepted by all parties (Mundy 1995, 64).

Runoff rights are assigned from specific slopes to parcels of bottom land in a proportion—sometimes up to 20 times the area of bottomland—adequate to grow a crop on the run-on land. These runoff rights are very important. It is claimed that, in Sa'adah, houses have no cisterns for domestic water because the cisterns would infringe the runoff rights of others (Lichtenthaler 2003, 51).

Every landowner has the right to abstract *groundwater* by digging under owned land. There are some traditional rules over access, for example, *harim* well-spacing rules. However, no traditional rules exist for quantities extracted or water charges (Al-Shaybani 2005, 3). In parts of Northern Yemen, shared wells are common. Each group of irrigators works out its own rules for sharing capital and operating costs and for taking water turns—usually a time-share. Rules governing water sales are unclear. In some localities, water sales between farmers are common. In other locales water may be sold to outsiders, and become a business. Many wells near cities, including Ta'iz and Sana'a (which gets two-thirds of its water from private wells), are wholly or partly converted to urban water supply for profit (box 14.6) (Moench 1997).

Factors Underlying Conflict

Conflict over water in Yemen is nothing new. Lichtenthaler (1997, 73) records that "until the mid 1970s water scarcity in Sa'ada was at the heart of most tribal conflict." In fact, groundwater seemed to offer a way out of old patterns of conflict. Groundwater freed farmers from tedious and risky cooperation for a very limited, fixed resource by offering an apparently unlimited new source. Ironically, it is this very freedom that is driving a new generation of conflicts (Al-Shaybani 2005; Lichtenthaler 2003).

Box 14.6 Growing Water Sales around Ta'iz Raise Equity Questions

In the Ta'iz area, a widespread response to water scarcity has been the emergence of informal water markets. Local farmers needing water may purchase it from adjacent well owners, or purchase tankers from farther afield to apply it sparingly to the highest value crops such as qat. The cost is huge, and farmers are charged more—more than $\$1/m^3$—if the crop is qat.

For Ta'iz city, a large fleet of private tankers lines up at the wells around the city that have converted from agriculture to water supply, generally because of these wells' proximity to the road. Domestic and industrial consumers or the numerous bottling shops around town then pay the tanker owners for supplies delivered to their door.

Although doing so seems to run against Islamic principles, these water sales underline that water has become an economic commodity in the area. However, the fact that well owners sell at low prices to neighbors for agriculture and at much higher prices for the tanker market does seem to reflect the recognition of the traditional principles of local cooperation over water.

As water sales become more common with the growing water scarcity, communities and government are giving thought to how water markets could be made equitable and less opportunistic.

Source: Moench 1997.

Types of Competition

Fast-rising demand and no new supply are creating intense competition characteristic of scarcity. This section discusses some types of competition for scarce water.

A classic form—*upstream/downstream competition*—has taken on a new form as upstreamers have employed new technology to capture more water (box 14.7). For example, the very poor farmers in the Tehama Plain have seen not only surface water but also groundwater recharge diminish, as spate-fed and pump-fed schemes have been developed (Dresch 2000, 138; van Steenbergen 1997, 106). Similarly the many small dams now being constructed throughout the highlands are changing the upstream/downstream distribution of water (Katariya 1999; personal communication from Gerhard Lichtenthaler).

The advent of the tubewell intensified *competition for groundwater*. Apart from local restrictions on well spacing, groundwater in Yemen is an open-access resource. To establish ownership, it is enough to drill a

Box 14.7 Upstream Prospers but Downstream Area Desolate in Wadi Bani Khawlan

The upper part of Wadi Bani Khawlan in Ta'iz Governorate is covered with crops and lush fruit trees. The lower area of the wadi, once also a rich agricultural zone, is now desolate. Dry wells dot the fields. In some areas, pipes still cross the ground ready to transport water to waiting fields, should water somehow return to the wells. In most areas, however, the pipes have been removed—sold since they no longer serve any purpose. Where wells still operate in the lower wadi (mostly at points at which minor side wadis enter the main one), women wait for 6–7 hours daily to fill up plastic containers of water for domestic use. Most men have migrated in search of work. A few remain, spending their time and the remittance money sent by others in the small dusty stores that are remnants of more prosperous days in the valley.

Source: Moench 1997.

well. Thereafter, the incentives are competitive exploitation and the "race to the bottom." Farmers are only now coming to understand that, depending on the shape of the aquifer and the gradients and rates of flow, over-pumped tubewells will dry up one another and also may dry up hand-dug shallow wells (Dresch 2000, 165–67).

There also is *competition between groundwater and surface water.* Hydrological connectivity means that overuse of groundwater can deplete springs. This fact has been documented for many areas of the highlands and for the southern uplands. Conversely, upstream diversion of surface water or runoff can reduce infiltration of groundwater for downstream users.

With the effective privatization of the entire water resource, *competition between well owners and the rest of the community* is growing. The well owners get the benefit of groundwater from the aquifers, but the whole community must pay in terms of water scarcity and rising costs. Particular tension is emerging between farmers and community drinking water needs. The drying up of wells is reimposing on women and children the *corvée* of the daily trudge to and from more distant wells for drinking water. In some places, water shortage is constraining certain crafts including tanning and leather working (Varisco and others 2005,11).

All of Yemen's growing towns are desperately short of water. Fierce rural-urban competition has taken hold over water resources in the urban environs, often becoming violent. Water in the periurban zone

Box 14.8 Urban Water Tactics Dry up and Pauperize Al Haima

Twenty-five years ago, lower Al Haima wadi was a vibrant agricultural community. Local inhabitants grew high-value fruit, vegetables, and qat. The Department of Agriculture ran a small horticultural station.

Now the area is dry. Dead trees surround the deserted agricultural extension office. Drying qat plants struggle to survive on water purchased from distant wells in tankers. Even drinking water is in very short supply. Children, women, and men travel long distances by donkey or camel to collect water at the few taps that still run.

The problem began in the early 1980s, when Ta'iz city drilled some wells and pumped out water from the valley for its urban water supply. The villagers were told that the new wells were in the deep aquifer, 500m down, and would not affect the shallow farm wells. However, people found their shallow wells drying up. Ta'iz city came in 1987 to drill more wells, but the villagers were refused permission to deepen their own wells. The locals stopped the city's drilling rigs by force of arms. The army came; the village men took to the hills with their arms; and five sheikhs were put in prison. Eventually, a minister came down from Sana'a and brokered a settlement.

By 1992, the villagers' wells were dry. They took up arms again and disconnected one of the water supply wells. Twenty truckloads of soldiers moved in. The President of the Republic intervened. The villagers were obliged to surrender their claims.

Sources: Moench 1997; World Bank 1997.

increasingly is a commodity for sale to towns. The same is true for the wells in al Dhabab that supply Ta'iz. In some villages, land and water sales have been prevented by community action. Generally, however, as is recorded for Sa'ada, well owners "form a dominant coalition that prevents others from blocking their sales" (Lichtenthaler 1999).

How Competition under Scarcity Turns into Conflict

As discussed above, conflict is only one possible outcome of scarcity and the pace of change. Under what conditions is scarcity likely to cause conflict?

Varisco (1983) argued that *predictability of the water flow* influences the level of conflict. Unpredictable flows such as spate give rise to intense stresses and conflict. Predictable flows such as spring waters do not—once the ownership and management rules are agreed. Varisco's argument corresponds to the historical facts. Far more conflict is recorded over spate than over springs. However, his explanation does little to explain the surge of conflict in recent years in nonspate systems.

A second factor that can affect the level of conflict is the *number of people sharing in the system*. Large systems of water-sharing among many irrigators generate more potential for stress at both the human and the hydraulic levels because individual control diminishes. By contrast, individual well systems involve only their owners.

A third factor is *visibility*. A moved boundary stone or a turn at a stream that lasts longer than agreed is a highly visible infraction. On the other hand, the depletion of an underground resource for which even the experts do not understand the hydrogeology and for which the pumps that are depleting the groundwater are on private land is hard to contest.

A fourth factor is the *degree of symmetry of cause and effec*t. Stealing a neighbor's water concerns only two parties. Depleting groundwater affects a broader community. However, in the latter case, a direct cause and effect relationship is not as discernible, and it is more difficult to claim harm to identified individuals.

Thus, it is not surprising that considerable conflict is reported over spate flows, but less over spring water. Until recently, conflict over groundwater was limited by the above factors, particularly visibility and symmetry. Now, however, rural people everywhere are aware that groundwater is a hydraulically connected and fast-depleting resource. Once the aquifer is fully developed, it becomes a zero-sum game. Every new well simply subtracts from the finite resource—and the wealth—available to existing participants. This growing awareness of the competitive nature of groundwater extraction has led to increasing conflict (previous section).

One additional important factor influencing whether conflict will develop is *power relations*. The groundwater problem highlights the unequal competition between large farmers, who have bigger land areas to drill over and more financial resources to dig wells; and smaller farmers, whose wells dry up or who find it harder and more expensive to access communal or third-party sources. In al Dumayd, a big trader established a 10-ha citrus orchard with 8 pumps. As a result, a number of wells in the vicinity dried up, and the farmers in the adjacent smaller farms were forced to abandon them. Conflict did not ensue because "the [small] farmers were aware that a big neighbour has no obligation to share" (Lichtenthaler 2003, 188) A similar situation exists in spate irrigation in which the "weak" tail-enders feel aggrieved but powerless to change things (case of Wadi Tuban Case Study D ahead).

There is some evidence that conflict is becoming more frequent. Certainly, tribal confrontations over water and land of substantial scale and intensity receive frequent notice in the Yemeni press (box 14.9). Government interventions also seem to be more common.

Public Intervention Also Can Provoke Conflict

The role of the state in Yemen has grown enormously in recent years. In the 1970s, much of the development of infrastructure and services was privately funded by community associations and philanthropists. These funding sources dropped away with the decline of remittances and the politicization of the community development movement.

Oil revenues now are centralized in government hands, and the growing volumes of donor aid are channeled through government. Consequently, the state has become the dominant investor in rural development. These interventions have not always had a positive

Box 14.9 Water and Land Disputes Leave Many Dead

"Six people were fatally shot and seven injured in tribal clashes in Hajja which broke out two weeks ago and continued till Tuesday between the tribes of al Hamareen and Bani Dawood. Security stopped the fighting and a cease fire settlement for a year was forged by key sheikhs and politicians, The fighting was triggered by controversy over agricultural lands and water of which both sides claim possession. Meanwhile…there is speculation of retribution attacks on government forces which used heavy artillery and tanks to shell several villages in al-Jawf…."

(*Al Thawra,* April 29, 1999)

"Sixteen people have been killed and tens injured since the outbreak of armed clashes between the villagers of Qurada and state troops, who used heavy artillery and rockets to shell the village.* Scores of villagers were arrested and hundreds fled their homes. The incident began when Qurada refused to share well water with neighbouring villagers…."

(*Al Shoura*, June 20–21, 29 1999)

Note: * = See more on the Qurada dispute in Case Study A ahead.

impact on water dispute and conflict (Varisco and others 2005, 12). *Many conflictual situations have been caused, at least in part, by public interventions*.

The development of upstream diversion structures on *spate schemes* in a series of public projects from the 1950s to the 1990s led to a de facto change in the spate water allocation rules (UNDP 1992, 106–07). More land is now irrigated at the head of the schemes and less at the tail. The negative distributional effect of this is stronger because the head-enders (for example in Wadi Mawr and Wadi Rima) generally are the better off, larger landowners. A survey showed that, for more than 80 percent of farmers in Wadi Rima, water delivery was not improved by the World-Bank-financed improvements (Al-Eryani and others 1998, 32). Instead, head-enders were able to take *all* of the base flow with impunity, increase their cropping intensity, and grow higher value crops, including the very water-intensive bananas, which require irrigation seven times a month.

Public interventions in *rural water supply and sanitation* also have created situations of potential conflict. Problems have included an approach to siting projects that focused exclusively on engineering issues while ignoring community wishes and existing tensions (Al-Shaybani 2005, 20), inappropriate technology imposed on the community, and little thought given to how subsequent operations were to be managed and financed. The principal causes have been the lack of community consultation and the inflexible, authoritarian approach of the implementing agencies, low professional standards, and alleged corruption. Changes underway to "demand-driven" approaches should help. However, there is a legacy of disappointed expectations, low or nonexistent service, and a potent brew of tensions that often explode into conflict (Al-Shaybani 2005: 12–14, 18).

The government-financed program for the construction of *small dams* also is creating many potential conflicts. Apart from the upstream/downstream stresses already mentioned, the poor performance of these dams creates conflictual stresses within the community and with government. Water quantities often have disappointed; siltation is very rapid; frequently no downstream development of irrigation canals has been provided for; and communities are not trained in operation and maintenance of the asset. The principal causes appear to be inadequate hydrological and engineering studies; an approach that focused exclusively on engineering issues and does not even ask how the water is to be used—sometimes it is not even

Box 14.10 Conflicts over Dam Construction in Hobah and Shahik End in Waste and Death

At Hobah in Al-Mahweet, villagers obtained a grant from USAID to construct the Al-Makik Dam. However, they made no prior agreement about who the beneficiaries would be. Downstream farmers who already were using the water proved unwilling to share in costs and management with upstream farmers, who intended to pump the water to lands previously unirrigated. As a result of the incomplete planning, the project comprised only the completed dam, which was not used. The irrigation area was not developed.

At Shahik in Khawlan Al-Tiyal district, disagreement over whether to use a new dam for groundwater recharge or for surface irrigation led to conflict in which one person was killed.

Sources: Vermillion and others 2004; Ward 2005.

clear which villages or individuals are the intended beneficiaries—and generally no provision for adequate upstream and downstream consultations (Al-Shaybani 2005, 20; personal communication from Gerhard Lichtenthaler).

Agricultural programs that have pushed farmers to invest in groundwater for cash crops are creating conflictual situations. The government's 30-year promotion in Sa'ada of oranges and pomegranates through subsidies and protection bound farmers to a huge long-term investment in tree crops. In many places, these trees now cannot be sustained by the water resource. A similar pattern is arising with the mango groves at Abs. Mangoes were promoted by the public subsidy for drip irrigation, but the water resource is rapidly disappearing. In time, the farmers are likely to engage in some form of conflict with the government (Bazza 1999).

Urban water supply. In the 1990s, the public utility aggressively transferred water from the southern end of the green al Haima Wadi to Ta'iz city. The ensuing drying up of that once fertile valley was a well documented national scandal. Since then, other communities in the Ta'iz region have fiercely guarded their water sources and chased off government prospectors. Government has learned the lesson and is trying other approaches. For example, government is using a form of contract in the Sana'a basin that is intended to reserve the deep aquifer for water supply, while giving farmers a free hand over the unconnected shallow alluvial aquifer.

Box 14.11 Wadi Habir Resists Surrenders Its Water to Urban Use but Is Defeated through Violence

In 1992 villagers in Habir discovered that their area had been proposed as the next source of water for Ta'iz city. They had seen the impact of water transfer on the neighboring valley of Al Haima so determined to resist. For three years, they succeeded in postponing the project. When the rigs finally arrived in April 1995, the Habir villagers drove the drillers off the site by using petrol torches. Their sheikhs were imprisoned. Eventually, a "compensation" package was agreed, so the villagers allowed the drillers in.

However, soon a farmer's shallow well dried up. When he was refused permission to dig a new, deeper well, the villagers again stopped the drilling for Ta'iz. When the army arrived, the women and children threw stones and tried to disarm the soldiers. The soldiers fired, and two women were seriously injured. Eventually, the wells were drilled, but with a legacy of distrust and anger that persists to this day.

Source: World Bank 1996.

Water Conflict Can Trigger a Larger Pattern of Conflict

Throughout Yemen, attachment to water and land is fierce and forms a central element of Yemeni identity.[4] Competition for these limited resources thus can quickly trigger a larger pattern of conflict. Yemeni rural society generally is arms bearing, and resort to violence is frequent. This is particularly true in the Northern Highlands, where tribal values of honor, shame, and revenge drive behavior, and where comparatively trivial origins can quickly escalate, especially when violence is employed. Socioeconomic factors also play a part: "unemployment and under employment mean many bored and frustrated young men sitting idle with their guns for much of the time, waiting for something exciting to happen" (Al-Shaybani 2005, 21).

These factors are less evident in the Southern Uplands and the coastal zones, in which the agrarian system has a more landlord/peasant character with roots in a feudal system (Carapico 1998, 67–68; Varisco and others 2005, 12). In these areas, tribal values are muted or non-existent. Here it is the intense economic competition for the resource that can lead to broader conflict. Varieties of competition include that

[4] Because water rights generally go with land, water and land disputes often are the same thing.

between large landowners and smallholders or sharecroppers, between town and country, or within communities over drinking water.

What Forms Does Conflict Take—and Why?

As background to this chapter, Al-Shaybani and Al-Zubayri (2005) carried out a field study of water conflict in Ta'iz and Lahej. The following four case studies from their findings illustrate many of the themes of this chapter.

Case Study A. Murderous Dispute over Spring Water Rights Is Resolved in Yemen's Highest Court

In 1997, a dispute over water arose between two villages on Jabal Sabr, the huge mountain that towers over Ta'iz city. The dispute lasted until 2001, left many dead, and had to be resolved in the Court of Appeal after the intervention of the army and the President of the Republic.

The story began in the mid-1990s, when one village—Qurada—received money from the government's rural water supply agency to rehabilitate the village piped water supply system. This system was fed from springs belonging to Qurada that flowed into a collection tank. However, the tank was sited uphill of a spring that belonged to a second village, al Marzooh. Al Marzooh became afraid that the project would reduce the flow of their spring.

In night raids, al Marzooh blew up part of the new project. The police made arrests, and the governor visited and ordered the project to continue. Al Marzooh responded by blowing up more installations and equipment. Soldiers sent in only exacerbated tensions (box 14.9). Although traditional mediation managed to get the case into court, the explosions continued. Gun battles left five dead (including one woman, a fact that really shocked the nation) and more than 20 injured. The situation got so out of hand that the President of the Republic intervened. Only then did both sides agree to go to court, from which the dispute rose all the way up to the Court of Appeal.

The final court ruling was accepted reluctantly on both sides. The villages were to construct one collective tank for their water supply. Qurada could connect a 4" pipe, and al Marzooh a 2" pipe, with a pro-rata reduction in supply in case of shortage.

It seems incredible that so much should be expended for such a seemingly small a problem. The *lessons* so dearly won were:

1. In some areas, water scarcity has reached a point that it is not agriculture but the much smaller quantities needed for drinking water that are under threat. Ta'iz Governorate essentially is a nontribal area, so the dispute was not inflamed by tribal values. Rather, the very high value that the two communities placed on drinking water made them prepared to resort to violence to defend it.
2. Public money, apparently allocated without proper understanding of the issues, was at the origin of the dispute.
3. Even when they were at each other's throats, the villages were highly opposed to outside intervention. When the army intervened, the villages effectively closed ranks against them. Ultimately, only the highest authorities in the land brought the villages to reconciliation.
4. The tensions around water are so great that traditional rules of mediation proved quite inadequate. Al Marzooh continued its assaults even while mediation was going on.
5. In the end, and only after extreme effort, the state was able to impose settlement in this water dispute. Mobilization on this scale is plainly out of the question for every 2" pipe dispute that may arise.

Case Study B. Two Village Water Committees Cooperate to Protect Their Resource—and Fight off Threat from Government Agency

In the very water-scarce Qadas area of Ta'iz Governorate, al Kareefah and al Dhunaib are neighboring villages. Each village has its own potable water scheme with its own management committee. Having seen the problems of water scarcity in other parts of Qadas, the two villages cooperate to protect the drinking water resource, which is their first priority.

The committees keep an eye on the activities of local farmers and have stopped the digging of many new wells. Armed with a permit from the NWRA branch office in Taiz, one al Kareefah farmer started to drill a new well. The al Kareefah water management committee entered an objection with NWRA, which then cancelled the permit. Another farmer, this time from al Dhunaib, failed to get a permit but started to dig a well anyway, stealthily by night. By the time the village found out, the well was more than 20 meters deep and lined with reinforced concrete. The farmer threatened to kill anyone who came close. The al Dhunaib water committee chairman convened a meeting of the whole community, and it was decided that the well should be filled in. Faced with this community solidarity, the farmer had no choice but to agree. The whole community took part in filling in the well.

Ironically, the committees had the most problem with the official rural water agency, the General Authority for Rural Water and Sanitation Projects (GARWSP). GARWSP started to drill a borehole in the catchment area of the existing drinking water schemes of both villages, and within 400 meters of an existing well. The committees pointed out to GARWSP that this proximity violated the 500 meter *harim* rule. Their protest fell on deaf ears. The two villages were on the point of resorting to violence to stop the contractor when it was learned that the new well was dry. GARWSP made a second attempt to drill, this time within 200 meters of the water source of al Kareefah and in the direct catchment area of Al Dhunaib's water source. This second attempt was met with armed resistance from both communities, and the contractor was forced to leave the area. The two committees then decided jointly to hand-dig a well for community use at the new site to prevent GARWSP from any future attempt to drill in this location.

The *lessons* are:

1. When water is very short, drinking water becomes the top priority for groundwater use, and communities show solidarity in setting up and running potable water schemes.
2. Community solidarity can influence or block even the most intransigent water users.
3. In situations of scarcity, cooperation among communities becomes possible.
4. Communities may deploy both traditional rules such as the *harim* rule and modern rules such as licensing to defend their water source.
5. Government agencies trying to help solve the water problem can create more problems than they solve. In this case, GARWSP's technical appraisal of the source was deficient. Furthermore, the agency totally lacked a "demand-driven" and participatory approach.

Case Study C. Dispute between Farmers Is Settled by NWRA's Proposal That New Well Be Used Largely for Drinking Water

A conflict between villagers from Al Sayani district of Ibb concerned a well drilled close to a neighbor's well without permission. The dispute started when a downstream well owner made a complaint to NWRA, asking that it stop a farmer who was digging a new shallow well upstream.

NWRA visited the site. Its team found that the new well was, in fact, close to *two* existing wells. The first well belonged to the complainant and was approximately 120 m downstream of the new well. The second old well belonged to the farmer who was digging the new well: it lay about 120 m upstream of the new well. The visit took place during the dry season, and all three wells were dry at the time of the visit.

Although the new well breached the 500-meter distance requirement under the *harim* rule, NWRA proposed that the well be regularized on condition that it be used only for the drinking supply of the villagers. Only surplus water during the rainy season could be used by the well owner for irrigation, and only on the condition that he paid the capital and operating costs of the well. This deal was agreed and confirmed in writing by all concerned.

This small case in which again the priority accorded to drinking water is clear demonstrates three important *lessons:*

1. The *harim* rule is being widely invoked as a useful rule of thumb to protect water resources. The potential of the new well licensing procedures being introduced by NWRA is beginning to be explored by villagers as part of their armory of water management rules.
2. Villagers may be willing to bring in NWRA as part of dispute resolution. This willingness is probably stronger in nontribal areas such as Ibb.
3. NWRA and the villagers proved capable of adapting the *harim* rule to suit local conditions and to reconcile the interests of the two parties and of the community.

Case Study D. Wadi Tuban Tail-Enders Say That Modernized Scheme Has Brought Them Less Water but That They Lack The Capacity to Fight for More

In the Wadi Tuban spate irrigation scheme, by law, an irrigation council composed of officials and representatives of the water user associations is responsible for deciding the rules of water distribution. These rules are quite precise (box 14.12). However, the field work done by

Box 14.12 Irrigation Council Water Allocation Rules

In theory, water allocation is to be based on a fixed irrigation plan:

- When the spate flow is low (5 m^3/s–15 m^3/s), priority is given to schemes in the upper part of the delta, namely, Ras Al Wadi and Al-Arais.
- When spate flow is of medium size (15 m^3/s–25 m^3/s), priority is given to schemes in the middle part of the delta, including Beizag and Faleg systems.
- When spate floods are high (25 m^3/s–40 m^3/s), the flow is directed at the main wadi bifurcation point at Ras al Wadi Weir: to either Wadi Kabir or Wadi Saghir, depending on which one's turn is due.
- When spate floods exceed 40 m^3/s, the flow is divided evenly between Wadi Kabir and Wadi Saghir.

Al-Shaybani and Al-Zubayri (2005) found that reality differed from theory.

Downstream farmers said that they used to have access to spate water on average once every two years. Now the interval is 5–10 years. These farmers believe that upstream farmers are taking more water than before thanks to improved concrete diversion structures and to the upstreamers' influence over the management agencies. The tail-enders believe that the traditional upstream first rule—*al 'ala fa al 'ala*—is abused by the big farmers upstream, who are expanding their irrigated areas, getting up to 4 floods in 1 year, and even planting bananas.

However, the downstream farmers have not lodged a complaint. The reason in part is that they are unsure which agency is responsible. They believe that, in addition to the Irrigation Council, the Ministry of Agriculture Irrigation Department and the new elected local authorities all have a say. They do not know to which agency or to whom to complain, nor what the rules and penalties are. They do believe that it would be a long and expensive (due to bribes) business to complain. They grudgingly accept that spate flows are uncertain and that spate water rights for downstreamers are hard to assert.

The case of Wadi Tuban reflects findings from previous studies in spate schemes. They showed that the benefits of spate improvement often go largely to the better-off upstream farmers. This case also shows other *lessons:*

1. The modernization programs that government has introduced have focused more on physical improvements than on strengthening management institutions. The user associations now being promoted in Tuban do not appear to have figured in the farmers' discourse, and certainly were not seen as powerful champions of their rights.
2. The old causes of friction regarding spate still exist. In fact, these frictions are built into a system with such uncertain water rights. At present, the power relations are such that downstreamers feel badly treated. Furthermore, they shrink from conflict with the powerful upstreamers.

Resolving Conflict

What dispute resolution mechanisms exist and how have they evolved to meet these new challenges?

Settling Disputes in Largely Tribal Areas

"Although it is important not to overemphasize the nature of tribalism, it must still be recognized as the major system of governance and community organization in most highland rural communities" (Varisco and others 1995, 12). In these tribal areas, sheikhs and tribal leaders still play a vital role in settling disputes. Elected officials also have tribal affiliations, so tribal and modern power structures largely overlap.

During a field survey, farmers in the Sana'a Plain were asked to explain the different mechanisms employed for resolving water conflict. The overwhelming majority of respondents (96 percent) said that water conflicts would be dealt with by local "arbitration systems." In other words, water conflicts would be addressed first by tribal arbiters at the neighborhood level. If not resolved at the first level, conflicts move to the sheikh at the head of the tribe. Most respondents said that only when a dispute could not be resolved through these procedures would it be referred to the courts. In general, respondents felt that the courts were expensive (largely due to bribes), slow, and remote from tribal concerns.

Al-Shaybani (2005, 22) argues that resolution of water conflict in tribal areas follows the same pattern as that of any other conflict. In a conflict, any respected person (*modareek)* can call a ceasefire. Then a mediation process takes place, often led by the clan head (*aqil*)) or the head of the tribe (*sheikh*), to agree the terms of a truce and to broker a settlement. In case of legal technicalities, a tribal specialist on customary rights and duties (*maragha*) can be called in. His decision is final.

In the past, the *sheikh*'s ability to mediate conflicts used to rest primarily on his social standing and on his knowledge of customary law. Over time, this has changed, as sheikhs have joined the political and economic elite of the country. It is now just as much the sheikh's status as a rich man and his political influence and power at the regional and national level that give him the authority to decide disputes (Lichtenthaler 2003, 74)

However, these additional sources of authority create a risk of conflict of interest. Sheikhs often are part of the problem because often they are the largest users of groundwater. Some sheikhs have become big commercial farmers and have benefited from their status in the tribe to build up large land holdings. In cases in Sa'ada, villages and communities have closed ranks to prevent their own sheikh from buying more land—and the water rights that come with it. Thus, while the cooperation of the sheikhs is crucial to conflict resolution in tribal areas, their role as big water users compromises their role as impartial mediators (Lichtenthaler 1999, 2, 14).

Tribal mediation also is limited by population movement and land sales. These days more than ever, villages may be inhabited by multiple tribes who do not cooperate. For example, villages in Amran often are inhabited by different branches of the great Hashid and Bakil confederations, and some by *sayyids* (religious scholars who have a knowledge of water rules) (Moench 1997, 16; Lichtenthaler 1999, 14). In addition, within one village, economic interests may be different—agricultural, artisanal, and domestic. These different interests can conflict and thus undermine solidarity.

Religious and cultural values play a role in reinforcing traditional dispute resolution mechanisms. These values recall principles of fairness, reconciliation, and integrity to a population still largely sensitive to these values. These values occasionally can be invoked directly in dispute resolution by the *sayyids*. Over the centuries, these religious scholars have been involved in the evolution of water rules. The recent revival of Zaydi scholarship and practice in Sa'ada has led to the emergence of a younger group of religious scholars and teachers. They invoke the Islamic principle of *maslaha 'amma* ("welfare of the community over individual interest"). It was a Zaydi scholar in Sa'ada who issued the *fatwa* on conversion of runoff rights in 1976 (Lichtenthaler 1999, 2–3, 18).

Settling Disputes in Other Areas

In nontribal areas of Yemen, traditional and modern community institutions exist for water management and for dispute resolution. These institutions can be highly evolved, as was shown by the management of spate in Wadi Tuban (Case Study D above).

In recent years, dedicated water management associations have emerged, most frequently for potable water supply. Some of these associations have grown into strong community institutions with a range of other activities, such as schooling, health services, rural roads, and water for livestock. The best documented example is that of the Administration of Local Projects of al Sinah near Turba (Moench 1997, 15). Water management associations focus on managing the water supply scheme rather than on the resource itself, However, most schemes are now experiencing problems with the source, as illustrated by the Qadas case above. Thus, the associations are obliged to become active in settling disputes over water resources. In some cases, associations—or the community at large—have organized themselves (box 14.13). Some have resisted new drilling. Others have prevented the loss of community water and land resources to the rich and powerful—traders, speculators, absentee landlords (Lichtenthaler 1999, 2).

Box 14.13 Sa'ada: Examples of Successful Community Initiatives

To safeguard their water resources, villages cooperate in a range of way to resist sheikhs, traders, and land dealers. Three examples follow.

- In one case in Sa'ada, fearing decline in groundwater levels, the tribal group refused the request from the community owning the runoff area to develop its groundwater resources. Now the sheikhs have agreed to a 20-year halt to any development of the land.
- In another area of Sa'ada, in consultation with the tribe, the sheikh ruled that no individual member was to sell land to people from outside the village. This community had seen what had happened when the neighboring tribe sold large amounts of land to investors, who then drained the area of groundwater.
- In several other cases in Sa'ada, villages and communities have closed ranks to prevent their own sheikh from buying land from them.

Source: Lichtenthaler 1999.

Modern Civil Dispute Resolution Mechanisms

Yemeni law provides for civil dispute resolution in courts. However, rural Yemen is generally mistrustful of outside involvement. Conflicting parties tend to close ranks in the face of it. No data exist on the actual number of water disputes referred to the courts. However, in the survey of farmers in the Sana'a Plain discussed above (Al-Hamdi 2000, 81), only 4 percent of respondents said that water disputes would be referred to the civil courts rather than to local arbitration systems. The proportion may be higher in nontribal areas that lack trusted local dispute resolution mechanisms. In Wadi Tuban, cited above, downstream farmers do not have much confidence in the capacity or probity of the courts either. A referral to the court is generally forced on the disputants by the civil authority, particularly for violence. If one of the disputants voluntarily refers a case, he generally does so because he sees it as a way to gain additional advantages.

Under the Water Law, NWRA has regulatory powers over water management. As a result, a number of disputes are now being referred to NWRA branches for a decision on the legality of well drilling and other issues. In four basins—Sana'a, Ta'iz, Sa'ada, and Amran—the central government has set up basin committees comprising representatives of central and local government and civil society. It is too early to tell whether this joint forum will be effective in imposing order on WRM. The new, elected local district councils have responsibility for all local affairs. NWRA's policy is to engage them in water resource regulatory activities. However, the little evidence that is available —for example, the local council involvement in spate water allocation in Wadi Tuban—suggests that this form of decentralization has multiplied, rather than solved, problems (Al-Shaybani 2005, 26).

In 2005, apparently alarmed at the prevalence of tribal disputes in general, the President of the Republic ordered a five-year truce. He established a National Supreme Committee for Dispute Resolution. This committee is chaired by a deputy prime minister and includes a large membership from the Cabinet, the judiciary, Parliament, and the sheikhs. Its mission is to put an end to tribal feuds through mediation. To date, there has been no indication of its effectiveness.

Power and Political Economy: Who Really Benefits from Water and How?

From the discussion above, it will be clear that *Yemen has moved a long way from the early Islamic moral economy of the "right of thirst*." Already in the nineteenth century, when the Ottomans installed the *iltizam* system of taxation of the agricultural surplus in the higher water- availability areas of the southern uplands and the eastern and southern escarpments and plains, control of water was readily identifiable with an accumulation of power. In these areas, it took a feudal form. Great sheikhs held sway over numerous tax-paying *ra'iyya,* or peasants. This system is still traceable in the pattern of land and water holdings in these areas (Carapico 1998, 67–68). In the dry north and east areas, scant water meant virtually no taxable surplus. In these areas, the warrior-farmer character of tribalism proved able to resist both Ottoman conquest and the imposition of centralizing tax transfers. The more egalitarian political economy of the tribe persisted until a generation ago.

Change in the use of water has brought profound shifts in economic and political power. In the *southern uplands*, the groundwater revolution is largely over. The process of appropriation of water by the locally powerful—and by the cities—has reduced the economic opportunities for small farmers. Appropriation is gradually returning most of these areas to the old rural ecology of rainfed agriculture. They have only sporadic access to supplementary irrigation and pumped drinking water. The political and social counterpart to this economic change seems to have given a new impetus to the civil society, local self-help mechanisms that have existed in the area for a generation or more. Associations of local people defend their communities' interests and conserve and develop what resources are available.

In the *coastal regions*, the brief improvement in the lives of downstream farmers that came with spate upgrading and the tubewell is dwindling as large upstream landholders appropriate both the surface flows and the groundwater.

In the *tribal areas of the north and east*, the end of the groundwater boom has left an impaired ecology of reduced groundwater and spring flow. These sources are less and less adequate to support the commercial farming that has developed. The available water and land resources have become more concentrated in the hands of tribal leaders. They have benefited from traditional patterns of loyalty and cooperation and from their access to the modern centers of political and economic power. A new class of capitalist investor/trader has sprung up, too. Those left out of this process have been the smaller farmers, who have seen the economic boom come and go in a generation. Among them, there appears to be a process of change, not yet radical, that consolidates resistance to further resource capture. Whether this resistance will have a political counterpart—for example, a distancing of tribesmen from their tribal leader—is far from clear.

These processes of capitalism and concentration of power have been readily abetted by the state through incentives for groundwater extraction and through direct investment. The rapid development of water resources helped to legitimize the state as a "development agent." Meanwhile, the more discreet underlying processes of accumulation of wealth and power through growing control of water and land have consolidated the important political support of the military and capitalist elite around the central state.

Lessons

Civil Society Lessons

Traditional Yemeni society and institutions have demonstrated considerable capacity to adapt to the changing challenges of water. The "upside" capacity to adapt to the changing supply and demand signals in the 1970s and 1980s was remarkable. Technology, farming systems, cropping patterns, and cultural and social attitudes adapted quickly to the market economy. Time-honored rules were adjusted; traditional institutions evolved; and new ones were established.

Naturally, the country's "downside" capacity to make the painful adjustment to scarcity, competition, and conflict has been more limited. Yemenis adapted rapidly to the tubewell but have had great trouble adapting to the resultant water stress and scarcity. Nonetheless, communities continue to evolve their own rules and have shown some ability to adapt to scarcity. Institutions have begun to adapt, and rules are being rewritten. The old harim rule on well spacing is now evoked almost everywhere to control new well drilling. Communities also may seek to restrict deepening, pumping time, or water sales. New users are being excluded by a variety of techniques.

In tribal areas, the ambiguous role of the sheikh is a problem. Nonetheless, even there, some communities have combined to neutralize the negative effects of the sheikh's business interests. In nontribal areas, community associations are commonly found, with varying degrees of capability to manage water resources and resolve conflictual situations.

Communities everywhere prefer to exclude government from their problems. This consensus is not surprising, given that government interventions frequently created rather than resolved conflict.

Government Lessons

The capacity of central government to regulate activities at the level of individual users is very limited. Typically, government intervention requires a show of disproportionate strength, justified only in extreme cases, after local dispute resolution methods have failed (Moench 1997, 3).

Government can best influence outcomes positively by broad policy and institutional measures. Good examples are the sectoral policy frameworks, and a few enforceable regulatory measures, such as the ban on import of drilling rigs (Norton 1995).

Government's move to improve the professionalism of its water management services by setting up NWRA and decentralizing its powers to local branches clearly was a step in the right direction. There is limited evidence that NWRA has helped in dispute resolution. The decentralization of some official responsibilities to the participatory basin committees and to the local authorities also may help. There is no reason to suppose that decentralized structures will be more efficient or less politically driven than centralized ones. However, the decentralization at least may back up the power of local communities to control abstraction and drilling (Lichtenthaler 1997, 11).

Evidence shows that it is not only scarcity, but also the supply side remedies introduced, that triggers conflict. Unfortunately, *government emerges as a leading source of conflict*. Some of this conflict stems from poor water resource decisions—particularly for projects based on inadequate understanding of the water balance or of water rights. Other conflictual situations arise from inadequate social and institutional preparation. Programs frequently fail to ensure that the community structure that can deal with planned changes is in place. In the most flagrant cases, government has ridden roughshod over all local understanding of water rights and appropriated the resource for transfer to the towns (World Bank 2005).

Looking to the Future

In the Yemeni context, the only viable solutions are local and participatory, initiated by the water users. Moench (1997) details the reasons that these solutions work:

a. Local people are the stakeholders.
b. Government can never have the capacity nor the full confidence of local people.
c. Every village has its own hydrology and history, and only micro-level solutions make sense.
d. It is not government but millions of individuals at the local level who take the decisions about Yemen's water management.

Clearly, *the future of water management and dispute resolution in Yemen depends on local institutions*. These institutions are creakily adapting to water scarcity. There is a role for government to lend a hand by supporting community self-management initiatives through education, training, and intelligent cost-sharing. Future government interventions must avoid creating new problems while trying to resolve others. To do so, government interventions in rural water and dams will have to be technically better prepared, demand driven, and negotiated by a more intelligent process that takes account of local social setups, institutional structures, and patterns of water rights.

Longer-Term Lessons

There is no "solution" to Yemen's water crisis. Given the population increases and lack of alternative employment opportunities, demand will continue to far exceed supply. The depletion of natural capital will oblige economic retrenchment, with painful political and social consequences. Managing the transition to extreme scarcity and avoiding conflict at the local level will be an obligation of all Yemenis. However, the government is responsible for mitigating the underlying causes of scarcity as much as possible and for planning for the longer-term structural transition of the economy.

- Government must pay attention to the uncompleted demand management agenda. In particular, readjusting the incentive system can reduce agricultural water use while equitably protecting incomes (Lichtenthaler 1999, 24; Norton 1995, 10–12)

- To replace the present ad hoc and arbitrary transfer systems, government needs to set fair rules for intersectoral transfer of water. These rules must require the development of equitable markets or other fair transfer mechanisms (Norton 1995, 13–14; Moench 1997, 4, 21).
- Government has to plan for a less water-intensive economy. The planning should include measures to ease the intersectoral movement of labor and to create an environment friendly to alternative economic activities (Norton 1995, 16).

References

Al-Eryani, M., and M. al-Amrani. 1998. "Social and Organizational Aspects of the Operation and Maintenance of Spate Irrigation Systems in Yemen." World Bank, Sana'a.

al-Hamdi, M. 2000. *Competition for Scarce Groundwater in the Sana'a Plain*. Delft: Delft University of Technology.

Al-Shaybani, S.R. 2005. "Conflict and Water Resources Assessment for al Jawf and Amran." Hydro Yemen for CARE/DfID, Sana'a.

Al-Shaybani, S.R., and A.S. Al-Zubayri. 2005. "Water Conflicts: Ta'iz and Tuban Case Study." World Bank, Sana'a.

Al Shoura. 1999. Article on deaths from armed clash between Qurada villagers and state troops over water. June 20–21, 29.

Al Thawra. 1999. Article on deaths from armed tribal clashes in Hajja over water. April 29.

Al-Zubayri, A.S. 2005a. "Abandoned Villages Due to the Shortage of Water." World Bank, Sana'a.

____. 2005b. "Water Conflicts: Field Visits Report." World Bank, Sana'a.

Bazza, M. 1999. "Technical and Economic Aspects of Water Saving." LWCP (Land and Water Conservation Project)/FAO (UN Food and Agriculture Organization). Sana'a.

Breton, J.-F. 1999. *Arabia Felix*. South Bend, IN: University of Notre Dame Press.

Carapico, S. 1998. *Civil Society in Yemen*. Cambridge: Cambridge University Press.

Dresch, P. 1993. Tribes, Government and History in Yemen. London: Oxford University Press.

____. 2000. *A History of Modern Yemen*. London: Oxford University Press.

Government of Yemen. 1995. "The Water Resources of Yemen." Report WRAY 35, MOMR and TNO, Sana'a.

Iskander, M., and S. Ueda. 1999. "Yemen: Preliminary Assessment of the Existing Dams." World Bank.

Katariya, S.R. 1999. "Improved Agricultural Practices in Sana'a Governorate." LWCP/FAO, Sana'a.

Lichtenthaler, G. 1997. *A Political Ecology of Water: Factors and Perceptions Influencing Groundwater in the Sa'adah Basin*. London: SOAS (School of Oriental and African Studies).

____. 1999. "Water Management and Community Participation in the Sa'adah Basin of Yemen." World Bank, Sana'a.

____. 2003. *Political Ecology and the Role of Water: Environment, Society and Economy in Northern Yemen*. London: Ashgate.

Maktari, A. 1971. *Water Rights and Irrigation Practices in Lahj: A Study of the Application of Customary and Shari'ah Law in South-West Arabia*. Cambridge: University of Cambridge Oriental Publications.

Milich, L., and M. Al-Sabbry. "The 'Rational Peasant' vs. Sustainable Livelihoods: The Case of Qat in Yemen." *Development* 3 (1995). http://ag.arizona.edu/~lmilich/yemen.html

Moench, M. 1997. "Local Water Management: Options and Opportunities in Yemen. Survey Report of the Decentralized Management Study." World Bank, Sana'a.

Mundy, M. 1989. "Irrigation and Society in a Yemeni Valley." *Peuples Mediterranéens* 46.

____. 1995. *Domestic Government: Kinship, Community and Polity in North Yemen*. London: I.B. Taurus.

Norton, R.D. 1995. "A Note on Economic Policies for Water Management in Yemen." World Bank.

NWRA (National Water Resources Association). 1999. "Water Resource Management Strategies in the Ta'iz Region." NWRA, Sana'a.

Turton, A.R. 1999. "Yemen: Water Scarcity and Social Adaptive Capacity." Water Issues Group, School of Oriental and African Studies (SOAS), London.

Turton A.R., and G. Lichtenthaler. 2002. "Natural Resource Reconstruction and Traditional Value Systems: A Case Study from Yemen." Occasional Paper 14. SOAS Water Issues Study Group, London.

UNDP (United Nations Development Programme). 1992. "Yemen: Water Resource Management and Economic Development." Final Report. High Water Council and UNDP, Sana'a.

United Kingdom Government. 1952. Report on the Abyan Scheme. HMSO (Her Majesty's Stationery Office), London.

van Steenbergen, F. 1997. *Understanding the Sociology of Spate Irrigation*. Arnhem: Academic Press.

Varisco, D. 2005. "Yemen: Sustainable Livelihoods Analysis." World Bank.

Vermillion, D., and S. Al-Shaybani. 2004. "Small Dams and Social Capital in Yemen." IWMI (International Water Management Institute), Colombo. www.iwmi.cgiar.org/index.aspx

Ward, C. 1998. "Practical Responses to Extreme Groundwater Overdraft in Yemen." World Bank, Sana'a.

____. 2000. "The Political Economy of Irrigation Water Pricing in Yemen." In A. Dinar, ed., *The Political Economy of Water Pricing*. London: Oxford University Press.

Weir, S., 1985. *Qat in Yemen: Consumption and Social Change*. London: The Trustees of the British Museum (British Museum Publications).

____. 2005. "Yemen: Proposal for a Study of Conflict in Water." World Bank.

World Bank. 1989. "Irrigation Sector Study." Report 8030-YAR. World Bank.

____. 1994. Wadi Al-Jawf Agricultural Development Project." Project Completion Report. Report 13822-ROY. World Bank.

____. 1996. "Yemen: Local Water Management in Rural Areas." Washington DC and Sana'a.

____. 1997. "Yemen: Towards a Water Strategy." World Bank.

____. 2005. "Yemen: Country Water Resources Assistance Strategy." World Bank

____. 2009. "Tapping a Hidden Resource: Energy Efficiency in the Middle East and North Africa."

15

Water Diplomacy in the 21st Century

N. Vijay Jagannathan

In many parts of the world, competition among countries for water resources is being exacerbated by population growth, urbanization, and industrialization. When water resources are shared across national boundaries, the challenge of sustainable management becomes even more complicated for several reasons. First, in the case of transboundary conflicts over water, international laws and conventions are not enforceable unless a process of ratification has been completed through national legislative bodies. Second, countries could cheat or not comply with water treaties unless these treaties are self enforcing. Finally, it would take just a small group of opponents of a water treaty to make any of these agreements "politically unacceptable."

In addition, two independent variables determine how countries interact when it comes to sharing international watercourses. First is the spatial configuration of the watercourse in relation to national boundaries: an upstream state has different incentives for cooperating compared to a downstream state. Dinar (2006) describes these as *through-border situations* in that the downstream state's ability to retaliate and reciprocate through its water policies to externalities created from the upstream state is minimal. Other situations exist in which externalities become reciprocal: any harm to an open-access resource (such as an inland sea, lake, or shared aquifer) affects all states that share this resource. Dinar terms these *border-creator situations*.

Second, relative political and economic strengths and weaknesses of countries that share the water resource influence their dealings with one another. If one state were far more economically advanced than its fellow riparians, its behavior would be influenced by the political and economic importance attached to maintaining and building on relations with its neighbors. On the one hand, a situation of complete asymmetry of economic power could tempt the powerful country to display "hegemonic" tendencies. On the other hand, trade and market protection considerations very well could induce the powerful hegemon to collaborate with its weak neighbor(s). Asymmetry in economic well-being also affects the way that countries view pollution. The capacity to accept pollution may be higher in a poor country than in a rich one, whereas the ability to mitigate the problem is the opposite.

When Do Bilateral Agreements Take Place?

Political, spatial, and economic interests propel countries to work out international water agreements with one another with or without an exchange of financial investments. When scarcity or degradation induces parties to coordinate actions, country-level interests could be congruent through a desire to negotiate and cooperate. Dinar analyzed the characteristics of these agreements and concluded that through-border situations carry a much greater likelihood of side payments or sharing investment costs from the downstream state to the upstream state.

The next paragraphs will discuss examples of situations in which a congruence of interests led to countries working out bilateral solutions to their water issues in the spirit of mutual accommodation. Typically, these solutions take place when the "low-hanging fruits" are obvious to all negotiating parties. For example, flood control and generation of hydroelectric power are obvious areas in which a downstream state perceives the need to cooperate. Iran paid Afghanistan; India has paid Bhutan and Nepal; the United States has paid Canada for hydropower, irrigation, and flood control.

There could be other examples wherein congruence of interests led to bilateral agreements. Table 15.1 illustrates some bilateral agreements among the Mashreq countries of the MNA region.

Challenge of Working through Bilateralism and beyond

However, for every successful treaty, there are many more situations in which mutually beneficial agreements are not concluded. These arise because there are many political, geographic, and economic considerations that lead to countries being either unwilling or unable to collaborate to share water resources. Typically, disagreements arise when countries assert their "rights" to water quantities. A downstream

Table 15.1 Disputes and Agreements in Mashreq Countries, 2008

Water conflict	Issue	Countries involved	Outcome
River Tigris	Irrigation in Syria with Tigris waters	Syria, Iraq, Turkey	No formal agreements as yet
Shatt al Arab River	Boundary demarcation	Iran and Iraq	1974 agreement by which the river is recognized as the boundary
River Euphrates	Sharing river for irrigation	Syria and Iraq	1990 agreement to share waters 42:58 between Syria and Iraq
River Orontes	Sharing river for irrigation	Syria, Lebanon, Turkey	Lebanon gets 80mcm, Syria 430 mcm. Turkey gets adequate water for irrigated lands.
River Jordan	Sharing river for irrigation, urban, and industrial use	Jordan and Syria	Syria retains flow from springs above 250m. Maqarin Dam flows used by Jordan but 70% of power generated allocated to Syria

Source: Hadadin 2008, 79–81.
Notes:
Mashreq = Eastern countries of the Arab Region.
In border-creator situations, as the water or the externalities are shared, the tendency is to share (often equally) the costs of mitigating measures. For example, the Baltic countries saw clear advantages of sharing the benefits and the costs of protecting the Baltic Sea from land-based pollution.

country with significant hydraulic investments, such as Egypt or the Netherlands, claims prior rights in that the water passing through its territory already has been put to productive use by its farmers and urban and industrial consumers and therefore needs to be safeguarded in any subsequent treaty. By contrast, an upstream country such Ethiopia or Turkey will claim sovereign rights to the water quantities flowing through its territory. In these situations, the absence of a viable international adjudication system often leads to a breakdown of the bilateral dialogue.

As a consequence, countries situated along the watercourse often are unable to work toward optimal utilization of the water. If the number of countries is three or more, the transaction costs of reaching such agreements become even more complex because these countries often do not fully appreciate their interdependence. Examples are countries that share water from very large watercourses, such as the Nile, Mekong, and Brahmaputra-Ganges Rivers, Nubian aquifer, and Arabian Gulf. Instead, as with bilateral water relations, countries tend to perceive water rights synonymously with country interests.

In such situations, crafting institutional platforms that facilitate water agreements becomes a formidable challenge. For example, since 1997, the UN Watercourse Convention has attempted to codify a broad framework for countries to work within to resolve water issues.[1] Despite almost 40 years of consultations and meetings, the suggested legal framework to govern international water agreements has not been ratified (table 15.2).

Table 15.2 UN Watercourses Convention Timeline, 1970–1997

Year	Result	Comment
1970	UN asks International Law Commission to start codification	5 rapporteurs produced 15 reports
1997	UN passes draft Convention on Watercourses	103 countries vote for convention
2007	Only 15 states sign the convention	Minimum of 35 states ratifying convention not achieved

Source: Salman 2007.

Delays in ratification have arisen principally because of differing interpretations of the relative importance of two articles of the Convention:

1. Article 5, which enjoins participating states to ensure equitable and rational utilization of shared waters
2. Article 7, which obligates states to do no harm.

Upstream states emphasize the need to honor Article 5 (protects their sovereign right to exploit the economic potentials of watercourses running through their territories). Downstream states emphasize the importance of protecting historic investments in hydraulic infrastructure (from future or contemplated actions by the upstream states) that could adversely affect watercourse flows.

When interpretations of water rights differ—as in any system of jurisprudence—there needs to be a body of tort law to guide the adjudication system. In the case of international water disputes, such a system is absent. Therefore, except in either the case of the "low-hanging fruits" referred to earlier, or cooperation through side-payments, differing interpretations of water rights quickly degenerate into zero-sum games.

Under these circumstances, water diplomacy needs to focus on building confidence and capacity among the parties sharing a watercourse.

---

[1] The full name is the United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses. The convention was passed in final by the General Assembly in 1997.

Diplomacy can enable the parties to see beyond arguing about conflicting interpretations of rights. It leads them to recognize that, because of their interdependence, cooperation is the only way forward if the water is to be utilized to its highest economic and environmental potentials. Sadoff and others (2008) have articulated the advantages of benefit sharing.

Three Phases of Interdependence

Geographic Interdependence

The fact that a watercourse is shared by two or more countries highlights the *geographic or spatial interdependence* of these countries. Whether it is a flow of a river from the headwaters to the sea, an aquifer across national boundaries, or a water body surrounded by countries, the resource is available through one ecosystem. Any action—water extractions or water insertions—taken by one state impacts all of the others. When populations were still relatively small and demands on the resource were low compared to the available resource, conflicting views of water rights could be resolved through bilateral agreements. These agreements took a static view of water availability (as validated by historical hydrological data): that future available quantities would be fully predictable.

Economic Interdependence

The second phase of water interdependence occurs as a consequence of growing *economic interdependence*. Through trade and commerce, countries have spun a complex web of interrelationships. As a result, often those sharing a watercourse become so economically interdependent that disagreements over water get resolved through "give and take" within a broader congruence of economic interests. In Europe, for example, disputes over the Danube and Rhine Rivers and other important international watercourses are no longer perceived by each country with the same degree of passion as in past centuries because the economic benefits from their interdependence far outweigh the advantages of nationalist rhetoric. Seeing beyond asserting rights to water quantity, these communities are moving forward toward institutionalizing the rights to water quality for the benefit of the entire ecosystem.

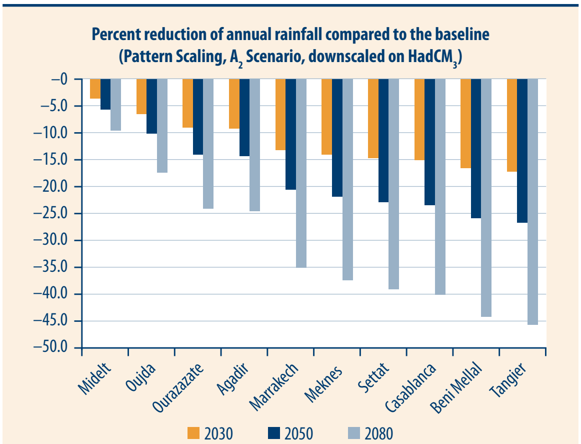
Water Interdependence

A third phase of water interdependence recently acquired prominence because inter-temporal projections warn of entire water ecosystems around the world being affected by climate change. Variability in rainfall patterns, retreat of mountain glaciers, and higher evaporation rates in reservoirs impounding water (particularly in arid regions such as the Middle East) bring in new climatic risks that need immediate and long-term mitigation. For example, the Khabour River in Syria has a large command area of irrigation. The country has witnessed a steady decline in discharge at Ras Al Ain from an average of 60 m^3 per second between 1942 and 1972 to *no water* after 2001. Figure 15.1 indicates similar trends in Morocco.

More fundamentally, *predicting future water flows in a watercourse on the basis of past historical data is becoming a dubious exercise*. In other words, country interpretations of quantity rights to international watercourses already are affected by prolonged droughts in many parts of the Middle East and North Africa. These new climate-induced risks are forecast to get worse in the ensuing decades. This prediction makes it imperative for countries that share watercourses to recognize their joint and individual vulnerability to catastrophic events such as prolonged droughts, floods, or both.

The three phases of water interdependence both influence and are influenced by different congruences of national interests. Historically, geographic interdependence has been the independent variable that has led to the largest number of international treaties on water. These treaties have institutionalized mechanisms for cooperation, even when the participating countries have widely differing economic and political power (Dinar 2000, 2005). In another paper, Dinar (2006) analyzed a wide cross-section of international water agreements. He concluded that treaties between countries for through-border configuration (water flows from one country to another) have

Figure 15.1 Secular Rainfall Trends in Morocco's Major River Basins, 2030–80 *(%)*



Source: MNA Staff Presentation on Climate Change in MNA, 2008.

involved tort-oriented outcomes in which richer downstream countries usually have financed upstream hydraulic infrastructure. By contrast, for border-creator configurations (waters are shared, as in an inland lake, or a river serves as an international boundary), treaties often have led to a more equal sharing of investment costs, even when power relations are asymmetric. There also could be situations in which the wealthier country agrees to finance a disproportionate amount for internal economic, social, or political reasons.

Regarding economic interdependence, factors "beyond the watercourse" have been the independent variables facilitating international cooperation along watercourses (Dinar 2005). For example:

a. The US and Canada share a close political, cultural, and economic relationship that goes much beyond the water resources they share. The resulting congruence of economic and political interests has facilitated agreements on sharing watercourses of 150 rivers and lakes.
b. Similarly, the International Commission for the Protection of the Rhine has been able to establish itself as a supra-national body because of the common economic and political interests of the Rhine riparian states (Sadoff and others 2008).
c. More recently, the European Water Framework Directive of 2000 (EU aquis) has created a binding legal framework to protect all European watercourses, over which the European Court of Justice has enforcement powers. These Water Directives become relevant in reshaping water policies for states that apply to join the European Union (notably Turkey). The directives have led to Turkey's National Programme for the adoption of the EU aquis, with consequences for how the country deals with downstream riparians with which it shares geographic interdependence (IDRA 2004).
d. There is also the example of the Mekong accord in which the riparians recognized their growing economic interdependence by agreeing to equal rights to the *use* of the Mekong waters according to economic and social needs.

The third phase of environmental interdependence—due to climate change—has just begun and still is not fully internalized by most countries. This concern was highlighted by the 2007 Inter-governmental Panel on Climate Change (IPCC) Report. This report projected global warming with very serious consequences for rivers whose headwaters are in tropical and semitropical zones. A combination of increased variability of rainfall with receding glaciers and rising temperatures makes the quantity of flows in the major international watercourses unpredictable. Certainly, historic data can offer no reliable forecast of the quantities and variability of future water.

In fact, many arid countries already are witnessing prolonged droughts and irregular rainfall. In the MNA region, Morocco and countries in West Asia (Israel, Jordan, Palestine, and Syria) have been particularly affected. In the future, Egypt runs the risk of losing a considerable part of its populous Nile Delta lands to sea-level rise by the Mediterranean. At Egypt's southern end, inflows to Lake Nasser/Nubia are projected to increase because extra precipitation in the Ethiopian highlands will exceed the reservoir capacity. This overflow will lead to two forms of wastage of the precious resource:

a. Excess waters increasingly will have to be diverted to the Toshka depressions. These function as mega-sized evaporation ponds (these water bodies already are so large that they are captured by remote-sensing images).
b. With the expected rise in temperatures, evaporation rates in Lake Nasser are expected to increase, thereby reducing the water stock available for use downstream of the High Aswan Dam.

Table 15.3 summarizes the suggested three-phase typology and its consequences on water diplomacy. The first column represents the *geographic interdependence* phase. These are situations in which countries have worked out bilateral or multilateral agreements based on recognition of common geography. The second column represents *economic interdependence*. In these situations, economic factors outside the geography of sharing watercourses have acted as powerful instruments to

Table 15.3 Typology of Interdependence

Geographic interdependence leads to agreements between/among countries based on:	Economic interdependence leads to agreements between/among countries based on:	Environmental interdependence leads to agreements between/among countries based on:
Territorial sovereignty and sharing water rights	Overall economic and political congruence through sharing economic benefits	Recognizing and sharing ecosystem risks due to climate change

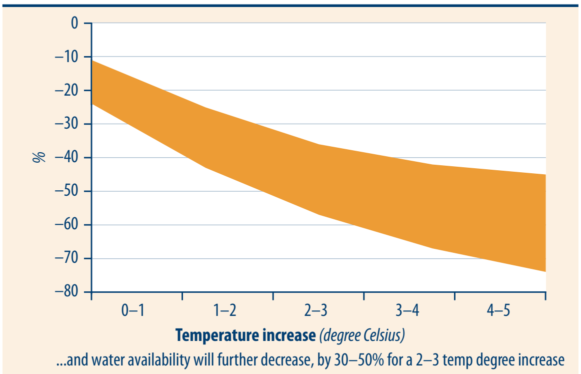
promote international water agreements. The third column represents the additional phase of *environmental interdependence*. It signifies emerging situations in which global externalities will require countries that share watercourses to work with one another to mitigate these emerging risks to their economies. The biggest challenges to water diplomacy in the years ahead lie in this third arena.

To sum up, the nature of interdependence among countries that share watercourses leads to either a congruence or lack of congruence of interests. These lead to either the success or failure of water diplomacy. Past disputes over international watercourses have arisen in the region from a variety of social, political, economic, and historical reasons. With projected increased variability in rainfall and rising temperatures, countries simply cannot afford to risk water conflicts based on existing rights-based paradigms such as territorial sovereignty and territorial integrity. *The development challenge is how to create a culture of learning and knowledge-sharing*, so that policymakers are able to understand that *growing environmental interdependence is forcing a much greater congruence of interests in managing water than has ever been necessary before*.

How Can Countries Be Persuaded to Recognize the Importance of Environmental Interdependence?

The IPCC Report of 2007 generated global awareness of the risks of climate change, particularly in terms of rainfall declines and variability (figure 15.2). Specific adverse impacts and risks are becoming apparent to policymakers at country levels. Under these circumstances, political leadership has been quick to recognize the importance of adapting policies to meet the challenges of rainfall variability. Tunisian President Zine El Abidine Ben Ali, for example, has directed the country's water utilities to explore how treated wastewater, which the country is discharging into the Mediterranean, instead can best be conveyed and reutilized in the drought-prone areas.

Figure 15.2 Climate Change Impacts in North Africa: Range of Change in Runoff *(%)*



Source: Stern Report Background Paper 2007.

In Morocco, many of the dams constructed over the past three decades are not filling to design capacity because of rainfall variability. Earlier, this variability was viewed as prolonged droughts. However, now it is being interpreted as the first stage of climate change. These shortages have affected carefully calculated allocations from the water stored in dams of the country's river basins for use by farmers, industries, and urban communities. Such experiences are galvanizing policymakers to work on a new range of economic and investment policies. Table 15.4 describes recent simulations of the Rio Bravo Basin in Mexico that show the extent of economic damage with a decline in rainfall.

Table 15.4 Simulations for Rio Bravo Basin, Mexico

If runoff falls by 20%: • $7.5B pesos of damages in the residential sector. • $5.3B pesos of damages in the industrial sector. • $69M pesos of damages in the agricultural sector. • Industrial and residential sectors will be damaged considerably more than agriculture because the third places a much higher value on water. • Overall welfare losses = $13.0B pesos annually.
If the reduction in runoff is 10%, the damages fall to $5.5B pesos. If the reduction in runoff is 5%, the damages are $2.6B pesos.

Source: B. Debewo, personal communication, 2008.

While country leaders have been quick to recognize the adverse impacts of rainfall variability and prolonged droughts on their economies, they are less familiar with the risks caused by the interdependence of countries that share watercourses and ecosystems. *The need is urgent to build collaborative learning and knowledge-sharing on how countries that share watercourses can work with each other in a new world of global externalities*. Regional resilience programs—similar to the one at country-levels—will be possible only when there is a universal recognition of the congruence of interests to cooperate among nations sharing watercourses.

Investment in Capacity Building Is Key

Recognizing environmental interdependence, therefore, poses a major capacity building challenge to the development community. Recognition requires investments on three fronts:

1. Developing communication strategies and country dialogues

- Making clear information on resource publicly available to all watercourse beneficiaries: How much water is available where, with what reliability, and of what quality to technical staff in all interested countries?
- Utilizing similar methods of data analysis, so that policymakers and other national stakeholders receive objective, professional advice on available options to share the resources equitably and without causing any harm.
- Articulating the risks posed by climate change projections, particularly regarding (a) design assumption failures for hydraulic infrastructure and (b) dangers of misdirected investments and misdirected water and energy policies.
- Facilitating country-level dialogues aimed at mitigating this new risk vector.

2. Build partnerships to understand and mitigate risk

A second front is to build partnerships among scientific institutions, civil society, international and bilateral donor agencies, and national policymakers, so that the nature and consequences of emerging hydrological risks are understood, and appropriate mitigating measures are taken. Some pilot initiatives are underway. The Red Sea-Dead Sea Study Program is a $15 million initiative financed by the international donor community in response to acute water shortage in the Jordan Valley and the rapid shrinking of the Dead Sea. Jordan, Israel and the Palestinian Authority are collaborating on this study because all three countries recognize not only their geographic interdependence but also the critical importance of building up joint resilience to climate change predictions.

The study is evaluating the feasibility of constructing a water conveyance system from the Red Sea to the Dead Sea to generate electricity and desalinating the water to meet the unmet water demand in Jordan. The feasibility of the project will be evaluated against other cost-effective options (including what is currently a politically unacceptable option of reducing water consumption by irrigated agriculture in Jordan and Israel), and establishing a common monitoring system for water resources in the Jordan Valley.

3. Develop regional investment programs to build regional resilience to climate change

The third front would emerge after the basic awareness of environmental interdependence and detailed technical knowledge are generated. The third front is to develop investment programs to build regional resilience to climate change. Of course, countries will need to agree to sign off on such programs.

If they do, it could be the evidence that hydropolitics and the ensuing water diplomacy finally have recognized the third aspect of interdependence: environmental interdependence. Awakening to this understanding is the challenge of water diplomacy in the early 21st century.

References

Bates, B., Z. Kundzewicz, S. Wu, and J. Palutikof. 2008. "Climate Change and Water." International Panel on Climate Change, Geneva.

Debewo, B. 2008. Presentation on the Impacts of Climate Change on the River Rio Bravo.

Dinar, S. 2000. "Negotiations and International Relations: A Framework for Hydropolitics."

____. 2000. *International Negotiations*, 375–400.

____. 2006. "Assessing Side-Payment and Cost-Sharing Patterns in International Water Agreements: The Geographic and Economic Connection I." *Political Geography* 412–37.

____. 2004. "Water Worries in Jordan and Israel: What May the Future Hold?" In A. Marquina ed., *Environmental Challenges in the Mediterranean 2000–2050*, 205–31. Kluwer Academic Publishers.

____. 2003. "Preventive Diplomacy, International Relations, Conflict Resolution and International Water Law: Implications for Success and Failure of the Israeli-Palestinian Conflict." In *International Journal for Global Economic Issues* 3 (2).

____. 2005. "Treaty Principles and Patterns: Selected International Water Agreements as Lessons for the Syr Darya and Amu Darya Water Dispute." In H. Vogtmann and N. Dobretsov, eds., *Transboundary Water Resources: Strategies for Regional Security and Ecological Stability*. Springer

____, and D. Ariel. 2000. "Negotiating in International Watercourses: Diplomacy, Conflict and Cooperation." In *International Negotiations* 5: 193–200.

IRA (International Research Associates LLC). 2003. "The Thread of Life: A Survey of Hydropolitics and Security in the Tigris-Euphrates Basin." Unpublished.

Munther, H. 2008. "Neighbor to Neighbor." In *Jordan Business* (October): 79–83.

Sadoff, C., T. Greiber, M. Smith, and G. Bergkamp. 2008. "Share Managing Water across Boundaries." IUCN Water and Nature Initiative.

Salman, M.A. Salman. 2007. "The United Nations Watercourses Convention Ten Years Later: Why Has Its Entry into Force Proven Difficult?" In *Water International* 32 (1) (March): 1–15.

Codification

16

Comparative Analysis of Water Laws in MNA Countries

Jackson Morill and Jose Simas

Codification of water laws creates the institutional environment in which water resources and water service deliveries are managed. The countries selected for this study were Egypt, Jordan, Lebanon, Morocco, Oman, Tunisia, and Yemen.[1] Choosing a group of representative countries within the region to use in a comparative study was somewhat complicated, as the majority of countries do not possess a framework water law. Given the authors' difficulty in locating legal texts, it is also hard to determine whether the analysis of each country represented in this study is totally complete. Laws may have changed or there may be new laws in force that have not been made public.[2]

Methodology

The methodology for this study was to divide the analysis of water laws in each country by religious and customary law background (addressed in the next section) and WRM topical areas. The topics are (1) principles and objectives, (2) water rights, (3) water allocation, (4) transfer of water rights, (5) water pricing, (6) management of water pollution, (7) flood control, (8) penalties, (9) planning, development and information,

[1] Based on the "Report Submitted to the Ministry of Water and Electricity, Kingdom of Saudi Arabia," 2005.

[2] The countries used for this study include (a) Lebanon, (b) Yemen, (c) Jordan, (d) Morocco, (e) Tunisia, (f) Egypt, and (g) Oman.

[3] *Editor's note:* Due to these authors' comprehensive documentation of their sources, the citations are in footnote form rather than text note form, as in the other chapters.

(10) groundwater management, and (11) institutional arrangements.[3] Several of these categories overlapped, and in these cases, the analysis was arbitrarily dedicated to one category and noted in the areas of overlap.

The list of water issues above is certainly not comprehensive. The topics chosen for discussion represented the most common issues addressed in the water laws of the region. There was a paucity of law in such areas as investment and conflict resolution.[4] If any law did exist in these areas, it was included in the institutional category.

This chapter does not touch upon the larger question of the administration or enforcement of water law. Given the limited capacities of ministries, some of these laws appear difficult to administer. For example, in Yemen, 6–7 people working in the ministry are assigned to the Sana'a Basin Catchment Area, in which over 1.5 million people live and over-extract groundwater for agricultural activity (especially qat), as well as sell to several water vendors in the city of Sana'a. It is difficult to imagine that so few staff could enforce the entirety of the legal regime of water for such a large populous area.[5]

Religious and Historical Influences on Water Law in Selected MNA Countries

Countries in the Middle East and North Africa (MNA) have a long, rich legal tradition in codifying water resource management (WRM). The scarcity of water in the region and its importance to early agrarian and nomadic societies necessitated the development of fairly complex systems of tribal law and Islamic doctrine to manage and share the resource. In modern day MNA countries, population growth and changing economies, as well as globalization and common water management principles, have led many countries in the region to consider modernizing their water law systems to address the modern-day issues of scarcity and demand management. The challenge for legal drafting in this region lies in aligning Islamic and customary law with the realities

[4] Conflict resolution usually involves some amount of "give and take," or bargaining (discussed in Bargaining), although bargaining does not lead to conflict resolution.

[5] Water laws have to take into account the limited capacity of those who are charged with enforcement. However, it seems that the legal minds working in international water law have yet to identify a legal framework for pollution prevention that is workable in the context of areas with limited capacity.

of modern day WRM law and policy. Any new water law framework must at least consider and respect the traditions built in the region over the centuries.

Islamic religious law, or *Shari'a*, regulates all human actions, including the use of water resources. The Holy *Qu'ran*, the fundamental text of the Islamic faith and the foundation of Muslim law, provides the central tenet of water resource management, which is that water is a gift of God and in principle belongs to the community.[6] This central tenet, in turn, creates a primary right of *shafa* ("drink") for all individuals and domesticated livestock. All Islamic water law is shaped by this baseline principle, as evidenced by the examples of religious doctrine developed in the Prophet's teachings, the *hadiths* and the *figh*.[7]

The application of Islamic law in WRM becomes complex when examining the varied approaches adopted by the different schools within Islam. The three main schools are the Sunnites, Shi'ites, and Ibadites. Within each of these schools, there are different branches as well,[8] and each of these schools has a nuanced approach that may differ slightly in certain areas of WRM. For example, under the Sunni, Shi'ite, and Ibadite traditions, the right of thirst applies to all public waters. The Sunni and Ibadite traditions expand the right of thirst to some private waters as well, but the Shi'ites hold that no one other than the proprietor is entitled to the use of his private waters. Examining the issue even further within the Sunni school, one of the branches (Malikite) holds that the right of thirst applies to private waters as well. However, if the one in need has the financial means, he is liable to pay compensation. Under the Hanbalite and Shafi'ite

[6] As Caponera wrote, "Islam always reacted against tribal life by preaching equality and fraternity in the faith. Prophet Mohammed preached charity as the principal virtue to help the destitute and to show detachment from material things." The idea of charity is represented in the basic principle of *shafa*. Where force was used to dictate water use in the tribal societies, water was made available to all in need. See D.A. Caponera, *Water Laws in Muslim Countries*, Irrigation and Drainage chapter (FAO 1973, 10) (hereinafter "Caponera").

[7] *Figh* can be found in the second part of the *Shari'a*. *Figh* governs the manner in which faithful Muslims should live their lives, including methods of worship, diet, and clothing. *Id.*, 1.

[8] Within the Sunni tradition, there are four recognized schools: the Hanifites, Malikites, Shafi'ites, and Hanbalites. The Shi'ite school has even more branches, including the Imamites, Ismailites, Zaidites, Carmatians, Assassins, Druses, Ahl-al Hagg, and Buhain-in. There are no separate branches within the Ibadite school. *Id.*, 5.

schools, the right of thirst may be exercised without compensation under certain conditions.[9]

While religious principles have maintained significant influence over WRM, practical needs also have had a significant effect on rules and regulations. Geography and the general availability of water vary within the region. Customary law also differs throughout the Muslim countries in this study. However, as Caponera writes in his article, "Water Law in Muslim Countries," core principles can be gleaned from the varied customs in place. First, it is clear that, due to scarcity in the region, water ownership is important and is seen as real property. Water rights can be held individually or collectively. These rights may be sold, purchased, inherited, gifted, donated, or transferred. However, the rights of religious communities cannot be alienated. Water rights often have been recorded by local authorities.

The Ottoman Empire,[10] which united the Middle East, also influenced modern day water law in the region through the *Majalla*, or the Ottoman Code.[11] Within the Majalla, a large section governs water rights, and many of its precepts still hold true in countries such as Lebanon.[12] In addition, the subsequent colonial influences of Britain and France are strong in MNA. Francophone countries possess a code-based system, whereas the British legacy was a more piecemeal, common law approach. As a result, some countries, for example, Morocco, have passed fairly comprehensive Water Codes, whereas other countries, Jordan, for instance, have a group of laws that addresses various aspects of WRM.

This historical background is not meant simply to elaborate on the diverse origins of water law in North African and Middle Eastern Islamic countries. While many modern water experts believe that the region is increasingly willing to stretch the bounds of Islamic and

---

[9] *Id.*, 14.

[10] Late 1200s to 1922.

[11] The Majalla was authored in the second half of the 19th Century by a council of major Hanafi *faqihs*. It is very significant for several reasons. It was the first systematic codification of Islamic law and was based on one school (Hanafi). It also consciously addressed many pressing issues in law. It came to conclusions that sometimes were not "traditional" positions of the Hanafi school, although they always were grounded in the positions of the Hanafi school's imams. The text was written so that someone without a deep background in the style and usage of classical *fiqh* texts could understand it.

[12] Lebanon still has in force Title 4, Chapter 10, Articles 1234–1328 of the Majalla.

customary law to better address modern issues of rising demand and rapidly decreasing supply, Government officials still have the clear intention to respect legal traditions. This is why, as Caponera writes in his seminal work, many Muslim communities have a "justifiable mistrust" regarding water code projects developed by non-Muslims, because they fear that innovations may offend religious law.[13] Therefore, *any legal reforms in the region must respect and attempt to incorporate the traditions of customary and Islamic law.*

Current Water Law in Selected MNA Countries

The following sections will address the approaches to 11 issues in each country, highlighting best practices and possible approaches.

Principles and Objectives

Morocco and Yemen have been two of the first countries to put in force a framework water law that reflects modern water principles and attempts to address the country-specific issues faced in these countries. Jordan, while it does not possess a framework law, does have a very well-developed set of water laws, which address groundwater, water rights, and water pollution; and the institutional mechanisms for managing them.

Many "modern" framework water laws contain a statement of principles or objectives, or both. For example, the Brazilian Water Law includes both a set of principles and objectives at the beginning of its law to establish the broad national water policy (box 16.1).

In the countries reviewed for this study, only Morocco and Yemen, the two countries with framework water laws in force, have a series of principles or objectives. Other countries, such as Jordan and Lebanon, clearly establish under their respective legal regimes the basic principle of water ownership by the state by virtue of its control of the public domain. However, each of these countries does not have any laws that begin with a set of principles and objectives.

Of the two countries with framework laws, Morocco's is the most complete. Yemen's law focuses almost entirely on the specifics of water rights administration.

---

[13] *Id.*, 1.

Box 16.1 Brazilian Water Law 9.433, 1997

Chapter I: Basic Principles

Art. 1. The National Water Resource Policy is based on the following principles:

1. Water is public property.
2. Water is a limited natural resource, which has economic value.
3. When there is a shortage, priority in the use of water resources is given to human consumption and the watering of animals.
4. The management of water resources should always allow for multiple uses of water.
5. The river basin is the territorial unit for the implementation of the National Water Resources Policy and the actions of National Water Resource Management System.
6. The management of water resources should be decentralized and should involve participation by the government, the users, and the communities.

Chapter II: Objectives

Art. 2. The objectives of the National Water Resources Policy are as follows:

1. To ensure that present and future generations have the necessary access to water of a quality adequate for their various uses.
2. To ensure the rational and integrated use of water resources, including transportation by aqueduct, with a view to achieving sustainable development.
3. To prevent and protect against water crises due to either natural causes or the inappropriate use of natural resources.

The Moroccan law begins with a basic set of principles, focusing on the fact that water is an "essential commodity" that is both scarce and extremely vulnerable.[14] A set of objectives for the law follow, which begins with an overarching statement of purpose:

> "Water resources development must ensure the availability of water adequate in quantity and quality to meet the needs of all water users, in accordance with the aspirations of balanced economic and social development, the guidelines of national land-use development

[14] See Moroccan Water Law (#10/1995), "Grounds for the Law" and "Benefits of Water Legislation," 1.

planning and the possibilities offered for harnessing potential water resources, all at lowest possible cost."[15]

The remaining objectives touch on issues of "coherent and flexible planning," using the catchment basin as the method for decentralized management, seeking optimal use of the resource that is in line with the priority uses outlined in the law, protecting the resource (both in quantity and quality), and establishing the appropriate water administration. Finally, the law outlines a set of "principles" that flow from the objectives. They further define the tools and parameters for achieving sound water management through the implementation of the framework law.[16]

Water Rights

As outlined in the background section, the history of water rights in the Islamic world is complex. In many ways, the basic tenet of *shafa* ("drink") continues today in all Muslim countries. However, how it is applied varies greatly. Most countries allow for customary private water rights to coexist with state-owned water administered by a permitting scheme. Several countries, most notably Egypt, tie water rights exclusively to land. Others separate water and land ownership/use rights. Each country also varies as to the rights and obligations that accompany water rights. Because of these great differences, this chapter presents a separate section on each country.

Egypt

Egypt is unique in that surface water rights are tied to land, and thus are tied to land ownership.[17] Egyptian water law provides water rights only for irrigation purposes. No other uses are addressed under the law. Landowners must submit to the irrigation supervisor a scheduling table for irrigation based on the amount of land and the type of crops to be grown. This schedule will dictate the amount of water allocated, a process covered more extensively in the next section.[18]

[15] *Id.*, 2.
[16] *Id.*, 2–3.
[17] Concerning the Issue of the Law on Irrigation and Drainage (Law 12/1982), Art. 18.
[18] *Id.*

Landowners have certain responsibilities that accompany their water use rights. The responsibilities include keeping the drains, *mesqas,* and canals clean and free of debris. For landowners holding water rights, a variety of actions are prohibited:

- Wasteful use of irrigation water through a private drain, public drain, fallow land, or unlicensed land
- Impeding the irrigation network
- Preventing flow in the main canal or any other action that might compromise the water elevation
- Opening or closing any lock or any other regulation works
- Demolishing any hydraulic infrastructure constructed by MWRI
- Cutting banks of the Nile or canals or drains without license
- Excavating in the banks or changing their elevation (hack filling mud or clay or soil).[19]
- Licenses are required for any water-related works or operation of equipment.[20]

Jordan

Jordan is distinct from the other countries primarily because it treats almost all water resources within the Kingdom, whether surface or groundwater, as state-owned property.[21] The slight exception lies with any waters that are not considered "under the management, responsibility or supervision of the Authority."[22] These waters may not be used in excess of personal or domestic needs or other acceptable private usage. Moreover, they may not exceed the amounts set in laws pertaining to drinking water and irrigation rights.[23]

Jordan also is somewhat unusual in that it maintains a separate law for the Jordan Valley that determines water and land use in that region. Under this law, waters acquired by means of government projects—and that were not used for irrigation purposes prior to the law—are considered government property. These waters may be leased, sold, or

---

[19] *Id.* at Art. 82.
[20] *Id.* at Arts. 9 and 49.
[21] Jordan Water Authority Law (#18/1998), Art. 25. See also Underground Water Control By-Law (#85/2002), Art. 3. Under the Underground Water By-Law, ownership of the land does not in fact include ownership of the underground water therein. Underground Water Control By-Law (#85/2002), Art. 3.
[22] *See* Jordan Water Authority Law (#10/1998), Art. 25.
[23] *Id.*

otherwise disposed of as decided by the Water Board. In addition, for any irrigation project, any excess water not claimed under registered water rights is considered government property.[24]

Lebanon

The law in Lebanon holds that the state has exclusive ownership over the public domain. Nonetheless, some acquired private water rights remain protected. Generally, private water rights could be acquired through the usual means of property acquisition (inheritance, settlement, or purchase) if acquired before 1926.[25] The right of use that accompanies these rights is governed by the Majalla, which distinguishes between two rights: drinking water, and water for livestock and irrigation.[26] Both of these rights are limited by the condition that they do not infringe on the rights of others. The right to drink water has fewer limitations than the right to water livestock.[27] For irrigation rights, in particular, it is prohibited for anyone to change the periodicity of irrigation by transferring water to land belonging to him or her if he does not hold irrigation rights for said waterway.[28]

Morocco

The Moroccan Water Law holds that "Water is a public asset and as such…cannot be the object of private appropriation."[29] The law lists 10 specific types of water body (natural and constructed) that are considered to be in the public domain.[30] Almost any conceivable surface water body falls within this definition. However, the law does provide that some vested rights over the public domain may be retained, provided that (1) ownership preceded the publication of the *Dahir* (law) (1914 and 1925) and (2) claims concerning these rights were filed within five years of publication of the law. After this date, no more claims may be filed.[31] These recognized water rights

[24] Jordan Valley Development Law (#30/2001), Art. 18.

[25] Decree #144, Art. 3. Note that these private rights are recorded in the Land Registry. *Id.*

[26] Majalla, Title IV, Chapter 10, Arts. 1262 and 1265.

[27] *Id.* at Art. 1254. For example, any person in full ownership of water in wells or streams is allowed to prohibit another's right for cattle to drink or to irrigate crops in the area if another source exists that is available to the public. *Id.* at Art. 1268.

[28] *Id.* at Art. 1269.

[29] Moroccan Water Law (#10/1995), Art. 1

[30] *Id.* at Art. 2.

[31] *Id.* at Art. 6.

will remain subject to the provisions concerning water use as laid down in the national water plan and in integrated water resources development master plans.[32]

Landowners have certain rights and obligations for use of water that falls outside the public domain. Owners have the right to use rain falling on their lands. However, any attempt to artificially collect rainwater is subject to regulation.[33] An owner may dig a well on his or her land not to exceed a certain depth and subject to concessions and public domain regulation.[34] In addition, landowners abutting a watercourse assigned to public use are subject to an easement within four meters of the freeboards. The easement will enable free passage for administration or catchment basin authority works.[35]

Oman

The available legal texts for Oman limited the analysis to groundwater. Under Article 2 of the Ministerial Decision No. 2/1990, all persons claiming ownership of existing wells, whether used or unused, must apply to the Ministry of Water Resources for registration. All wells were to be registered by July 1990. Any well that was not registered by that date would be considered illegal thereafter.[36]

Tunisia

Under the Tunisian Water Code, water use rights are private rights existing prior to the commencement of the law, provided that they are recognized by the Drainage Commission.[37] The code also provides that any existing water right at the time of the publication of the code becomes a private right.[38] Water use rights are appurtenant to the land. As a result, when land on which a water right exists is sold or transferred, the water use right is transferred to the new landowner. In addition, if the land is parceled, then a new water right must be requested and issued to reflect the change.[39] Existing rights for the use of natural spring waters located on private lands also may be recognized by the

[32] *Id.* at Art. 8.
[33] *Id.* at Art. 25.
[34] *Id.* at Art. 26.
[35] *Id.* at Art. 31.
[36] Oman Ministerial Decision No. 2/1990, Art. 4.
[37] Tunisia Water Code (1975), Art. 53.
[38] *Id.* at Art. 21.
[39] FAO, Water Law and Standards: Framework for Analyzing National Water Laws, Tunisia, 3. www.who.int/waterlaw/WQ.exe$QU_Search

Ministry of Agriculture, provided that these rights are not suitable for exploitation and use for public purposes.[40]

Yemen

Under the 2002 Yemen framework water law, all watercourses in the *wadis* (natural streams) are the common property of all beneficiaries. In contrast, all water installations and wells set up by the government are considered public property and subject to registration and licensing.[41] As evidenced by this water rights regime, the Yemen water law provides for a significant number of private water rights. Existing and acquired water rights, whether prior to the issuance of the law or thereafter, are maintained. They are not touched by the government except in times of critical need and for the public welfare. The government should compensate any infringement on the right of use.[42]

Traditional water rights derived from rainwater harvesting and natural runoff flows that are tied to irrigation are protected for all owners of agricultural lands. The law gives due consideration to customs, traditions, and irrigation systems in effect.[43]

Traditional rights of use from natural springs, brooks, creeks, and surface wells (the depth of which can not exceed 60 meters) are maintained, provided they were held prior to the issuance of the law.[44] Finally, quantities of water may be collected in cisterns, pools, or streams, provided that this acquired right does not infringe on other acquired rights and that the use accords with traditional rights and customs.[45] The only caveat for all of these rights is that they must be registered with the Water Authority within three years of the date of the announcement of the issuance of this law.[46]

Allocation of Public Water

Every country examined in this study has in place a scheme to allocate publicly owned water. However, as might be expected, differences

---

[40] Tunisia Water Code (1975), Art. 30.
[41] Yemen Water Law (#33/2002), Art. 5.
[42] *Id.* at Art. 27.
[43] *Id.* at Art. 28.
[44] Id. at Art. 29. Note that these rights must be registered and also be used only for their original purposes. *Id.*
[45] *Id.* at Art. 30.
[46] *Id.* at Art. 32.

are significant depending on whether the water allocation is tied to the land or is considered a separate right. In addition, countries differ as to which type of water abstraction requires a permit and which does not. Some countries allow underground abstraction to a certain depth while others require a license for any underground abstraction. Finally, administration of the allocation system varies among countries.

Egypt

As mentioned previously, water rights in Egypt are tied exclusively to land, and water rights are used only for irrigation. The effect is to create a flexible system of water allocation based on factors similar to those of the Jordan Valley Development Law, including size of the land and crop rotations. Therefore, water rights allocations are tied to land-holding and the types of crops licensed to be grown on each parcel.[47]

The Ministry of Water and Irrigation (MWRI) is responsible for the distribution of water in all waterways up to the mesqa level and for determining and publishing the irrigation calendar.[48] MWRI reserves the right to modify the system in accordance with agricultural needs.[49] In fact, the Irrigation Director is empowered to stop diverting water from a main canal to ensure more equitable distribution or to avoid over-application.[50]

To irrigate new lands, defined as lands that have never received an irrigation license, the MWRI must approve the appropriation to ensure that there is enough water. Then a license is required from the Irrigation Director. The licensee must include in the license application the acreage, soil classification, irrigation source, irrigation technology, and cropping calendars. The Irrigation Director is then responsible to validate the data and determine how much water to allocate and which irrigation technology should be used.

---

[47] Since the water legislation was passed, the proportion of crops regulated by licensing has fallen considerably.

[48] Egyptian law: Concerning the Issue of the Law on Irrigation and Drainage (Law #13/1982), Art. 36.

[49] *Id.*

[50] *Id.* at Art. 37. In fact, the Irrigation Director may alter the flow coming through a privately constructed withdrawal on the Nile or a main canal should she/he feel it exceeds irrigation needs. However, a public hearing is required, and any increase or decrease will be at the expense of the government. *Id.* at Art. 40.

The law also requires licensing for any water works completed on public lands,[51] or for any water intake established on the Nile or main canals,[52] to construct any pumping stations,[53] and even to cultivate lands.[54] Each of these requirements is designed to further control the withdrawal and use of public water resources drawn from the Nile.

Jordan

The amalgamation of laws in Jordan covers the allocation of *underground water* through the Underground Water Control By-Law (#85/2002) and of *surface/groundwater* in the Jordan Valley through the Jordan Valley Development Law (#30/2001). These two laws work in entirely different ways. The underground water law calls for a standard permit system for well digging and water abstraction.[55] The Jordan Valley law ties water allocation to land size and crop rotations.[56] In addition, it was not apparent from any of the laws reviewed for Jordan whether it has a national scheme for allocating surface water.[57]

The surface and groundwater allocation system for the Jordan Valley Authority is managed by a Board. It sets all of the necessary regulations to control the use of water in farm units in the valley. The Board determines when to allocate or cut off water flows. It also fixes the maximum quantities in accordance with water availability and the nature of the crops planted in each unit. Finally, the Board enforces the water prices set by a Cabinet of Ministers upon recommendation by the Board.[58]

The Authority also may expropriate any lands, water shares, or both, as necessary for projects, either by absolute expropriation with compensation or by lease for any period it deems appropriate.[59] The law establishes a fairly complex system for estimating the value of

---

[51] *Id.* at Arts. 9–16.
[52] *Id.* at Arts. 39–44.
[53] *Id.* at Arts. 49–60.
[54] *Id.* at Art. 7.
[55] Underground Water Control By-Law (#85/2002), Arts. 4–42.
[56] Jordan Valley Development Law (#30/2001), Arts. 18–24
[57] The Water Authority Law calls for the Water Authority to "regulate the uses of water, prevent its waste and conserve its consumption." See The Water Authority Law (#18/1988), Art. 6(h). In addition, Article 25 provides that all waters available in the Kingdom are State-owned property and may not be distributed, except in compliance with this law. *Id.* However, no guidance is provided in this law as to how publicly owned water will be allocated.
[58] Jordan Valley Development Law (#30/2001), Art. 24.
[59] *Id.* at Art. 21.

the lands or water rights, and provides for appeals as to the amount granted for the expropriation.[60] The Authority also has the right to take all necessary measures to implement irrigation networks and improve their works.[61]

To avoid overlap, the discussion of Jordan's Underground Water Control By-Law appears in the groundwater section.

Lebanon

The Lebanese framework water law provides that the state has exclusive property rights over water resources in the public domain, Nevertheless, many private water rights are held in the country. The allocation law concerning private water rights seems to focus on water extraction. For example, the use of water from wells drilled on private lands, the flow of which does not exceed 100 m^3 per day, is exempt from any permit or other authorization.[62]

Under Decree 320/26, the head of state or any other delegated authority can require specific permits for:

1. Temporary erection of structures for the use of waters in the public domain
2. Extraction of materials from a permanent or seasonal water body
3. Planting or construction on the sides of waterways
4. Prospecting for underground water (but not for its use)
5. Structures designed to control and use waters from natural sources, whose flows are not sufficient to justify needing these waters for public use.[63]

To drill for underground waters, permits are required.[64] Any civil engineering works on waterways require a permit that specifies the scope of the work, its nature, materials to be used, and the overall management scheme.[65] Although the duration of a permit is usually provided case by case, some activities are accorded temporary use of

---

[60] *Id.*
[61] *Id.* at 22. Note that no other Agency or Ministry can execute "any construction activities" in the Jordan Valley. *Id.* at Art. 32.
[62] Lebanon Decree 320/26 (Titles 2–3), Art. 3.
[63] *Id.* at Art. 4.
[64] *Id.* at Art. 5.
[65] *Id.*

up to four years.[66] If the permit is issued to a farmer, it may be renewed indefinitely for successive periods of 40 years.[67]

Morocco

Morocco has in place a system for allocating all water held in the public domain through a permit system administered by Catchment Basin Authorities.[68] Permits are required to (1) prospect projects for tapping underground or out-welling water, (2) construct dug wells with depths exceeding the maximum provided in law (Art. 26), (3) establish works to impound and harness natural spring water on private property, (4) establish works meant for using waters of the public domain (for five-year intervals with possibility of renewal), (5) establish intakes from the underground water table in excess of the maximum set by regulation, (6) establish water intakes on watercourses or canals derived from wadis, (7) establish intake of water of any kind for sale or therapeutic use, and (8) operate ferries or crossings on watercourse.[69] The permit granted by the Catchment Basin Authority specifies the duration (not to exceed 20 years), and renewal is possible.[70] The permit also should include the measures to be taken by the recipient to prevent water degradation, amount of the fee and payment arrangements, and terms of use.[71]

The Authority is granted the ability to revoke a permit at any time, without compensation, following written notice, if (1) the terms of the permit have not been met, (2) utilization of the permit does not begin within two years, (3) permit is assigned or transferred without agreement of the Authority, (4) fees or dues are not paid, and (5) water was used for a purpose other than that authorized by the permit.[72] The Authority also may revoke, amend, or restrict the permit for reasons

---

[66] *Id.* at Art. 7. The activities include (1) permanent pumping of water from a waterway; (2) irrigation of lands by waters of the public domain by motorized methods or the use of such waters for energy; (3) use of underground and spring waters; (4) use of hot and mineral springs; and (5) purification and development of marshes. *Id.* Note also that these uses may be declared public and thus subject to the specific regulations of the concessions. In such cases, the length may not exceed 75 years. *Id.* at Art. 12.

[67] *Id.* at Art. 10.

[68] Moroccan Water Law (#10/1995), Art. 39.

[69] *Id.* at Art. 38.

[70] *Id.* at Art. 39.

[71] *Id.*

[72] *Id.*

of the public interest, subject to prior notice of not fewer than 30 days. The permit holder is entitled to compensation.[73]

In addition, the law provides for a system of concessions for various categories of works, including development of thermal springs, construction on public water domain, water storage, flood protection, or derivation works.[74] These concessions are considered real rights, but they do not entitle the holder to the right of ownership over the water.[75] The law limits what the concessionaire may do under the contract,[76] and specifies a set of events that would forfeit the concession contract.[77] The Authority may demolish any structure constructed without a permit or concession and order the offending party to restore the area to its original condition.[78]

Finally, in cases of water shortage, the law provides that the administration can declare a state of shortage, define the affected area, and enact the necessary local temporary regulations to ensure, at the least, potable water for human and livestock consumption.[79] During this period, the administration is entitled to requisition water, provided it follows prevailing law.[80] The cost imposed may be borne in part by the government. During times of shortage, specific regulations that restrict water use apply to areas under irrigation.[81]

Oman

The available law for Oman provided guidance only on groundwater allocation. This guidance will be discussed in the groundwater section.

Tunisia

Under the 1975 Water Code, Article 1, it is clear that most water in Tunisia is within the public domain.[82] Water may be used subject to a

---

[73] *Id.*
[74] *Id.* at Art. 41.
[75] *Id.*
[76] *Id.* at Art. 44.
[77] *Id.* at Art. 45.
[78] *Id.* at Art. 47.
[79] *Id.* at Art. 86.
[80] *Id.* at Art. 87.
[81] *Id.* at Art. 88.
[82] Water Code (1975), Art. 1. The water bodies include all watercourses and the land comprised within their overflow banks, springs, groundwater, lakes and subkhas, aqueducts, wells and watering places constructed in the public interest, irrigation, and navigation canals including the land comprised within their overflow banks, and their appurtenances. All belong to the public domain of the State. *Id.*

simple authorization or concession, or under a water use right.[83] An authorization is required (1) to use public domain water for nonpermanent waterworks; (2) to construct infrastructures located within the overflow banks of a watercourse or on canals, lakes, and *subkhas*; (3) for groundwater exploration and exploitation activities, but not for the use of the water; and (4) for the exploitation and use of natural spring waters that are located on private lands but are not suitable for exploitation and use for public purposes.[84]

Concessions are granted for (1) permanent water intakes in watercourse beds, (2) use of underground or spring waters, (3) use of mineral and thermal waters, (4) construction of permanent dams and use of the water stored therein, and (5) drainage of lakes and subkhas and their use.[85] Concessions may be renewed, but the law is silent on the duration.[86] The law does provide for specific instances in which concessions may be forfeited.[87] In addition, the law exempts some uses from licensing requirements, including any well dug no deeper than 50 meters[88] and rainwater falling on a landowner's property.[89] The concessions or authorizations can be altered or forfeited if the water is needed for a public purpose so long as compensation is paid for any damages or loss.[90] Nothing in the legislation covers the recording of water rights or the monitoring and enforcement of water abstraction licenses.

Yemen

Yemen is approving a series of amendments to the Framework Water Law (#33/2002). Among many other issues, the government may alter the process for allocating water resources. Generally, the proposed amendments are designed to address the creation of the new Ministry of Water and Environment. It has taken over the functions of several

---

[83] *Id.* at Arts. 21, 52, and 53.

[84] *Id.* at Art. 52.

[85] *Id.* at Art. 53. In certain cases, a concession may be decreed a public utility. *Id.* at Art. 56.

[86] *Id.* at Art. 60.

[87] Id. at Art. 67. Forfeiture occurs in these instances: (1) nonobservance of the law; (2) if the concessionaire uses waters for purposes other than those granted in the concession; (3) if charges are not paid; (4) if the concession is transferred without authorization of the responsible authority; (5) if water is not used for a consecutive period of one year from the issuing of the concession; or (6) if the concessionaire fails to make full beneficial use of the water for a consecutive period of two years. *Id.*

[88] *Id.* at Art. 9.

[89] *Id.* at Art. 33.

[90] *Id.* at Art. 72.

different ministerial bodies that either predated it or were created by the 2002 law. These amendments have not been passed, so it is not possible to speculate on their impact on the water allocation law or the other issues covered in this chapter. The only area for which reliable information on the proposed amendments is available regards the division of administrative duties, a topic addressed in the institutional section of this chapter.

The 2002 Yemen framework water law provides guidance on allocation of groundwater and of water between catchment basins or zones. However, the law says little about surface water. Article 5 of the law does provide that the wadis are property in common to all beneficiaries. Thus, all water installations and water wells set up by the government are considered public property and require a license. However, these requirements are the extent of the regulation for surface water allocation.

What is interesting is that the law considers allocation among basins and provides specific guidance as to when these transactions might occur. Under certain conditions (listed in the law), after reviewing all possible options and alternatives, the National Water Resources Authority (NWRA) may permit the pumping of specific volumes of ground or surface water from one basin to another on a temporary or permanent basis. The six conditions are that:

1. Conveyance does not damage the potable and domestic water. Furthermore, it creates no future adverse effect on quantity and quality of the water in the basin or zone from which it was conveyed.
2. Water is conveyed only for drinking and domestic uses in the recipient region.
3. Water in the recipient basin is either insufficient to meet the needs due to the shortage of the water there, or unsuitable for drinking after all other uses have been suspended.
4. Coordination and consultation have taken place with the local authorities, water basin committees, and actual beneficiaries of the water basin from which the water is conveyed.
5. If conveyance of water damages any existing interests of beneficiaries (the holders of use rights), such damages will be compensated fairly and only once.
6. In some cases, several possible source basins exist, and the economic costs of conveyance from all or some of these basins is close

to the cost of conveyance from a single basin, In these cases, due consideration shall be given to drawing the required quantities of water from more than one source to distribute the effects of drawing water among the basins accordingly.

The licensing regime for groundwater is discussed in the groundwater section.

Transfer of Water Rights

Generally, every country reviewed for this study allows the transfer of water rights, but the mechanisms vary. In Jordan, all natural or juridical bodies may sell or transfer water from any source only with advance written approval from the ministry. The conditions of the sale or transfer will be included in a contract between the transferring party and NWRA.[91] In Lebanon, water rights are transferable by sale or inheritance, provided they have been recorded in the Land Register and were acquired before the 1926 Decree 320. Yemen provides for the transfer of all traditional or vested rights (natural springs, streams, brooks, creeks, and maintained surface wells that do not exceed a depth of 60 meters).[92]

Many countries tie the transfer of land to the transfer of water rights. In Tunisia, if the land on which a water right exists is sold, the water use right is transferred with the land. The new landowner must notify the ministry of the transfer within six months of the land sale.[93] In Yemen, if the land upon which a water right exists is partitioned, the rights are apportioned by land area.[94] In Morocco, when an irrigated landholding is transferred, the water use permit passes automatically to the new owner. He or she must declare this transfer to the Catchment Basin Authority within three months of the change.[95] If a water permit is held separately from a land holding, for the transfer to comply with the law, the buyer must own agricultural land to which the water rights can be attached.[96] Any transfer of a permit effected separately from the holding for which it was granted is null and void and, in

[91] Jordan Water Authority Law (#18/1988), Art. 25.
[92] Yemen Water Law (#33/2002), Art. 29.
[93] Tunisia Water Code (1975), Art. 23.
[94] Yemen Water Law (#33/2002), Art. 29.
[95] Morocco Water Law (#10/1995), Art. 40.
[96] *Id.* at Art. 9.

effect, revokes the permit.[97] Furthermore, the holders of vested rights over water, or over water they use only partially for their land, are required to assign all or part of the rights that they do not use to either individuals or juridical persons who own agricultural holdings that can benefit from the water.[98]

Water Pricing

In the Islamic world, this segment of water law is perhaps the most difficult to implement due to the right of *shafa* ("drink") for every Muslim and his or her livestock. The Shi'ites believe that water may be transferred or sold on a volumetric basis but not *in globo*. However, several Sunni branches are not as open to selling or transferring water. The Hanifites and Hanbalites allow only the sale of water from receptacles. In contrast, the Shafi'ites and the Malakites follow the principle that the owner of a water supply may sell and dispose of it at will, except water in a well dug for livestock.[99] Clearly, these policies allow persons to sell water from private sources. Many MNA countries charge water user fees for public water.

Egypt

Egypt does not charge for the water itself. However, the law envisages that the state should recover the cost of all of the money expended in administering the water. MWRI is to accomplish this by preparing an inventory of expenditures for drainage and then adding 10 percent for administrative costs. These costs are to be shared proportionally among beneficiary land owners.[100] MWRI is to impose fees on the use of government-owned water intakes, pumps, and drains.[101] In addition, anyone who draws from a government-owned pump should pay for that water if it is not meant for agricultural use.[102]

Jordan

Jordan has a fairly well-developed system of water charges. It charges for the base resource as well as processing fees for ground-

[97] *Id.* at Art. 40.
[98] *Id.* at Art. 10.
[99] Caponera, 20.
[100] Concerning the Issue of the Law on Irrigation and Drainage (Law #12/1982), Art. 32.
[101] *Id.* at Arts. 49, 53, and 73.
[102] *Id.* at Art. 74.

water.[103] First, a series of fees are levied for drilling licenses, drilling permit renewal, well deepening, well maintenance, and possession or use of a drilling rig.[104] The prices levied annually for water abstracted from private sources are fixed by law. There is no charge for water use under 150,000 m^3/yr. There is a 25 Fils charge/m^3/yr from 151,000–200,000 m^3/yr, and a 60 Fils charge/m^3/yr for over 200,000 m^3/yr.[105]

Prices also are fixed for water extracted annually from government-owned wells, for industry-owned wells, for wells used for tourism or university purposes, and for active unlicensed agricultural wells whose status will be rectified under the law.[106] There is a charge of 250 Fils per m^3 for the sale of water from wells designated as drinkable water, as well as a lesser charge for water extracted from wells designated as nondrinkable.[107] Finally, the law provides for charges imposed by the government for services rendered in supervision, technical field inspections, and other monitoring activities.[108]

Lebanon

Lebanese law holds that beneficiaries and users of household, irrigation, and industrial water are subject to an annual contribution fixed by, or in proportion to, their water use. However, as in many of the countries reviewed in this region, these fees were fixed by law, making readjustment very difficult. As a result, almost all of the water charges are outdated and do not reflect the full cost of the water. However, this legal lag does not take away from the extraordinary commitment by many of the countries in the region to encourage controlled water use through water fees.

Morocco

In Morocco, any individual or juridical person using public domain water is required to pay a water user fee. It is unclear whether the regulations

[103] In Jordan, as mandated by the Underground Water Control By-Law, the financial resources of the Authority consist of (among others), revenues from water prices, subscriptions, deposits, and other fees the Authority may collect for its services. Underground Water Control By-Law (#85/2002), Art. 15.

[104] *Id.* at Art. 37.

[105] *Id.* at Art. 38. It is interesting to note that water extracted from the Al-Azraq-area licensed wells that fall within specified quantities are free. Charges for withdrawals up to and then exceeding 100,000 m^3/yr incur two separate costs. *Id.*

[106] *Id.*

[107] *Id.*

[108] *Id.* at Art. 39.

have been passed that would govern the collection and quantification of the fees.[109] Collection of fees can be enforced against either the owner or the operator of a water intake (jointly and severally liable).[110] Tunisia also provides for water use fees for authorizations or concessions not declared of a public nature. Charges are calculated based on the volume of water granted in the agreement.[111]

Management of Water Pollution

The law on managing water pollution is very rich in some countries. Egypt, Jordan, Morocco, and Yemen are at the forefront.

Egypt

The basis for the protection of surface and groundwater may be found in the Protection of the Nile from Pollution Law (#48/1982). Under it, MWRI is responsible for licensing wastewater discharge, and the Ministry of Health is responsible for monitoring effluents. Only the discharge of treated effluent is permitted, and treated wastewater from animal or human sources can be discharged only into nonpotable water.[112] Water quality standards are provided in the Executive Regulations to Law 48 for 5 categories of water bodies. Finally, the law establishes a fund to be supported by fines and cost recovery mechanisms that can be used for water administration, donations, research, and rewards.[113]

Jordan

Jordan has an extensive group of laws and regulations that govern water pollution. The identification of pollutants and their use and disposal are governed under two laws: (1) Protection of the Environment Law (#13/1995) and (2) Environment Protection Law (Temporary Law #1/2003). Under the 1995 law, the dumping, disposal, or piling up of any substance that is detrimental to the environment (solid, liquid, gaseous, radial, or heat in water sources) is prohibited. Storing any of these substances within a specified proximity to water sources also is

---

[109] Morocco Water Law (#10/1995), Art. 37.
[110] *Id.*
[111] Tunisia Water Code (1975), Art. 63.
[112] The law also calls for the regulation of weed control and waterway pollution by agrochemicals.
[113] Egyptian National Water Resources Plan (June 2004), 17.

prohibited. However, the law provide exceptions for certain substances: those used to treat pollutants, to fight epidemics (including weeds, flies, and rodents—all within approved specifications), and to carry out experiments or research.[114]

The 2003 law expands upon the provisions of the 1995 law with articles that address the importation, use, storage, and disposal of environmentally detrimental substances.[115] This law also provides that any owner of a factory or workshop, or any person who practices any activity that negatively impacts the environment, should install devices to prevent or reduce the diffusion of such pollutants to meet the standards established by the ministry.[116] In addition, this law entitles the minister to require any legal entity or party to prepare an environmental evaluation of its activities prior to the law's coming into force.[117] A set of penalties applies to any violations of the law.[118]

One other large body of law deals with the collection and treatment of wastewater. A Law on Public Health provides the basic framework for establishing the wastewater network in Jordan.[119] Supporting this law is a major Wastewater Regulation (#36/1994), which provides the regulations for the disposal of wastewater. Under the law, it is prohibited to dispose of waste and liquids (with some noted exceptions) into the public watercourse without having treated the water and acquired a written approval from the Water Authority. The law also governs the management of public and private wastewater disposal with provisions mandating connection to public systems at a cost to the user. As would be expected, the Water Authority is entitled to act on any violation through fining or even blocking a watercourse to prevent further pollution.[120]

As with the other water issues discussed previously, Jordan maintains a slightly different regime for the Jordan Valley. Articles of the Jordan Valley Development Law ban the importation of certain chemicals. The authority is given the ability to monitor water pollution through periodic testing. The authority also possesses the right to cut off or alter water sources that have been polluted to

[114] Jordan Protection of Environment Law (#13/1995), Art. 26.
[115] The Environment Protection Law for Jordan (#1/2003), Arts. 6 and 11.
[116] *Id.* at Art. 13.
[117] *Id.*
[118] *Id.* at Art. 17.
[119] Jordan Law of Public Health (#21/1971).
[120] Jordan Wastewater Regulations (#36/1994).

prevent further damage. A series of penalties are made available for enforcement.[121]

Morocco

The Moroccan framework water law empowers the administration to prescribe quality standards for water according to its use. Wastewater and polluted water are distinguished and treated separately.[122] Any person seeking to discharge effluents into surface or groundwater must apply for a permit with the Catchment Basin Authority. Thirty days are allowed for public inquiry, after which the permit may be issued for a fee.[123]

The law outright forbids seven distinct activities such as dumping wastewater or solid waste into dry wadis, dug wells, or water sources; and washing linens or food products in water supply sources.[124] The Catchment Basin Authority is authorized to periodically monitor the point source.[125] The Authority may take any appropriate actions against any nuisance that could affect public health or safety.[126]

The law also governs any kind of excavation or works that might affect a watercourse and, in a number of instances, calls for formal authorizations from the Authority. Certain acts that might damage a watercourse or its banks are prohibited.[127]

Yemen

Yemen also has a permit system in place, under the framework law, for any activity that changes the physical or chemical characteristics of water.[128] All entities that dispose of liquid, solid, radiation, thermal, or lubricant wastes must follow executive regulations (not yet in force) and the framework law regarding their transport, handling, and disposal. Special regulations (also not yet in force) will apply to the Protected Water Zones, which are determined by NWRA. The Authority also is empowered to protect all water resources from pollution. Last, NWRA monitors water quantity and quality.[129] NWRA is free to alter or change

---

[121] The Jordan Valley Development Law (#30/2001).
[122] Moroccan Water Law (#10/1995), Art. 51.
[123] *Id.* at Art. 52.
[124] *Id.* at Art. 54.
[125] *Id.* at Art. 56.
[126] *Id.* at Art. 55.
[127] *Id.* at Art. 12.
[128] Yemen Water Law (#33/2002), Art. 24.
[129] *Id.* at Art. 59.

any permit in cases in which circumstances changed after the permit was issued and for which continued operation under the permit would cause damage.[130] The National Water Supply and Sanitation Authority (NWSA) is called on to regulate the disposal of industrial wastes, fertilizer, and pesticides; and other hazardous substances.[131]

Flood Control

Given the fact that most surface water sources (such as wadis) are fed seasonally, provisions for flood control have been made in several countries. In Morocco, the protection of public property is the only purpose for which the construction of submersible lands, dikes, or levees to hinder floodwater runoff does not require a permit.[132] The Catchment Basin Authority is entitled to construct any dike or other structure if doing so is in the public interest to prevent flooding.[133] Under Tunisian law, permits granted for water use may be forfeited or varied in case of flood.[134] The Yemen Water Law grants the Ministry of Agriculture and Irrigation the responsibility for controlling and regulating rainy areas that get rainwater runoff and flooding, their related collections areas, and the water flow and drainage passages. The ministry also is called on to prepare a plan for rainwater runoff and flood drainage outlets, and to collaborate with other related entities and local authorities in executing this plan. The law further provides several provisions on erosion control, including protecting agricultural terraces.[135]

Egypt has in place a somewhat unique flood control legal regime. The Irrigation and Drainage Law is clear in granting the government immunity from any fault for flood damage to lands or infrastructure neighboring the Nile or main canals.[136] Because flooding can happen quickly, several people are authorized to gather citizens to prevent breaches of the banks of the Nile or main canal. The people empowered to organize flood prevention teams include the chief engineer and the

---

[130] *Id.* at Art. 58.

[131] *Id.* at Art. 54.

[132] Morocco Water Law (#10/1995), Art. 94.

[133] *Id.* at Art. 96. The law also provides a special provision for agricultural land, stating that the government may execute works necessary for the protection of property and utilization of water on such lands. *Id.* at Art. 85.

[134] Tunisian Water Code (1975), Art. 72.

[135] Yemen Water Law (#33/2002), Art. 61.

[136] Concerning the Issue of the Law on Irrigation and Drainage (Law #12/1982), Art. 6.

mayor or community leader.[137] MWRI also is entitled to take action when water levels are high.[138]

Penalties

The enforcement of water laws can be accomplished through a system of both carrots and sticks. It appears that the majority of countries in the region have opted more for the stick (command and control regulation) than the carrot approach. Every country except Egypt provides for the possibility of both imprisonment and/or fines. The penalties are meted out for violations of the laws that affect both the quality (antipollution provisions, effluent standards, permitting, implementation of best available technology) and quantity (drilling without a permit, illegal use of water) of the resource.

Most countries include the penalties within the water legislation, but Lebanon has chosen instead to include all of the pollution control penalties in the penal code. Several countries, such as Morocco, have opted to leave many of the specifics as to fine amounts and terms of imprisonment to regulations. The majority of the other countries provide specific maximum and/or minimum penalties for every offense. In the majority of countries, the lead water authority is charged with the enforcement of all penalties. However, Morocco takes a unique approach by calling on the police force, agents commissioned by the administration, and the Catchment Basin Authority to enforce the laws after swearing to uphold the law.[139]

Planning and Development and Information

The importance of long-term planning in the water sector has come into greater importance only in the last decade as water shortages coupled with dramatic increases in demand have captured the attention of policymakers. Only the most recent framework laws in the Middle East and North Africa region include any significant coverage of planning for the water sector. Both Yemen and Morocco have developed significant legal frameworks for planning. However, as with enforcement, the larger issue is really how well the law is applied.

---

137 *Id.* at Arts. 78–80.
138 *Id.* at Art. 77.
139 Morocco Water Law (#10/1995), Art. 114.

Although information gathering is critical for planning, almost no law includes any significant attention to providing a structure to gather information and translate it into plans for the short, medium, and long term.

Morocco

The catchment basin is the chosen planning and organizational unit.[140] Under the water law, the administration is responsible for developing integrated water resources development master plans for each catchment basin or group of catchment basins.[141] These plans are designed to last for 20 years. The opportunity for revision is available every five years or if there are exceptional circumstances that require a change. Regulations govern the procedures for revision.[142] The law provides specifics as to what each integrated development master plan should include:

1. Territorial boundaries of basin(s) to which it applies.
2. Assessment and development, in both quantity and quality, of water resources and needs within the basin.
3. Plan for water-sharing among the various sectors of basin and chief water usages therein. Where appropriate, this plan shall specify which surplus water quantities may be transferred from one basin to another.
4. Operations required for harnessing, distributing, protecting, and restoring water resources and public water domain, notably water infrastructure.
5. Quality goals and deadlines and required measures for achieving them.
6. Priority ranking to be applied in water-sharing pursuant to point(3) above, and measures required to cope with exceptional climatic conditions.
7. General scheme of water development of basin required to ensure conservation of resources and their adaptation to needs.
8. Safeguarding and interdiction perimeters.
9. Special conditions of water utilization, notably those relating to its optimal use, preserving its quality, and combating waste.[143]

[140] *Id*. at Art. 15.
[141] *Id*. at Art. 16.
[142] *Id*. at Art. 17.
[143] *Id*. at Art. 16.

The administration also is responsible for developing a National Water Plan based on the results and conclusions of the catchment basin integrated water resources development master plans. The national plan is approved by decree after consultation with the Council for Water and Climate. The national plan is prepared for at least 20 years, with the possibility of revision every 5 years. The law provides the specifics of what the national plan should cover, including national priorities, timetable and program for completion of all works, linkages to land-use development plans, support measures including education and grassroots work, and the conditions for transferring water among catchment basins in times of shortage.[144]

Yemen

In Yemen, the water planning units are water basins and water zones.[145] The NWRA is responsible for all planning. It is charged with developing a classification system for water basins and water zones; and determining indicators of the water situation; trends for demand; and short-, medium-, and long-term water budgets.[146] The law provides that NWRA must develop water plans for each water basin and water zone. After they are ratified by the Council of Ministers, these plans become part of the National Water Plan.[147] The process for gathering the standards, data, and measures used to develop the unit plans is governed in separate executive regulations. However, the law does provide a list of what should be included in these plans.[148] Priority is given to critical water basins or zones by preparing these plans first.[149] Water plans are binding on everyone, and acting outside of their guidelines or contrary to their stipulations is forbidden under the law.[150]

Coordination of the National Water Plan is important, because two other ministries are responsible for issuing plans in the water sector. The Ministry of Agriculture and Irrigation is charged with preparing and implementing plans and programs related to the control of wadi flows and general canals, monitoring rainwater runoff and floods, and overseeing the use of irrigation water and installations.[151]

---

[144] *Id*. at Art. 19.
[145] Yemen Water Law (#33/2002), Art. 13.
[146] *Id*. at Arts. 13–14.
[147] *Id*. at Art. 16.
[148] *Id*. at Art. 17.
[149] *Id*.
[150] *Id*. at Art. 19.
[151] *Id*. at Art. 25.

The Ministry of Electricity and Water is responsible for preparing policies and executive plans for the water and sanitation sector.[152] To facilitate cooperation among these plans, the National Water Plan is considered one of the components of the economic and social development plans of the government, thereby suggesting that it reaches the highest levels of Government.[153] NWRA is charged with reviewing other sectoral plans and coordinating with relevant concerned entities before preparing the National Water Plan.[154]

Wastewater Reuse

Wastewater reuse is of tremendous potential importance for the region. It can serve as additional supply for irrigated farming and groundwater injection, thereby reducing groundwater overdraws that plague many MNA countries. Fortunately, many countries have in place provisions to govern the handling, and in particular, the reuse of wastewater. Jordan, Morocco, Oman, and Yemen have included wastewater reuse provisions in their laws.[155]

Jordan

Under the Reclaimed Domestic Wastewater Standard Specification (Standard No. 893/2002), the reuse of reclaimed water to replenish artificial groundwater is allowed if its quality meets agreed standards. However, using groundwater replenishments for aquifers used for drinking is forbidden. Reclaimed water is prohibited in irrigating vegetables eaten raw and in sprinkler irrigation. Irrigating fruit trees with reclaimed water must be stopped two weeks prior to harvest time. The uses for reclaimed water allowed by the law are split into three different classes, each requiring different quality standards:

1. Field crops, industrial crops, and forest trees
2. Fruit trees, sides of roads outside city limits, and green areas

---

[152] *Id.* at Art. 26.
[153] *Id.* at Art. 19.
[154] *Id.* at Arts. 15 and 17.
[155] Egypt has a small provision in Concerning the Issue of the Law on Irrigation and Drainage (Law #12/1982) that states that drainage water may not be reused for irrigation unless MWRI issues a license. The reuse must be in accordance with the conditions of the permit. Art. 46. The Protection of the Nile from Pollution (Law #48/1982) regulates the reuse of drainage water.

3. Cooked vegetables, parks, playgrounds, and sides of roads within city limits.[156]

Morocco

The central administration is charged with prescribing the conditions for the use of wastewater. Any use of wastewater requires an authorization granted by the Catchment Basin Authority.[157] The use of wastewater for agricultural purposes that do not meet the standards set in regulation is prohibited.[158] To encourage the proper reuse of wastewater, users are entitled to government financial assistance and technical assistance from Authority if the use achieves water economies and preserves water resources against further pollution.[159]

Yemen

The Ministry of Electricity and Water is responsible for the treatment and disposal of wastewater in accordance with a uniform system that conforms to qualitative and environmental standards.[160] However, the reuse of wastewater is allowed only after coordinating with NWRA and other affected populations nearby.[161] NWRA is responsible for issuing the reuse permits for treated wastewater that must meet specific conditions, standards, and specifications described in separate regulations.[162]

Oman

Under Ministerial Decree (#5/1986) on Regulations for Wastewater Re-use and Discharge, it is permitted to reuse wastewater in four situations: (1) a buried drip-feed system to irrigate ornamental trees and shrubs in areas in which there should not be public exposure; (2) approved groundwater recharge areas in which there should not be public exposure (may include open lands or wadis); (3) reuse of treated effluent for industrial processes within a closed-circuit system that will pose no dangers to the workers; and (4) flood, hosepipe,

---

[156] The Reclaimed Domestic Wastewater Standard Specification, Jordanian Standard, No. 893/2002.
[157] Morocco Water Law (#10/1995), Art. 57.
[158] *Id.* at Art. 84.
[159] *Id.* at Art. 57.
[160] Yemen Water Law (#33/2002), Art. 26.
[161] *Id.*
[162] *Id.* at Art. 47.

sprinkler, or spray irrigation, on condition of prior consent from the ministry. The full details and nature of reuse of treated effluent for industrial purposes within a closed circuit system are provided in the permit for discharge.[163] Wastewater quality requirements for reuse and discharge are provided in table I of the Ministerial Decree (#5/1986). The reuse of wastewater or sludge containing radioactive material is not permitted.[164]

The law provides specific instruction as to how owners of wastewater treatment plants should handle and transport sludge. Each is required to keep a detailed record specifying at least (1) date of delivery; (2) name and address of contractor or user of sludge; and (3) quantity delivered.[165] These regulations do not apply to owners of septic tanks and holding tanks, as they are subject to a separate set of regulations (not available).[166] Finally, if wastewater or sludge is used in a manner outside the stated limits and represents a risk to public health, the ministry or approved authorities reserve the right to inspect, record, and request samples and tests in accordance with a separate royal decree (#10/1982).[167]

Groundwater Management

All of the countries reviewed in this study require some form of authorization for drilling new wells, but this is their only similarity. Only Jordan[168] and Yemen[169] have laws with provisions for registering preexisting wells. Yemen,[170] Morocco,[171] and Lebanon[172] do not require well permits unless the well will exceed a certain depth. Jordan requires a permit for all well-drilling activities regardless of depth.[173] Jordan[174]

---

[163] Oman Ministerial Decree (#5/1986) on Regulations for Wastewater Re-use and Discharge, Art. 6.

[164] *Id*. at Art. 15.

[165] *Id*. at Art. 11.

[166] *Id*. at Art. 14.

[167] *Id*. at Art. 13.

[168] Jordan Underground Water Control By-Law (#85/2002), Art. 41.

[169] Yemen Water Law (#33/2002), Art. 33.

[170] *Id*. at Art. 29. A permit is required only for drilling over 60 meters. *Id*.

[171] Morocco Water Law (#10/1995), Art. 26. The minimum depth at which a permit is required is to be fixed by regulation. *Id*.

[172] Lebanon Decree No. 14438, Art. 2. Under this article, a permit is required only for drilling over 150 meters. *Id*.

[173] Jordan Underground Water Control By-Law (#85/2002), Art. 8.

[174] *Id*. at Arts. 31–33.

and Oman[175] are the only countries to require a license for professional drillers. Jordan also requires a license for drilling rigs.[176] Given these significant differences, each country's legal approach to groundwater management is detailed individually below.

Egypt

In accordance with relevant regulations, a license from MWRI is required to dig any groundwater well (shallow or deep) within national lands.[177] For desert lands, Special Law #143/1981 applies. This law requires that a license must be obtained from MWRI, but only after meeting the approval of the Ministry of Agriculture and Land Reclamation.[178]

Jordan

Jordan maintains perhaps the most complete and extensive legal framework for managing groundwater resources. The central piece of legislation is the Underground Water Control By-Law (#85/2002).[179] This by-law governs the permitting system for drilling any new well;[180] deepening, cleaning, or maintaining existing wells;[181] digging substitute wells;[182] and licensing drill operators and drilling rigs.[183] In addition, a system to register and monitor preexisting wells[184] and provisions governing the use of underground water and the transfer or sale of wells are in place.[185]

Under the by-law, the ministry is charged with performing the technical studies for all underground water resources, including any exploratory activity; monitoring the quality and quantity of the resource;

---

[175] Oman Ministerial Decision (#2/1990), Arts. 21–28.

[176] Jordan Underground Water Control By-Law (#85/2002), Art. 34.

[177] Egypt Concerning the Issue of the Law on Irrigation and Drainage (Law #12/1982), Art. 46.

[178] *Id.*

[179] Without violating the provisions of the Jordan Valley Development Law in force, the rules governing the construction of public and private water wells, methods of using the underground water extracted therefrom, and quantities thereof are determined by regulatory decisions issued by the Board upon the submission by the minister. *Id.* at Art. 7.

[180] *Id.* at Arts. 8–31.

[181] *Id.* at Art. 28.

[182] *Id.* at Art. 27.

[183] *Id.* at Arts. 31–35.

[184] *Id.* at Arts. 40–42. However, there is no provision as to the creation of a cadastre for preexisting wells.

[185] *Id.* at Arts. 11–12.

and identifying the appropriate uses of these resources.[186] On the submission of the minister, a board determines the maximum quantity of underground water permitted to be extracted annually from each groundwater basin, within the limits of safe yield. With board approval, the Council of Ministers can identify areas in which drilling is prohibited, provided such resolutions are published in the "Official Gazette" and two local newsletters.[187] The Water Authority is responsible for administering all of the permitting procedures.[188]

The drilling permit system has the following key provisions. First, before granting a permit, the Water Authority is required to carry out a pumping test before the well may be used. The test measures the well production capacity and water quality to determine the amount of water that can be extracted annually, and the possible uses for the resource.[189] After the study performed by the Authority, the application for the drilling license may be submitted. It must include a recent real estate deed for the relevant plot of land. The secretary general publishes the application in two publications at the licensee's expense. Any person has 15 days within which to raise an objection. After the expiration of this period, the secretary general presents the application to the board for final decision. If approved, the minister issues the drilling license,[190] which contains the specifics, including the permitted depth. The license is valid for one year, renewable by decision of the

[186] *Id.* at Art. 4. The competent officials nominated by the minister or secretary general have the right to enter any land for conducting studies or investigation or collection of information related to underground water or for carrying out any measures related to the by-law. *Id.* at Art. 6. The law requires that any landowner who discovers water seeping up on his or her land notify the secretary general in writing within seven days of the discovery. *Id.* at Art. 15.

[187] *Id.* at Art. 6. An exception occurs when ministries, governmental departments, official institutes, universities, and the industry and tourism sectors find it impossible to secure their water needs from the public water supply network. In this case, the Board may grant any of them a license to drill wells in the prohibited areas pursuant to the provisions of the by-law. *Id.* at Art. 6.

[188] No drilling licenses may be granted in the Jordan Valley areas without consultation with the Jordan Valley Authority. *Id.* at Art. 22. The board also retains the right to reject any drilling license application if the public interest requires it. *Id.* at Art. 23.

[189] *Id.* at Art. 9. This process must be completed within six months of receipt of the permit application. *Id.*

[190] There are certain limitations to granting drilling permits: (a) the distance between drilling permits granted can not be less than one km (Art. 25); (2) granting more than one license per plot of land is prohibited (Art. 30); (3) a drilling permit may not be given to anyone who holds a valid drilling license for another well that has not been completed (Art. 21); and (4) any person who has violated this by-law more than once is no longer eligible for a drilling permit (Art. 21).

minister. The license is deemed cancelled if drilling is not completed within the established time.[191]

Each drilling permit has a series of other conditions that apply, some of which are listed below:

- Licensee is prohibited from undertaking any activities that could cause pollution or deplete the resource.[192]
- Owner or the possessor of a private well is prohibited from (1) irrigating any land other than that specified in the water extraction license or selling this water for irrigation; and (2) selling the water extracted from the well by water-tankers for drinking or any other purpose without obtaining a prior written approval from the secretary general, or his delegate, and according to conditions outlined for this purpose.[193]

On the submission of the secretary general, the board may cancel a drilling or extraction license if the licensee violates any of the license conditions, or if the public interest so requires.[194] In addition, the secretary general may take any of the following measures: (1) backfill any well drilled without a license in pursuance of the provisions of this bylaw; (2) backfill any well whose owner did not abide by the conditions of the license granted thereto. The offender must bear the costs of rectifying these violations. Should the offender not rectify the offense, the license is cancelled.[195]

Every owner of a drilling permit also must obtain a license for water abstraction from the secretary general or a delegated authority. Eight conditions are required to be included in the application:

1. Maximum amount of water that may be extracted from the well within a fixed period.
2. Purpose of water use.

[191] *Id.* at Art. 21.

[192] *Id.* at Art. 10. If any areas were found to be polluted or depleted, the board should take a decision to set the appropriate measures that would end such pollution or depletion and restore the natural balance to the aquifer or the underground water basin. Such measures could include the rationalization or reduction of the extraction rate. *Id.* at Art. 16.

[193] *Id.* at Art. 11.

[194] *Id.* at Art. 17.

[195] *Id.* at Art. 18.

3. Maximum area that may be irrigated using water from the well licensed for agricultural purposes.
4. Installation, at the expense of the well owner, of a water meter that has been approved and stamped by the Authority. This condition should be met prior to the issuance of the water extraction license.
5. Notification of the Authority within a period not exceeding 48 hours in case of nonfunction of the water-meter. The owner of the well shall reimburse the Authority for the fixed maintenance expenses.
6. Taking no measure that impedes the flow of water from the well directly to the water meter that will measure it.
7. Obligation of the licensee to pay to the Authority, in time, the prices fixed for the extracted water.
8. Maintaining by the licensee of a register, approved by the Authority, in which all data relating to the well and extraction shall be registered regularly in accordance with instructions issued by the Authority.[196]

A license for drilling operators may be obtained from the secretary general. It is valid for one year and renewable for the same period.[197] In turn, the Authority is required to keep official records of rigs and drillers and all activities related to the profession.[198] Licenses granted for drilling rigs themselves are obtained from the Authority. It is prohibited to transfer a drilling rig to a different site without an additional permit.[199]

Lebanon

Citizens may prospect for groundwater, provided an application is made to the administration[200] for any well that will exceed 150 meters.[201] Decree #14438/1970 provides details of what should be included in the application. Specifics include the location and aim of the works, copy of the land registry, and survey maps.[202] After the application

[196] *Id.* at Art. 29.
[197] *Id.* at Art. 34.
[198] *Id.* at Art. 35.
[199] *Id.* at Art. 36.
[200] Lebanon Decree #320/1926, Art. 6.
[201] Lebanon Decree #14438/1970, Art. 2.
[202] *Id.* at Arts. 3–4.

has been presented, the Directorate General for Equipment within the Ministry of Water Resources and Electricity examines the permit and makes a recommendation to the minister.[203] Once granted, the proposal will provide the specifics as to the location of the well, modes of prospecting, data required for collection, and determination of taxes to be paid by the applicant.[204]

Any use of underground water that did not result from the drilling of a well is governed by a decree that grants temporary occupation of four years.[205] The decree includes information on the nature of the use, number, and size of the properties concerned; maximum authorized quantities; and required equipment and installations.[206] A permit is not required for the use of water from a drilled well on private property if the use does not exceed 100 m^3 per day and the water does not come directly from a river or water course.[207]

Morocco

Under the Morocco Water Law, a license is required to drill any well that would exceed a depth to be determined by regulation.[208] Any person wishing to drill a well may approach the administration for information as to the technical, hydrological, and hydrogeological characteristics of the proposed site. Authorizations are granted by the Catchment Basin Authority.[209] After receiving the authorization, the well driller is required to provide the Authority with any data required and to permit the Authority to enter on his/her property at any time to do so.[210] One of the most interesting provisions deals with safeguard perimeters in areas in which groundwater levels appear to be low. Within these perimeters, prior authorization is required to drill, reconstruct wells, and/or extract water.[211] Some exceptions might be made in the case of severe shortages, but the water extracted could be used only for consumption by people or livestock.[212]

---

[203] *Id.* at Art. 5.
[204] *Id.* at Arts. 6 and 10.
[205] *Id.* at Art. 11.
[206] *Id.* at Arts. 15–16.
[207] *Id.* at Art. 13.
[208] Morocco Water Law (#10/1995), Art. 26.
[209] *Id.* at Art. 89.
[210] *Id.* at Art. 92–93
[211] *Id.* at Art. 49.
[212] *Id.* at Art. 50.

Oman

The Ministry of Water Resources is charged with specifying the water quantity discharged from any well and is responsible for monitoring the use through well meters issued to each well owner. These meters are the responsibility of the well owner, who must keep them in working order.[213] Permits may be granted to landowners for any groundwater exploration activities. These include the construction of a new well, modifications to an existing well, change in the use of an existing well, or installation of a pump in a borehole.[214] The permit holder must register his/her well permit to obtain a Well Registration Certificate and a Well Registration Plate, to be placed on the well. To register, the responsible authority must verify that the permit holder has complied with the conditions set in the permit.[215] At any time, Ministry of Water Resources staff may enter the property of a permit holder to inspect, take samples, or carry out tests.[216]

No well construction, development, maintenance, modification, yield testing, or pump installation on boreholes may be carried out except by a government-registered contractor.[217] Contractors are classified into categories that reflect their technical capabilities and qualifications.[218] Registration is valid for one year and subject to renewal.[219] The contractor is responsible for making sure that any well s/he works on has a permit.[220]

Tunisia

Groundwater exploration activities are subject to an authorization.[221] In contrast, the extraction and use of groundwater are subject to a concession.[222] Detailed provisions on groundwater are said to be set by a specific decree (not available).[223]

---

[213] Oman Ministerial Decision (#2/1990), Art. 5.
[214] *Id.* at Art. 7.
[215] *Id.* at Art. 16.
[216] *Id.* at Art. 14.
[217] *Id.* at Art. 17.
[218] *Id.* at Art. 21. Note that a contractor can appeal any refusal for certification. *Id.* at Art. 22.
[219] *Id.* at Art. 23.
[220] *Id.* at Art. 28.
[221] Tunisia Water Code (1975), Art. 52.
[222] *Id.* at Art. 53.
[223] *Id.* at Art. 75. It is not clear whether this decree has been passed and, if so, what provisions it includes.

Yemen

The Water Law provides a licensing regime to control drilling and to classify drilling operators, and provisions to control the equipment used in drilling wells. Under the drilling permit system, a permit is required for any well that will exceed a depth of 60 meters.[224] To deepen a well, no permit is required if it is the first time and the depth does not exceed an additional 20 meters.[225] All procedures for the administration of the permit process are to be detailed in regulations yet to be formulated. However, there is some guidance on how to register the wells. Holders of permits to drill wells must approach the NWRA within three months of completing the authorized works to register the wells. Well owners acquire their water rights within 15 days of presenting the application.[226]

Contractors and engineering offices must obtain a permit from the NWRA for three activities: (1) drilling water wells; (2) exploring for groundwater, executing consultancy studies, and carrying out works in the field of water resources: and (3) distributing well waters, whether directly or indirectly, through private supply networks or by bottling it.[227] Any natural or legal person must register her/his offices or firms with the NWRA to obtain a license to undertake any groundwater exploration activities.[228] In addition, all important drilling rigs or water well metal casings must meet specifications issued by the NWRA.[229]

Institutional Arrangements

Jordan

In 1992 the Administrative Organization for the Ministry of Water and Irrigation Law (#54/1992) consolidated the previous administrative system under one ministry. According to the law, the Ministry of Water and Irrigation, Water Authority, and Jordan Valley Authority all come

---

[224] Jordan Underground Water Control By-Law (#85/2002), Art. 29.
[225] *Id.* at Art. 35.
[226] *Id.* at Art. 39.
[227] *Id.* at Art. 42.
[228] Id. at Art. 42. The following activities are considered: (1) drilling water wells; (2) sites and general plans for water and irrigation installations; (3) general plans for water treatment and distillation; (4) protected wells, streams, creeks, and natural springs; (5) drilling equipment; and (6) pumps. *Id.* at Art. 46.
[229] *Id.* at Art. 44.

under the purview of the Minister of Water and Irrigation.[230] As a result, the minister assumes responsibility for WRM in the Kingdom. WRM includes the roles and responsibilities set out in the Water Authority Law (#18/1988) and the Jordan Valley Authority Law (#19/1988).[231]

Ministry of Water and Irrigation

The Ministry of Water and Irrigation consists of a secretary general, the minister's office, and six directorates. They are (1) Planning, Development and Information, (2) Financing and Loans, (3) Legal Affairs, (4) Citizens' Service, (5) Financial and Administrative Affairs, and (6) Projects Follow-up.[232] The roles of these directorates are outlined in the law.[233] The secretary general is responsible for implementing the ministry's policy and running its affairs according to the laws in force.[234] In addition, the directorates report to the secretary general, who channels the information to the minister.[235] The law creates one additional body, the Consultative Body, which is formed in the ministry and chaired by the minister. The Consultative Body's three core members are the (1) Secretary General of the Ministry of Water and Irrigation, (2) Secretary General of the Water Authority, and (3) Secretary General of the Jordan Valley Authority. Four additional members may be added, on the recommendation of the minister.[236] The consultative body is charged with providing the minister with technical, economic, legal, financial, and administrative advice on policy, water planning, and strategies.[237]

Water Authority

One of the key bodies incorporated under the Minister of Water and Irrigation is the Water Authority, created by law in 1988 as an autonomous body with financial and administrative independence. This ministry is charged with the full responsibility for all water and

---

[230] Jordan Administrative Organization for the Ministry of Water and Irrigation Law (#54/1992), Art. 3.

[231] *Id*. at Art. 4.

[232] *Id*. at Art. 5.

[233] For their duties, as described within the law, see Articles 9–16 of the Jordan Administrative Organization for the Ministry of Water and Irrigation Law (#54/1992).

[234] *Id*. at Art. 6.

[235] *Id*. at Art. 9.

[236] *Id*. at Art. 17.

[237] *Id*. at Art. 18.

wastewater systems and related projects.[238] Among the many tasks and responsibilities assumed by the Water Authority are to (1) establish plans and programs to implement water policies and exploit the resources for domestic and municipal purposes; (2) administer the licensing regime for groundwater; (3) study, design, construct, operate, and maintain water and public wastewater projects; (4) develop standards and special requirements for the preservation of water and water basins (quality and quantity); (5) carry out related research and studies on water and wastewater; (6) regulate the uses of water, prevent its waste, and conserve its consumption.[239]

The secretary general is the executing agent for the Water Authority.[240] The Authority is empowered to establish additional departments for implementing all of its duties as it sees fit. In addition, water departments are to be established in all parts of the Kingdom, with a Water Council in each department. These councils are to provide citizens and local authorities with the opportunity to participate in deciding priorities regarding water and wastewater projects and plans for implementation. Gathering from all of these sources, the Authority is responsible to submit to the Council of Ministers a report on the Authority's activities, general budget, and balance covering the preceding year.[241]

Supporting the Authority is a Board of Directors made up of related ministries' representatives. The board meets when called upon by the Minister of Water and Irrigation, who is its chairperson.[242] The board is responsible for setting water policy, approving policies and plans for the development and conservation of water, reviewing the Authority's draft regulations and submitting them to the Council of Ministers for approval, reviewing the annual budget, obtaining foreign and local loans, recommending water fees and pricing tariffs, investing the Authority's revenue, and appointing members to district Water Councils.[243]

Jordan Valley Authority

The other important body incorporated under the Minister of Water and Irrigation is the Jordan Valley Authority (JVA), created by

---

[238] Jordan Water Authority Law and Amendments thereof (#18/1988).
[239] *Id.* at Art. 6.
[240] *Id.* at Art. 12.
[241] *Id.* at Art. 23.
[242] *Id.* at Arts. 8–9.
[243] *Id.* at Art. 10.

law in 1988 under the Jordan Valley Development Law (#30/2001 as amended). The JVA is responsible for carrying out the social and economic development of the Valley, including the development of all water resources and the works associated with water use and conservation. In particular, the JVA (1) carries out studies for evaluating water resources (both surface and groundwater); (2) plans, designs, and carries out irrigation projects and related works, including dams, hydropower stations, well-pumping stations, reservoirs, distribution networks, drainage works, and flood protection works; (3) surveys and classifies soil to determine lands suitable for irrigation; (4) settles disputes on water use; and (5) organizes and directs the construction of private and public wells. In addition, the JVA is responsible for protecting and improving the environment in the Valley. The JVA's duties also extend to developing tourism in the Valley and studying and improving the agricultural road network.[244]

JVA is made up of the minister, board of directors, secretary general, executing staff, and administrative units.[245] These different groups work together in much the same way as the administration of the Water Authority.[246] Because the JVA is considered an autonomous corporate body, it, too, may raise funds; lease, purchase, and acquire land or immovable properties; and borrow through bond issues.[247] JVA also may raise funds through fees and can benefit from national or international grants or loans. All funds raised are placed in a special account in the Central Bank to be administered by a Special Treasury established by the JVA. The withdrawal of any monies is to be governed by regulation.[248] Given the relative financial autonomy of the JVA, it is responsible for a series of reports to the Cabinet of Ministers, including annual reports on works undertaken or completed, audits, future planned works or projects, and any other data requested by the Cabinet.[249]

Relevant ministries and coordination

Two ministries share the responsibility for managing potable water and protecting water quality. The Ministry of Health is charged with the

---

[244] Jordan Valley Development Law (#30/2001 as amended), Art. 3.
[245] *Id.* at Art. 9.
[246] *Id.* at Arts. 8–12.
[247] *Id.* at Art. 13.
[248] *Id.* at Art. 17.
[249] *Id.* at Art. 36.

control of potable water to ensure its fitness for human consumption.[250] In so doing, it is entitled to control (1) potable water resources and their networks to ensure that they are not affected by pollution; and (2) the method used for treating, transmitting, and storing water.[251] The Ministry of Health also is charged with managing sewage networks, including all treatment stations, to ensure that health conditions are maintained.[252]

The Ministry of Environment is the competent authority for developing all standards and specifications governing environmental protection, including water resources.[253] The Ministry of Water and Irrigation is a member of the Council for the Protection of the Environment, which is chaired by the Minister of Environment.[254] The Ministry of Environment conducts all research, issues all regulations and enforces them, prepares all emergency environmental plans, and executes all awareness-building efforts for the environment.[255]

One final government body, the Standards and Specifications Corporation, is responsible for issuing all of the standard specifications and technical rules. In addition, the corporation is responsible for supervising the application of all standard specifications.[256]

Egypt

The Ministry of Water Resources and Irrigation (MWRI) oversees all public-water-related entities but can outsource management responsibilities to other ministries or public authorities.[257] MWRI's responsibilities include the protection of Nile and Main Canal banks, O&M of all publicly owned infrastructure,[258] allocating water up to the main canals, adjudicating water rights conflicts,[259] enforcing the provisions of the Irrigation and Drainage Law (#12/1982),[260] and building and maintaining the covered drain systems.[261] Mayors and village elites are charged with

---

[250] Jordan Temporary Public Health Law (#54/2002), Art. 39.
[251] *Id.* at Art. 41.
[252] *Id.* at Art. 52.
[253] Jordan Environment Protection Law (Temporary Law #1/2003), Art. 3.
[254] Jordan Protection of Environment Law (#12/1995), Art. 6.
[255] Jordan Environment Protection Law (Temporary Law #1/2003), Art. 4.
[256] The Jordan Standards and Specifications Law (#22/2000), Art. 5.
[257] Egypt's Concerning the Issue on Irrigation and Drainage Law (#12/1982), Art. 4.
[258] *Id.* at Art. 5.
[259] *Id.* at Art. 18.
[260] *Id.* at Art .5.
[261] *Id.* at Art. 31.

protecting the industrial works for irrigation and drainage that have been handed over to them in accordance with MWRI decisions.[262]

Lebanon

At the national level, the Ministry of Energy and Water is charged with managing all water projects, applying the laws and regulations regarding the protection and use of public waters, supervising the work of 44 autonomous offices and the commissions responsible for water,[263] and controlling water concessions. The ministry is divided into two directorates: (1) Water Infrastructure and (2) Management. The Directorate for Water Infrastructure (*équipement hydraulique*) oversees the construction of all hydraulic equipment and has delegated to the 44 water offices and commissions the responsibility for distributing water to users.[264] The Directorate for Management has responsibility for overseeing the 44 water agencies (granted by decree from the state) and controls water concessions.

Decree 320 provides for the possibility of owners to enter into partnerships to undertake certain works, including flood control, clean-up and maintenance of watercourses, marsh drainage, and organizing collective irrigation. The decree provides a series of administrative procedures for creating the partnership. In over 60 years of operation, only 1 project has come to fruition.[265]

Morocco

The Moroccan Water Law establishes two government bodies that are responsible to support the government's role in managing water resources in the country. These bodies are the (1) High Council on Water and Climate[266] and (2) Catchment Basin Authority.[267] The High Council formulates the general guidelines of national water and climate policy. In particular, it is responsible for commenting on the national strategy to improve knowledge of the resources, the national water plan, and integrated WRM plans for the catchment basins.[268] Member-

---

[262] *Id.* at Art. 101.

[263] The local water offices are characterized by conflicts of jurisdiction and fractionalization. In fact, the state has begun gradually repurchasing hydraulic concessions granted to improve control of water use.

[264] Lebanon Decree No. 20 (1966).

[265] Lebanon Decree No. 320, Arts. 30–56.

[266] Moroccan Water Law (#10/1995), Arts. 13–14.

[267] *Id.* at Art. 20.

[268] *Id.* at Art. 13.

ship of the High Council includes government officials, scientific and academic communities, and community representatives.[269]

The Moroccan Catchment Basin Authority (CBA) is the most complete attempt by any country in the region to decentralize the management of water resources. Each CBA is considered a public entity with a juridical personality and financial autonomy. The responsibilities of each CBA are to:

1. Draw up the integrated water resources development master plan for its particular area of operation
2. Monitor implementation of the water resources integrated development master plan within its particular area of operation
3. Issue the public domain water usage authorizations and concessions provided for in the water resources integrated development master plan for its particular area of operation
4. Furnish any financial aid and provide any services, including TA, to public or private persons who request it either to prevent water pollution or to develop or harness public domain water resources
5. Carry out all piezometric measurements and gauge operations and all hydraulic, hydrogeological, planning, and water management studies at both the quantitative and qualitative levels
6. Perform all quality measurements and apply the provisions of current legislation on the protection of water resources and restoration of water quality, in collaboration with the government authority with responsibility for the environment
7. Propose and implement appropriate measures, particularly regulatory measures, to ensure water supply in the event of an officially declared water shortage or to prevent the risk of flooding
8. Manage and control use of the water resources harnessed
9. Build the necessary structures to prevent and combat floods
10. Maintain a register of recognized water rights and of water intake concessions and authorizations granted.[270]

The CBA is administered by a Management Board chaired by the government authority responsible for water resources. The board is responsible for (1) examining the catchment basin integrated development master plan prior to its approval; (2) studying the authority's

[269] *Id.* at Art. 14.
[270] *Id.* at Art. 20.

WRM and development programs and its annual and multiannual programs of activities prior to their approval by the governmental water resources authority; (3) drawing up the authority's budget and accounts; (4) determining pollution-related fees to specific water pollution correction measures; (5) proposing to the governmental water resources authority the charge base and rates for user fees remunerating the authority for its services; (6) drawing up the authority's personnel rules, which shall be approved in accordance with the current legislation governing public establishments' personnel; and (7) approving agreements and concession contracts entered into by the Catchment Basin Authority.[271]

At the local level, a Prefecture or Provincial Water Commission should be created to assist in the preparation of catchment basin water resources development plans, support water saving and pollution prevention activities in the municipalities, and help build public awareness.[272] Under the law, local communities can undertake partnership projects with the assistance of the CBA. These projects could include cleaning out watercourses, conserving water resources (in quality and quantity), and creating necessary flood prevention structures.[273]

Outside of these new government bodies created under law, the "administration" maintains certain responsibilities related to developing the catchment integrated development national water plan. These national water plans would result from the inputs from all of the various CBAs.[274] The law does not make it clear who the "administration" would be.

Oman

Finally, in Oman, there are two separate laws that created two entities responsible for administering the country's public water resources. This section will focus only on the more recent Ministry of Water Resources.

The Ministry of Water Resources is charged with the development and conservation of all water resources in the Sultanate. The ministry is responsible for making general policies for the preparation of long-term plans consistent with the economic and social develop-

---

[271] *Id.* at Art. 21.
[272] *Id.* at Art. 101.
[273] *Id.* at Art. 102.
[274] *Id.* at Art. 19.

ment plan of the Sultanate. The ministry also is endowed with all of the appropriate authorities to carry out 13 other activities:

1. Undertaking the general plan for the development of water resources and their conservation after coordination with other ministries and government units
2. Establishing an information and data center for water resources and programs related to the use of water resources
3. Collecting data and information about ground and surface water resources and springs, as well as the computation, classification, and filing of these data for use in related studies
4. Undertaking research, studies, and surveys aimed at the exploration of other water resources; executing studies on conservation and use of available water
5. Operating, developing, and maintaining the hydrologic and hydrogeologic monitoring networks in the Sultanate; recording, reviewing, and analyzing information on different uses of the resource
6. Assessing the water balance and water availability in the Sultanate
7. Collecting water samples from wells and *aflaj* ("traditional channels") and analyzing these samples to determine salinity rates, treatment methods, and suitability for different uses
8. Undertaking site visits to new agricultural lands to ensure water availability in new lands and to ensure their suitability for growing crops
9. Coordinating with the Ministry of Agriculture and fisheries to ensure the suitability of agricultural development
10. Issuing permits for the construction of new wells that take into consideration the regulation in regard to banned areas and distance from mother wells
11. Providing TA and policy advice to government units in the water field and providing methods for determining use
12. Preparing regulations according to Royal Decree #100/1989, after coordination with concerned authorities
13. Undertaking the training and qualification of Omani employees working in the Ministry of Water Resources.[275]

---

[275] Royal Decree #100/1989: For the Establishment of the Ministry of Water Resources and Designation of its Duties and Responsibilities, Art. 4.

Tunisia

The Ministry of Agriculture and Water Resources is entrusted with the administration and management of public domain waters.[276] Under the 1975 Water Code, within each governorate a "Water Interest Group" is to be established. These groups would prepare studies for the implementation of water works of public interest, advise the governorate on waterworks undertaken in the area, and control WUAs.[277] WUAs can be freely established upon the request of interested water users, or they can be established by the state. Responsibilities of WUAs could include the management of an irrigation system, drinking water system, and/or the undertaking of drainage works.[278]

Yemen

As mentioned, in 2003 the government of Yemen created a new Ministry of Water and Environment (MWE). The creation of MWE has since triggered a series of pending amendments to the Framework Water Law (#33/2002). MWE was created by pulling the environmental responsibilities from the Ministry of Tourism and the water responsibilities from the Ministry of Water and Electricity, leaving a self-standing, separate Ministry of Electricity. The NWRA, NWSA, General Authority for Rural Water and Sanitation Projects (GARWSP), Environmental Protection Agency (EPA), and local corporations that operate urban water supply and sanitation systems in a quasiprivatized manner all have been brought under MWE's control.

MWE is separate from the pre-existing NWRA, NWSA, and others. Internally, MWE's responsibilities have been divided into two separate groups: (1) Environment and (2) Water Supply and Sanitation. Under the Environment group, there are subunits in charge of policies and programs, treaties and regulation, and emergencies. The Water Supply and Sanitation group has subunits for water resources, water supply and sanitation (WSS), and water sector reforms.

It is clear that the pending amendments will alter the current structure posed by the 2002 Framework Law. However, it is unclear as to how much change will occur in the duties of the NWRA and the NWSA as outlined in the 2002 Law. This chapter therefore will provide a description of the 2002 Yemen Water Law's institutional

---

[276] Tunisian Water Code (1975), Art. 4.
[277] *Id.* at Art. 153.
[278] *Id.* at Art. 154.

framework with the caveat that all may change after the passage of the amendments. The 2002 law centralizes authority under the NWRA. Nevertheless, the Ministry of Agriculture and the Ministry of Electricity and Water still hold important responsibilities over the irrigation and WSS sectors, respectively.[279] The central responsibility of the NWRA is to control the use of the country's water resources.[280] Control includes monitoring, data collection, and information-gathering that can be used to estimate water budgets and evaluate demand and the quantities that can and may be exploited.[281]

The NWRA also is charged with collecting the information that can serve as the basis for water planning,[282] as well as preparing the National Water Plan through reviewing sectoral and water basin plans.[283] The NWRA must devise a classification system for water basins and water zones to control water use.[284] Additional tasks include (1) enforcement of the law through inspectors, with the cooperation of the police and security forces;[285] (2) providing farmers with support to new technologies and modern irrigation methods to improve water savings; (3) setting up water dams, dikes, and reservoirs to harvest rainwater and make optimal use of all surface water resources; (4) preventing desertification through conserving soil and water; and (5) encouraging community participation and education.[286] Finally, the NWRA is responsible for establishing Water Basin and Water Zone Committees to operate under its supervision. These basins or committees are encouraged to include nongovernmental organizations (NGOs) and community representatives. The NWRA has yet to develop the Executive Regulations that would govern the operation of the basins and zones.[287]

MAI rations the use of water for irrigation and potable water use in rural areas in accordance with the Water Plan developed by the NWRA. MAI's other responsibilities include:

[279] Yemen Water Law (#33/2002), Art. 74. Under this article, the law states that NWRA should consult and coordinate with the Ministry of Agriculture and Irrigation and the Ministry of Electricity and Water regarding their respective tasks. *Id.*

[280] *Id.* at Art. 7.

[281] *Id.* at Art. 12.

[282] *Id.* at Art. 13.

[283] *Id.* at Art. 17.

[284] *Id.* at Art. 14.

[285] *Id.* at Arts. 63–66.

[286] *Id.* at Art. 17.

[287] *Id.* at Art. 11.

1. Preparing irrigation policies and executive plans, which ensure the optimal benefit of the agricultural sector's share of water.
2. Undertaking theoretical and practical studies, implementing the extension programs, and taking all the measures that will lead to the rationing of water use, increasing the productivity of water and agricultural crops, and encouraging the use of modern irrigation methods. All of these actions should be in keeping with economic feasibility and adjusted to the set allocation of water for such use and for the conservation of water and the environment.
3. Setting up, operating, and maintaining water installations to lead to benefit from the use of rainwater and rainwater runoff, within the context of the indicators of the national water plan, water budgets for the Water Basins and Zones, and Water Plan.
4. Drawing up a plan for protection from rainwater runoff and flooding; setting up meteorological agricultural surveillance stations; analyzing, recording, documenting, and exchanging the information picked up by these stations with the NWRA and with the beneficiaries thereof; and making use of the output of the national hydrological station network.
5. Preparing and implementing the plans and programs related to the control of wadi flows and general or public canals; monitoring the flow of rainwater runoff and floods; and monitoring the use of irrigation water and installations to ensure the safety of such installations and the protection of water from waste and pollution.
6. Preparing indicators for the short-, medium- and long-term demand for irrigation water. Demand includes the need of private sector projects for irrigation water, whereby they constitute—after the review and assessment thereof—one of the inputs of the water plans.[288]

Under the 2002 law, the former Ministry of Electricity and Water (MEW) was responsible for managing all water allocated to it through the NWRA's Water Plan. The water was to be used largely for water supply and sanitation. MEW was charged with preparing policies and executive plans for the WSS sector; ensuring potable supply for domestic uses and applying the proper standards for water quality; and

[288] *Id.* at Art. 25. Executive Procedures are to be developed for setting the controls for coordination among MAI, NWRA, and the other relevant concerned entities accordingly.

providing water supply to public and private industrial, tourism-related, or other service-provision areas. In addition, MEW was responsible for setting up and managing wastewater networks for collection, treatment, and disposal. MEW also oversaw projects in potable water supply and sanitation, with NWRA participation. The treatment of wastewater would be governed by a uniform system established by MEW. Any reuse would be strictly regulated and coordinated with the NWRA.[289]

Finally, water user groups and beneficiary associations may be formed to involve the public and the beneficiaries of water in regulating water resources or in the O&M of water installations. The Executive Regulations would establish the implementation of this provision.[290]

Conclusions

Many MNA countries have successfully developed new water law regimes that address modern water demand and supply concerns, while remaining fully compatible with customary law and religious doctrine. Maintaining such a balance is feasible because society has internalized the customary laws and religious doctrines. Often, introducing new ideas and technologies is possible within the existing frameworks. For example, the region-wide interest in wastewater reuse has evolved gradually as stakeholders began appreciating that treated wastewater is a significant additional resource so long as treatment was adequate, and use restricted to tree crops and fodder crops. Where the balance has been disturbed (as in countries witnessing excessive drawdowns of groundwater), the problem has been caused by perverse economic incentives (such as the diesel subsidies in Yemen).[291]

Good examples of modern legal approaches exist for such key issues as groundwater management, water rights allocation, and wastewater reuse. Other chapters that follow deal with specific aspects of codification, such as financing rules aimed to better target government subsidies to the poor, and bidding rules aimed at creating incentives for private sector participation in irrigation infrastructure.

[289] *Id*. at Art. 26.
[290] *Id*. at Art. 10.
[291] See World Bank, Project Appraisal Document for the Yemen Water Sector Support Project, 2009.

17

Subsidies for the Poor: An Innovative Output-Based Aid Approach

Providing Basic Services to Poor Periurban Neighborhoods in Morocco

Xavier Chauvot de Beauchêne and Pier Mantovani

What Is Output-Based Aid?

Output-based aid (OBA) is an innovative approach to increase access to basic services for the poor in developing countries and to improve the delivery of services that exhibit positive externalities, such as reductions in CO_2 and improvements in health.[1] OBA is also known as "performance-based aid" or (in the health sector) "results-based financing." OBA is part of a broader effort to ensure aid effectiveness.

OBA links the payment of aid to the delivery of specific services, or "outputs" (box 17.1). These can include the connection of poor households to electricity grids or water and sanitation systems, the installation of solar heating systems, or the delivery of basic healthcare services. Under an OBA scheme, service delivery is contracted out to a third party—usually a private service provider but, in some cases, community or nongovernmental organizations or public sector utilities. The third party receives a subsidy to complement or replace connection fees for poor households (HH) that cannot afford to pay the full connection fee. The service provider is responsible for "pre-financing" the project until output delivery, when it receives reimbursement through an OBA subsidy. The subsidy is performance based, meaning that most of it is paid only after the services or outputs have been delivered and delivery verified by an independent agent.

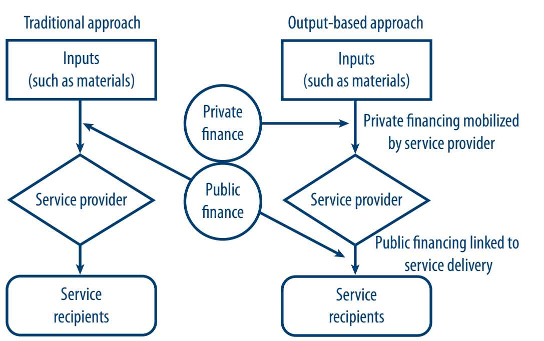
[1] For more information, visit Global Partnership on Output-Based AID's (GPOBA) website, www.gpoba.org

Box 17.1 Output-Based Aid: Core Concepts

- ***Increased transparency through the explicit targeting of subsidies*** and tying these subsidies to defined outputs
- ***Increased accountability through shifting performance risk to service providers*** by paying them after they have delivered an agreed output
- ***Increased engagement of private sector capital and expertise*** by encouraging the private sector to serve customers, usually the poor, whom they might otherwise disregard
- ***Encouraging innovation and efficiency*** by leaving the service "solutions" partly up to the service provider
- ***Increased sustainability of public funding*** through the use of one-off subsidies and by linking ongoing subsidies to sustainable service
- ***Enhancing monitoring of results*** since payments are made against agreed outputs

OBA schemes contrast with traditional aid approaches, which usually focus on financing "inputs" such as infrastructure (for example, a water treatment plant or a hospital) or equipment (such as books for schools) (figure 17.1). Under the OBA approach, the priority shifts from making a service generally available to ensuring that the poorest households actually benefit from the service. For instance, a traditional electricity project might finance the expansion of the electricity grid to poor areas. In contrast, an OBA project would subsidize the cost of connecting households in the poor areas to the grid, or it could subsidize off-grid solutions such as solar home systems for communities in remote areas. OBA schemes thus can complement traditional aid and make service delivery more inclusive.

Figure 17.1 Input-Based Approach vs. Output-Based Approach



Source: Author.
Note: Scale = 1: 70,000.

Why Is OBA Relevant for Morocco?

By regional standards, Morocco already has good water infrastructure assets. Ninety percent of accessible resources are stored in 116 large dams; irrigation is developed over 1.4 million hectares (ha); and potable water supply reaches almost all urban dwellers. In fact, with individual connections and continuous service for 83 percent of households, Morocco has one of the best potable water supply rates in the region. However, infrastructure is lagging for rural water supply (70 percent in 2007), urban sewerage (70 percent of households connected as of 2005), and wastewater treatment (5 percent of discharges treated in 2004). Access to service remains particularly inadequate in poor urban and periurban areas.

Today, the country faces two challenges. First, it must adapt water usage to levels compatible with the renewable resources supplied by nature. Second, Morocco has to improve service access and efficiency while reducing the burden on the state and on poor consumers. Reforms have been initiated to address these challenges, including through policy and expenditure reorientation.

The government developed a comprehensive reform program that focused on the integrated and sustainable management of water resources. This program included the National Initiative for Human Development (INDH), launched by the King in May 2005. This initiative included a significant component to expand basic services to the poor, particularly those in urban and periurban settlements previously considered illegal and, therefore, ineligible for services.

Pilot OBA schemes were set up to encourage water utilities to improve access in low-income communities. The next sections review the design and results of these pilot interventions.

Nature of Service Deficit in Periurban Areas of Morocco

Currently, approximately 2 million Moroccans remain without access to water supply and sanitation services (WSS) in illegal settlements surrounding the country's major cities.[2] In the Casablanca metropolitan area alone, approximately 145,000 households (or 900,000 inhabitants) are estimated not to receive adequate water supply and sanitation services. These residents who lack access to reliable and clean water supply services get water from (1) contaminated shallow wells; (2) water providers selling nonpotable water at a relatively high unit price;

[2] In this context, "periurban" includes all settlements located at the outskirts of a city and structures in city quarters or hamlets, illegal or not; and encompasses hamlets presenting characteristics of rural areas but not belonging to rural communes (municipalities).

or (3) standposts located at the entrance of these areas, which often require women or children to stand for several hours in a queue.

Access to basic sanitation is even more deficient. A majority of households use cesspits and poorly designed septic tanks. These rudimentary accommodations risk increasing the contamination of shallow groundwater. A large number of inhabitants of the poorest areas remain without any form of sanitation.

The situation described above directly affects people's health, their ability to engage in income-generating activities, and, for children, to attend school. It also harms the water utilities' finances, as cost recovery from these public standposts is usually very low. The municipalities (communes) responsible rarely pay the bills.

Four factors have contributed to the lack of WSS for Morocco's poor:

- Unplanned growth of periurban areas and the fact that they were systematically not included in the service areas of water and sanitation operators.
- Technical and administrative hurdles that made interventions by operators in illegal settlements difficult, linked to, for instance, lack of title, poverty, and lack of basic access infrastructure.
- Operators' difficulty in financing infrastructure for water users eligible for the loss-making "social tranche" of existing water tariffs.
- Connection fees charged to the beneficiaries at their marginal costs, to which a *Participation au Premier Etablissement* (PPE)" fee is added. The latter drives up costs of access to unaffordable levels for most HH living in the city outskirts, even when the option of payment by installments is available through the "Social Connection" program.[3]

Mobilization through the National Initiative for Human Development (INDH)

Since 2005, the National Initiative for Human Development (*Initiative Nationale de Développement Humain*, or INDH) and the government's

[3] "Social Connection" programs offer to pay HH for the full connection cost in installments over time. However, the program requires that, to access these basic services, households get into debt for durations of 7 to 10 years. This outcome appears neither plausible nor equitable.

Cities Without Slums program (*Ville Sans Bidonville*, or VSB) have mobilized stakeholders to upgrade poor urban and periurban areas.

INDH/VSB programs removed the most important obstacle by recognizing informal areas, and promoting their inhabitants' resettlement to housing units in apartment buildings (*relogement*), their resettlement in fully or partially serviced plots (*recasement*), or "restructuring with on-site upgrading" through the expansion and strengthening of basic infrastructure. INDH also promotes service coverage expansion by promoting agreements among relevant stakeholders. The specific arrangements developed through INDH regarding the financial contribution of households[4] for a house connection to water and/or sanitation services[5] are of paramount importance in reaching coverage objectives.

Although significant, the activities above only partly address the INDH's water and sanitation access objectives for 2010:

a. Due to lack of financing, connection development is inadequate for on-site upgrading areas. For example, in the metropolitan Casablanca area, INDH is considering expanding WSS only to the 65,000 households to be resettled either in housing units or in serviced plots. That leaves a population of approximately 80,000 households, representing over 500,000 inhabitants, targeted by the on-site upgrading approach for whom no service expansion solution is proposed.
b. Implementation of INDH/VSB programs is not always optimal. For example, problems linked to coordination and implementation of network expansion works often prevent house connections from being established.

INDH's Urban Water Supply and Sanitation OBA Pilots

The objectives of the project pilots are to demonstrate replicable OBA mechanisms to extend WSS services in poor and vulnerable communities, as part of the INDH.

---

[4] Households are offered the opportunity to pay their connection fees over time, the terms varying by operator. For instance, in Meknes, the household contribution has to remain below MAD 9,240 for connections to WSS services, reimbursable in 84 monthly payments of MAD 110.

[5] Waiver of an important "First Settlement Fee-*Participation au Premier Etablissement* (PPE)" and of the 10% design and supervision fee otherwise charged by the operators.

Started in the spring of 2007, Morocco's Urban WS&S OBA pilots aim at connecting 11,300 households to piped WSS in poor, unzoned, periurban neighborhoods of 3 municipalities: Casablanca, Meknes, and Tangiers. The pilots are funded through a US$7 million grant by the Global Partnership for Output-Based Aid (GPOBA). They are implemented by the respective service providers in these municipalities: 2 international private concessionaires, namely, Amendis in Tangiers and LYDEC in Casablanca; and 1 municipal utility, the Régie Autonome de Distribution d'Eau et d'Électricité de Meknès. The Government of Morocco is also a partner to this approach, playing an oversight and monitoring role.

While the details of the schemes vary, the common objective of the pilots is to test an OBA subsidy mechanism specifically targeted toward poor neighborhoods and households; and bridging the gap between capacity to pay and a competitive cost of connection. In addition to the waiver, for areas identified as part of the INDH program, the scheme offers a subsidized connection fee for some of the fees otherwise charged by the operator.

The approach builds on previous "social connection" programs by which households were offered the opportunity to pay their connection fees in installments.

Awarded to individual eligible households who agree to pay the operator-specific beneficiary contribution, the subsidies are prefinanced by the operators, who first are required to complete the pipe and connection works. They get reimbursed after a verification process that certifies that the eligible household is in fact receiving piped WSS service (that is, the output).

The built-in incentives of this OBA approach are designed to mitigate traditional impediments of service expansion programs in marginal neighborhoods. Impediments include (1) unaffordability of connection costs by households, (2) unsustainable program financing for operators, (3) complex technical and administrative obstacles to infrastructure development in poor unzoned areas, and (4) reticence by national and local governments to fund subsidy programs that have no accountability or guarantee of results.

The outputs for which OBA subsidies are disbursed are individual HH network connections for simultaneous water supply and sewerage services in designated, predominantly poor periurban neighborhoods. These HH have the recognized right to access services through the INDH program. In Meknes, the output is the connection to either service.

The disbursement profile of the individual subsidy follows: (1) 60 percent of unit subsidy is released upon verification of eligible water and sewerage household connection, and (2) 40 percent of unit subsidy is released upon verification of sustained service for at least 6 months.

Subsidy Targeting Is Geographic in Nature

The target neighborhoods are recognized as being among the poorest in urban Morocco, and are on the INDH's shortlist of 160 most disadvantaged urban and periurban communities. All households in the selected pilot areas are eligible to participate in the connection subsidy program. However, participation is strictly demand driven. It therefore requires communication campaigns to raise awareness about the program and explain its conditions. Operators also develop new means of reaching potential customers. They use dedicated teams who go to market places or to the heart of the targeted neighborhood to record the demands of beneficiaries who may not easily travel to one of the operator's agencies.

Scope and size aside, the project breaks new ground in many regards. It is the first

- OBA project in Morocco
- Project involving multiple incumbent operators
- Project involving a public operator
- World-Bank-implemented OBA involving connection to sanitation
- World-Bank-implemented OBA project in local currency.

Lessons Learned So Far

A key element of the approach is to shift risks to incentivize all parties to perform. In this case, the financial and operational risk in extending service requires a good assessment of the demand for services by the targeted population, as demand will determine the amount of subsidy the operator will receive.

Another key element is the limitation of the risk of capture of outputs. As in former social connection programs, an authorization to connect from the municipality is required. Therefore, there is a risk that political pressure could be put on the operator to extend subsidized connections to populations who may otherwise have the means to pay the full cost of connection. The pilot is organized on a geographic basis, for lack of a better targeting mechanism. However, it targets poor neighborhoods that had been without piped services up to that point. Socioeconomic surveys carried out show that a significant share of the population living in these informal areas are below the poverty or vulnerability lines for Morocco.

Nevertheless, to avoid the risk that the relatively wealthier households could benefit from the subsidy, the operator and local authorities (province, governor) have developed additional eligibility criteria, for example, based on the number of stories or house size and appearance. Moreover, to increase transparency, the operator has requested that the list of beneficiaries be signed by the municipality and countersigned by the governor (local representative of the state).

Although a substantial number of outputs have been delivered and verified in all three sites, the pilots experienced a slow start. The first 12 months of the pilot program have produced approximately only 2,000 connections, that is, 15 percent of the program's 3-year objective. However, an independent midterm review of the pilots shows that the delay is due to implementation difficulties unrelated to the OBA approach: procurement procedures, upstream investment delays, and lack of clarity over land tenure. The parties appreciate that conventional financing would have resulted in fewer connections than OBA in the same circumstances. Thus, scaling up the OBA approach to other INDH areas now is considered possible before pilot program completion in December 2009.

The midterm review confirmed important direct benefits[6] to households, and recorded the high satisfaction of beneficiary households with the service provided. This information is further demonstrated by evidence of uptake significantly increasing after works start and a collection rate equal or superior to the average experienced by each operator in his/her service area.

Operators and government generally are satisfied and appreciate the flexibility allowed by the pilot. The OBA approach is seen as helping to improve processes, overcome financing blockages, and mobilize stakeholder partnerships. In addition, all parties appreciate that quarterly inspections by the Technical Independent Reviewer have proven

[6] Essentially, benefits are time savings but also can include reduced health costs and improved hygiene practices. Further study would be necessary to quantify such benefits.

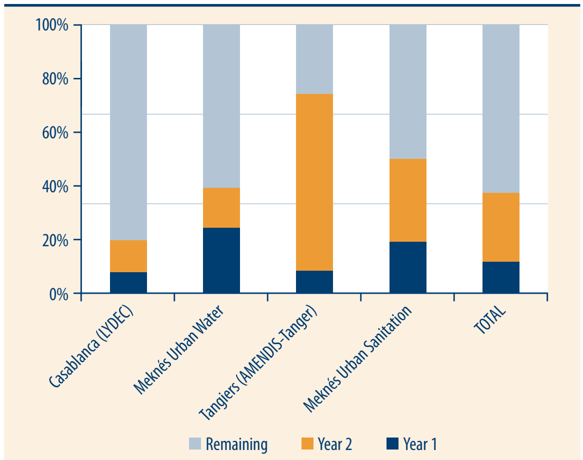
effective in firming up the operators' reporting requirements as well as improving their implementation methods. The demand-driven approach contributed to refocus service provision around the households, which increased accountability, strengthened partnerships between local authorities and operators, and prioritized monitoring of service delivery.

After a slow year 1, a doubling of connection rates is reported in year 2. Figure 17.2 shows connection realizations during the first two years of implementation.

Lessons learned for the potential scale-up of the pilots include the need for:

a. Better advance planning and working partnerships among operators, local governments, and neighborhood associations to clarify eligibility and permitting questions
b. Streamlining OBA-specific ex-post eligibility verification procedures.

Figure 17.2 Connections Realized in the First Two Years of Implementation



Note: Figure 17.2 reflects progress on the defined "outputs" under the project, namely, the working connections to water and/or sanitation services. The figure does not reflect the progress achieved on the upstream/trunk infrastructure development necessary to deliver the outputs. Therefore, it may not accurately reflect the progress under the pilots.

Scaling up OBA: Toward a National Strategy to Reduce Urban and Periurban Service Access Deficit

Given the lack of targeted subsidy mechanisms for poor households, especially in informal urban settings, OBA is perceived as strategically relevant to Morocco. The OBA pilots are taking place at a time that the government of Morocco is seeking new ways to deliver on INDH's promise. The government has expressed interest in replicating, with due adaptation, the OBA approach on a citywide or nationwide scale. The Bank is working with the government on the best ways to evolve toward a scaled-up operation, while strengthening coordination among institutions in charge of the different aspects of periurban utility service.

18

Use of Output-Based Aid to Jumpstart a Rural Water Supply Service Market in Morocco

Xavier Chauvot de Beauchêne and Pier Mantovani

In a Nutshell

As mentioned in an earlier chapter on Moroccan water strategies (Chauvot de Beauchêne and Mantovani 2009), developing access to potable water in rural areas became a policy priority only in 1995. Since then, Morocco's PAGER (National Program for Rural Water Supply and Sanitation) has made big strides in developing drinking water sources. PAGER has provided over 87 percent of the rural population with access to drinking water, typically through public fountains. Today, the government of Morocco is aware of the need to redeploy its rural water supply (RWS) strategy to promote the development of RWS service through individual household (HH) connections.

The RWS objective is the same as for urban and perirurban areas: to expand access to water supply services. However, the approach piloted in Morocco's rural areas is rather different from the approaches pursued in urban areas. In rural areas, the National Water Supply Company (ONEP) is evolving from its core business of producing and delivering water to service providers to becoming a provider of water supply and sanitation services. To facilitate this new mission, ONEP has developed an important network of standpipes within rural communities.

However, HH in these communities were asking for domestic connections. ONEP then engaged in the development of house connections in small centers and rural areas. In fact, organizational structure and internal procedures translate into fixed costs that make service provision to smaller communities a loss-making business. ONEP is piloting the subcontracting water service provision and management in 8 rural communes (municipalities) to a private operator through a

10-year management subcontracting arrangement with aspects of an affermage-type contract. During the first years, the private sector will receive performance-based subsidies from ONEP under an output-based aid (OBA) approach. Specific outputs eligible for a subsidy are water production, service expansion to new settlements, and a working HH connection. The private operator will be selected competitively on the basis of the lowest total subsidy. This approach is expected to be win-win for all parties. ONEP will benefit from the efficiency gains of the private operator. From day 1, the private operator will have incentives to work to establish a profit-making business before the fifth year of service provision. While this OBA approach is still to be tested, it appears a very promising management model for water service provision in small towns and surrounding rural areas.

In Morocco, local authorities are responsible for water supply and sanitation (WSS) services. Major cities have delegated WSS either to the private sector or to financially independent municipal utilities. ONEP is the national utility in charge of potable water production and transmission in bulk to large urban distribution utilities. Because small cities and rural areas lacked capacity, they increasingly requested ONEP's assistance to manage their water distribution services. As a result, over time, ONEP's mandate broadened to include the provision of water supply services to small towns and rural areas. More recently, ONEP has been mandated also to bring sanitation services to secondary urban and rural centers.

Urgency to Increase Rural Household Water Connections

At the same time, the government decided to accelerate the pace of ONEP's investments in RWS to reach the coverage target of 90 percent of the rural population by 2007. This coverage target was one destination on the way to the overarching objective: reaching the Millennium Development Goals (MDGs) for Morocco by 2015. At the end of 2008, ONEP covered 80 percent of national water needs. It also is the country's leader in water distribution and provides water to 28 percent of the Moroccan population. The national company distributes water to 5.6 million people in medium-sized cities and to 2.8 million people in rural areas. ONEP is a profit-making, autonomous public corporation. However, its organizational structure and internal procedures translate into fixed costs that are too high to make service provision in smaller scale operations profitable.

Morocco's rural sector is composed of 31,000 localities (*douars*) with a total population of nearly 13 million. Prior programs contributed to provide water to 70 percent of the douars through public standpipes. Those programs left unserved approximately 10,000 douars. In addition, the demand for rural HH connections to water supply is estimated at 1,700,000. ONEP and village associations have already developed approximately 680,000 HH connections in rural areas. Therefore, the challenge in the rural areas consists of connecting a little over 1,000,000 new HH to water supply.

In the meantime, ONEP is facing the following constraints: (1) the necessity to satisfy so many new customers without hiring new staff; (2) the necessity to keep operational charges in line with its costs; and (3) the necessity to preserve its financial equilibrium, because its investment needs are skyrocketing. Regarding point 2, the tariff structure is the same throughout Morocco. The tariff levels for bulk and retail water are fixed by the government. As for point 3, in recent years, ONEP has tested different models of private sector involvement, from established standpipe-managers to more comprehensive performance-based service contracts. Learning from these experiences, ONEP is ready to take private sector involvement in water service distribution in rural areas one step further.

ONEP Pilots Innovative Public-Private Partnership to Increase Household Connections

ONEP intends to pilot the first public-private partnership for extended subcontracting of its water distribution responsibilities. The objective of the pilot is to provide sustainable water supply services and service expansion in rural areas served by ONEP through a new PPP approach that includes both technical and, for the first time, commercial management. The private sector would be expected to develop technically and financially efficient management of water distribution in rural areas. The private sector also would be encouraged to develop access to piped water supply services through HH connections and to expand the service area to other douars. This approach should enable ONEP to significantly reduce its O&M costs in water provision while maintaining its current staffing level, thus ensuring its long-term financial sustainability. To sum up, the pilot will help ONEP to determine the future organization of water services management in rural areas. This is an important issue for Morocco's water sector sustainability, itself a focus of World Bank dialogue with the government.

ONEP determined the pilot area based on six elements. They were (1) poverty and vulnerability levels; (2) readiness of primary and secondary infrastructure to enable quick service expansion; (3) high HH demand for house connections; (4) difficulties faced in providing an appropriate level of service; (5) size of the pilot area enough to enable financial and technical feasibility of the operation; and (6) positive deliberations of councils of all concerned communes to authorize ONEP to develop the proposed PPP approach.

For the pilot, ONEP selected the Sidi Kacem area in northwest Morocco, which comprises small towns and the surrounding rural areas. By bundling rural areas with more densely populated small towns, the pilot area has a population of 130,000 inhabitants. Of these, approximately 25 percent are poor HH,[1] that is, HH with monthly incomes under US$201 (MAD 1745). Another 25 percent of HH are considered vulnerable, that is, their monthly incomes are below US$302 (150 percent of the poverty line). ONEP is providing services to approximately 7,200 of these vulnerable HH at a loss. As a result, ONEP has no incentive to connect additional vulnerable HH. In any event, poor or vulnerable HH would not be able to pay for the full connection, which costs on average US$577 (MAD 5,000).

Using Output-Based Aid to Subsidize Rural HH Water Connections

Although demand for house connections in the pilot area was high, demand correlated strongly with the cost of the connection fee. This correlation threatened the financial sustainability of the pilot and, therefore, the interest of the private sector. Building on the output-based aid (OBA) approach developed in urban areas, ONEP decided to add to the proposed PPP an OBA approach that decreased the connection fee and subsidized house connections developed by the private operator. The innovation is that the private operator must prefinance the outputs, for instance, the working connections to piped water supply service. The operator receives the subsidy after these outputs have been delivered and independently verified. ONEP requested support from the World Bank and the Global Partnership on Output-Based Aid

[1] A rural household is estimated to include 6.4 people.

(GPOBA)[2] to design the OBA approach. GPOBA funded an important technical assistance contract to help design the pilot and help structure the OBA approach. GPOBA was not in a position to fund the pilot. Nonetheless, ONEP decided to use the approach and finance it.

The main goal for ONEP is that the subcontracted private operator who takes on the management of small-scale operations for a 10-year period is able to reduce O&M costs to a level enabling ONEP to break even early enough to develop a profitable business within the existing tariff structure. The private operator would not receive a management fee but would be remunerated through the revenue collected from customers. In addition, the operator would have specific performance targets and associated outputs for which it will receive an OBA subsidy from ONEP. The three required outputs are (1) water sales in the pilot area, new douars or settlements reached, and new house connections. Each output was designed to help the private operator develop the critical mass of customers and water sales to make its business financially sustainable. To incentivize performance, the subsidies will be time bound. The outputs and associated subsidies appear in table 18.1.

Table 18.1 Performance Targets and Outputs Required to Receive ONEP OBA Subsidy

Contract objective	Output	Measuring unit	Targets	Subsidy available for the first
Minimize initial operational deficit	Water sales in the pilot area	m^3 sold	3 million m^3	3 years of operation
Expand service area to 14 new douars	New douars or settlements reached	Linear meters (ml) of expanded network	Initial estimates: 40,000 ml	4 years of operation
Increase customer base through new house connections	New working house connections to piped water supply	House connection	8,500 new house connections	5 years of operation

The amount of subsidy, hence the unit cost per connection, would be determined by a competitive bidding process based on targets clearly stated in the bidding documents. The bidder requiring the least

[2] The Global Partnership on Output-Based Aid (GPOBA) is a global partnership administered by the World Bank. GPOBA was established in 2003, initially as a multidonor trust fund to develop output-based aid (OBA) approaches across a variety of sectors including infrastructure, health, and education. OBA subsidies are designed to create incentives for efficiency and the long-term success of development projects. For more information on output-based aid approaches, go to www.gpoba.org.

amount of combined subsidy wins the bid. The allowable subsidy may be capped.

The following paragraph details the OBA approach to house connections. The private operator would be expected to make approximately 8,500 new connections during the 10-year contract period, thus increasing the connection coverage rate in the pilot area from 32 percent to over 68 percent of HH. The OBA subsidy for a house connection would equal the difference between a set discounted connection fee for the HH and the cost of connection.

Household Connection Cost

ONEP has promoted MAD 2,500 (US$289) as the country-wide set discounted connection fee in ONEP-managed rural areas.[3] To be eligible, a HH needs to express interest and provide a down payment of MAD 1,000 before the completion of service extension works in its area. Households that fail to do so will later be charged the full connection fee. Poor and vulnerable HH that meet the "social connections" criteria (monthly revenues lower than MAD 3,000) will have the option of paying the remaining MAD 1,500 in installments over 3 years at 5 percent interest (compared to the usual 18 percent microcredit rate).

Under the proposed PPP, the user contribution to house connection would amount to MAD 2,500 (US$289), that is, half of the connection cost. However, it will be up to the private operator to decide whether it wants to develop conditions similar to the ones proposed by ONEP, or to develop new ones that would better serve its interests in promoting house connections. Surveys carried out in the pilot area have demonstrated that 80 percent of HH would be willing to connect at the MAD 2,500 price.

While only 50 percent of the pilot area population is below the vulnerability or poverty lines, the assumption is that the wealthiest HH are among the 7,400 already connected. For lack of a better targeting mechanism, it was decided that *all* HH located in the pilot area will be eligible for a subsidized connection, on a first come-first served basis.

---

[3] This amount is to be confirmed and may increase. The current discounted fee refers to 2005 prices. With support from the World Bank, an analysis is ongoing to update the information that will lead to the proposed revised discounted fee.

The scheme ensures that monthly payments for poor and vulnerable HH will be affordable, based on the unit price of water and projected monthly consumption after the connection. Currently, HH purchase water from standpipes within 500 meters of their settlements at an average price of MAD 10 per m^3, and consume on average 8 liters/capita/day. After connection, experience shows that the average monthly consumption increases over time to an average of 45 liters/capita/day, corresponding to a unit cost of water of MAD 4.9 per m^3.[4] On this basis, and assuming that payment is made under ONEP conditions, the cumulative user's monthly payment represents approximately 5 percent, or 3.4 percent of the monthly spending of a HH at the poverty or vulnerability line, respectively. This cost is deemed affordable, as demonstrated by the 100 percent collection rate experienced by ONEP nationwide.

Multiple Benefits of Household Connection

The expected benefits resulting from house connections include, first and foremost, having access to safe and reliable water supply at home, in appropriate quality and quantity, and at an affordable price. Additional benefits include time savings that can be used for income-generating activities primarily by adult women and improved education for children; reduced health costs and improved hygiene practices resulting in decreased morbidity and mortality rates, especially among children under 5; reduced medical expenditures; and improved labor productivity. Broader outcomes of the pilot will include the introduction of demand-driven service provision in rural areas. Currently, significant investments by ONEP to develop access to water through standpipes generate very little income because populations increasingly disregard the standpipes. Moreover, the pilot also will demonstrate and document one possible solution to reduce ONEP's fixed and variable O&M costs, which, if replicable, might improve ONEP's long-term financial sustainability.

This pilot is very innovative. In fact, it will pave the way for a reform of water distribution management in Morocco's rural areas for at least four reasons. The pilot:

1. *Will bring a new dimension of risk-sharing* by introducing the first PPP in water supply distribution in small towns and surrounding

[4] At 2.54Dh for the first 6 m^3 and 7.91Dh for the following 14 m^3.

rural areas in Morocco. For the first time, ONEP will subcontract utility management, including commercial risk. The pilot structure creates the right incentives: it provides targeted support until a critical mass of customers enables the financial sustainability of the operator. Namely, ONEP will retain the legal responsibility, and final beneficiaries will remain ONEP's clients. The private operator will bear technical, financial, and commercial risk. The approach will provide both ONEP and the private operator with the highest incentives to perform. The private operator risks losing the subsidy funds if the outputs are not delivered. ONEP risks having to take over if the private operator does not perform.

2. *Will result in a win-win situation*. The pilot will test a possible solution to ensure ONEP's long-term financial sustainability, while accompanying the creation of a new set of local operators for utility management. These local operators might, at a later stage, bid for full delegation of service and/or manage sanitation.
3. *May involve local commercial banks to channel the subsidies*. This arrangement might create favorable conditions for ONEP, the private operator, and that bank to develop integrated financial packages for HH through small short-term loans to HH to pay the whole of the users' contributions. This arrangement would enable each party to concentrate on his/her respective core business and would give the private operator more assurance that it would get paid timely after the independent verification recommends the payment.
4. *Presents a window of opportunity for small and medium private-sector firms (SMEs)* in Morocco to develop a new expertise in the water sector. These firms have seen large, international private operators capture water business opportunities in large cities such as Casablanca, Rabat, and Tanger/Tetouan. This proposed rural water operation, with its smaller size, gives SMEs a chance to enter the water business on a scale that they can handle.

The pilot is at advanced stages of procurement and has generated great interest from the private sector. Because of the pilot's innovative nature, workshops were organized to gather prospective bidders to present the pilot and answer questions. Recently, another workshop was organized with prequalified bidders to explain the bidding documents and go through the financial model it entails. The Bank financed consultants to help ONEP organize and moderate each of these workshops, and Bank staff participated in and contributed to them. Given the significant interest demonstrated by the private sector in ONEP's two workshops, ONEP is confident that all shortlisted bidders will submit qualifying bids.

If successful, this model for rural water supply can be scaled up in other bundles of small towns and surrounding rural areas in Morocco, thus presenting business opportunity for the Moroccan private sector while enhancing access to piped water services in rural areas. *This pilot is a pivotal operation. It is providing the Moroccan private sector with unique market entry opportunities in the rural water sector and potentially in large urban centers.*

References

Chauvot de Beauchêne, X., and P. Mantovani. 2009. "Subsidies for the Poor: An Innovative Output-Based Aid Approach. Providing Basic Services to Poor Peri-Urban Neighborhoods in Morocco," this volume.

19

New Approaches to Private Sector Participation in Irrigation: Lessons from Egypt's West Delta Project

Aldo Baietti and Safwat Abdel-Dayem

In Middle East and North Africa (MNA) countries, the irrigation and drainage sector plays a vital role in food production and rural development. However, the sector has faced very difficult challenges in financing capital and maintenance costs.

Cost recovery in the sector has been exceedingly low, even for solely operation and maintenance (O&M) functions. Indeed, investment and O&M of irrigation schemes traditionally have been founded on massive public funding programs. In many cases, these resulted in a significant and unplanned fiscal burden on government, long after the programs' initial commissioning. Following a prolonged period of inadequate funding for O&M, many schemes have been abandoned.

Fortunately, the irrigation sector now is benefiting from new approaches to planning, design, and financing. There is particular emphasis on involving private investors and the farming community in sharing risks.

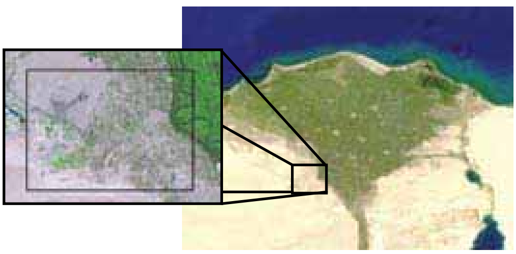
Private-Public Partnerships in Irrigation

A study by Tardieu and others (2004) examined the experience in private participation in the irrigation sector. The study reviewed approximately 21 cases of projects with some level of private sector participation, most of which was in the form of service contracts for O&M and financing schemes for farmers to invest in on-farm pumping equipment. Moreover, these experiences limited the role of the private sector because they dealt primarily with smaller systems.

Important developments are taking place in MNA in expanding the role of private participation in financing and operation. The West Delta Project is a large-scale project based on the "utility model," which introduces reforms of the sector as well as new approaches to project development, transaction design, and public-private arrangements.[1] Useful lessons are already emerging from the West Delta design.

West Delta Project Concept

Figure 19.1 Aerial View of West Delta of Nile River



Note: The West Delta area is located approximately 60 km north of Cairo to the west of the Nile Delta. The West Delta consists of 255,000 feddans of primarily commercial farms that cultivate high-value fruits and vegetables, much of which are exported to Europe and other markets.

Since the late 1960s, with the support of the government, Egyptian commercial farmers have been reclaiming desert lands. The West Delta region is one of these areas (figure 19.1). It comprises 255,000 *feddans* (approximately 110,000 ha total)[2] on the fringes of the delta. Beginning in the early 1990s, through the exploitation of groundwater resources, the West Delta Region has been developed into a flourishing agricultural economy.

Today, the West Delta Region contributes between $300 million–$500 million annually to the Egyptian economy. The area supplies domestic and European Union markets with high-value fruits and vegetables. Moreover, the area is now home to 500,000 people and provides approximately 250,000 jobs in the agriculture sector alone. However, the rapid development of the past few years has been accompanied by excessive exploitation of groundwater reserves, resulting in costly and deeper pumping as well as eroded water quality.

In response to concern about a possible collapse of this thriving agricultural economy, the Government of Egypt (GOE) conceived a surface water irrigation project that would replace groundwater pumping. However, the government also took this opportunity to advance a

[1] A similar model of public-private partnership is under implementation in Guerdaine, Morocco, in an area close to Agadir. In this model, high-value export crops are being grown with irrigated water from rapidly depleting aquifers.

[2] 1 feddan = 0.42 hectares (ha).

new vision for irrigation services. The new approach was founded on full cost recovery, volumetric pricing, formal water entitlements, and private-sector participation in financing and management.

The proposed model was for a public-private partnership (PPP). A private investor would be identified through a competitive tender. The investor would build the irrigation system, operate the system, and earn a commercial return by collecting water fees from farmers. The private investor would be offered concessional credit from international financial institutions (IFIs) channeled via the GOE.

The rest of this chapter describes the project design and the rationale for the chosen approach in more detail. At the time of writing, bidders for the West Delta project are preparing their bids, so it is too early to judge its performance on the ground. This chapter instead describes the structure of project rules and incentives, as these have useful lessons for the practice of irrigation.

Demand-Driven Approach to Project Design

At government's request, the World Bank commissioned an assessment in 2004–05 using a grant from the Public-Private Infrastructure Advisory Facility (PPIAF). The assessment presented a conceptual framework and transaction model for implementing a surface water irrigation system on a cost-recovery basis and with private sector participation.

Farmers' involvement in the design was essential to minimize the risk of low participation in the scheme. After an initial focus on demand forecasts and technical specifications, the emphasis of the design process therefore shifted to extensive user consultations and surveys. From these, the growers' service requirements and their willingness to connect and pay would guide the development of technical design options. Each design option entailed a corresponding level of tariffs.

A key feature of the West Delta preparation work involved a detailed "willingness to connect" survey of the farms in the area to understand their needs and willingness to pay for surface water.

No longer could the government expect farmers to sign up to the system by GOE's simply carrying out the required engineering studies, forecasting an appropriate mix of crops and water requirements, and designing the layout of the main and subsidiary branch canals. *Too many projects had been built around this top-down approach and were lying idle in red ink.*

Instead, the West Delta approach placed the farmers in the driver's seat and informed them so that they could:

1. Understand what service and performance standards are expected of them
2. Understand their ability to absorb the cost of service and convince them to buy into the project
3. Take an early stake in the preparation.

Accordingly, the preparation work at the outset involved extensive consultations with farmers in the area as well as setting up an advisory group that would represent all beneficiaries throughout the entire project preparation process.

Preference for a Piped System

The technical work began with a longstanding preconception that an open channel system with several intakes and a network of main and subsidiary branches would be the most cost-effective technical option. However, user surveys revealed that, while the open channel system was perhaps the least-cost solution on a unit-cost basis, it could not fully meet the performance standards of farmers.[3]

The closed conduit or piped system also was found to offer distinct advantages to a prospective private operator, who would be expected to operate the system on commercial principles and assume the related risks. Most important, the piped system would enable the private investor to better manage its cash flow. A piped system could be constructed in smaller modules, thus spreading capital costs over time and allowing the private operator to generate revenue in the early phase of implementation, while other parts of the systems were under construction. The open channel model was cheaper on a unit-cost basis, but the piped system offered fewer risks for a PPP operator and better addressed the expressed needs of farmers (table 19.1).

The piped system could (1) be implemented in smaller, financially sustainable modules based on the exact location of connecting consumers; (2) deliver a pressurized water flow directly to a connecting farm; (3) offer better control over water usage through metering, and

[3] There also was concern that an open channel would lead to significant water theft between the intake point on the River Nile and the project area.

Table 19.1 Comparison of Characteristics of Piped and Open Channel Irrigation

Feature	Piped	Open channel
Cost	Generally more costly per unit	Traditional low cost solution but high fixed cost element
Implementation	Highly flexible. Can adjust system to actual demand	Not adaptable to large variances in demand
Land Acquisition	Minimal	Substantial. Can reduce agricultural area substantially
Commercial Control	High control for water theft, metering UFW, and disconnection	Lower distribution efficiency, higher commercial risks
Environmental	Minimal	If not supervised closely, channels can become dump sites

lower evaporation, water losses and water theft; and (4) raise minimal right-of-way issues, land acquisition, and other environmental and safeguard concerns. In essence, the piped system was the preferred choice because it offered a prospective private operator better control over its financial operations.

Risk Allocation and Mitigation

Much of the PPP design work focused on the assessment and mitigation of risk factors and on determining which party should assume which risks. The financial analysis, which was supported by a dynamic financial model, analyzed how variation in key parameters such as construction period, conjunctive use of water, cost, capitalization requirements and financing plan, financing terms, currency movements, interest-rates, and bonding and insurance requirements would affect tariffs.

The intent was to identify the transaction elements that would minimize tariffs and mitigate risks.

- Pre-eminent among the risks are *demand risk*, due to the possibility of continued groundwater pumping; and system-planning risk due to oversized infrastructure. Either would lead to the system being underutilized. The project must not only yield positive returns but also ensure positive cash flows throughout the entire project, especially during the critical early years. Maximizing utilization efficiency of the system from the outset would contribute significantly to this end. Two devices were introduced to mitigate demand risk:
  - Tariff structure that would minimize the risk of conjunctive groundwater use by employing a fixed-capacity charge.

  - "Subscription period." The selected operator would carry out a subscription program to sign up farmers to the service. The operator would have the option to cancel in the event that the subscribing farmers came up short of the required 90,000 feddans. Moreover, it would be after the subscription that the operator would design the system.
- The analysis studied *financing risks*, including securing the longest possible loan terms available to keep user tariff affordable. Needless to say, the longer the debt repayment terms, the lower the user tariffs could be.
- The team further found that *construction delay* is a major risk factor. The operator must therefore implement the construction program swiftly to take full advantage of the long term of initial IFI loans that were being made available through GOE.
- The preparation team also well understood the *political risk* involved, given Egypt's lack of experience in public-private partnerships and, most importantly, the lack of comparable successful efforts in the irrigation sector.
- Finally, the issue of *currency risk* was daunting, given that the project was financed in foreign currency but generated revenues in Egyptian pounds. Although local currency financing was available in Egypt, it could not be offered in the maturities needed to make the project viable.

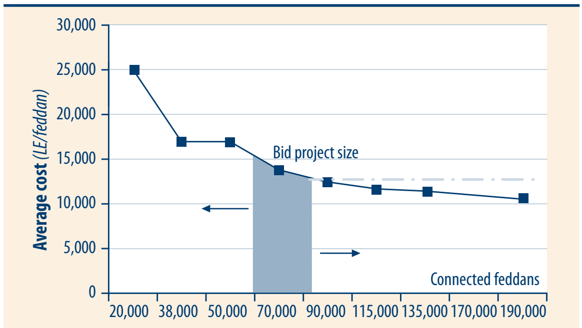
Cost Analysis and Minimum Bid and Project Size

The technical analysis reviewed numerous design options to reduce the risk of oversizing. First, the analysis determined which basic infrastructure was common to all scenarios (that is, the fixed cost component). Second, it simulated the addition of independent modules of land area (that is, the variable cost component) such that the operator could connect farmers on the basis of demand without jeopardizing his own cash flow. This was a critical element of the analysis. The analysis yielded the supply cost curve in figure 19.2.

The cost analysis provided both important information on minimum project size to ensure that user tariffs remained affordable and incentives for the operator to expand coverage.

On this basis, the minimum project size was determined to fall within the range of 60,000–90,000 feddans, this being the range at which the development cost per feddan would achieve the affordability thresholds indicated in the user survey. More importantly, the cost curve revealed that as the scheme approached 100 percent coverage, average costs would continue to drop. In other words, the private investor would continue to have the incentive to expand the network and connect the additional farms. As such, the *reference project* for the bid tariff was set at 90,000 feddans.

Figure 19.2 Supply Cost Curve to Develop West Delta Project



Structure of PPP Transaction

The West Delta PPP transaction was to be a hybrid scheme, largely founded on the Design-Build-Operate (DBO) model. Under this model, the government contracts a private operator take over a concession area consisting of approximately 190,000 feddans in the southern portion of the West Delta. The operator will design, construct, and assume the full responsibilities of operating the system for 30 years, including taking on the associated demand and commercial risks.

In turn, the public sector party will assume ownership of the assets and most of the financing-related responsibilities and risks, including the currency risk related to the potential devaluation of the Egyptian currency. For its part, GOE will make available financing on the order of US$175 million to the operator for the initial phase of the construction. The funds were to be sourced through a loan facility that GOE had already established with the World Bank and Agence Française de Développement (AFD).

The private operator, at its option, may draw up to 85 percent of total construction costs from the facility, leaving the private operator's own contribution to be at least 15 percent.[4] As the operator draws down from the loan facility, it triggers an annual repayment obligation (annual concession fee) to GOE based on defined payment

[4] The loan facility would reimburse a maximum of 85% of the total eligible construction costs to the private operator, meaning a minimum of 15% contribution from the private operator. The private operator may, in some circumstances, be required to increase its proportion of financing, particularly if the initial subscription by farmers exceeds 90,000 feddans. No restrictions are provided as to where the private operator can source this financing. It can be in the form of both equity and debt.

terms and conditions. The amount of the annual concession fee will be in direct proportion to the amount of funds drawn down and would cease upon the private operator's fulfilling completely its full repayment obligations over 20 years. The concession fee is designed as a back-to-back payment to cover GOE's loan obligations to the World Bank and AFD.

Once the initial loan facility of $175 million is exhausted by initial construction costs, the operator will be obliged to source its own funding by debt and equity to expand the system to the extent of additional demand. In this phase, the structure would revert more to a traditional concession Build-Operate-Transfer (BOT) model, with the operator assuming full financing risks.

The private operator would collect combined two-part tariffs denominated in Egyptian pounds (LE) from connecting farmers to recoup its costs. He will collect a fixed tariff (flat tariff) that will be charged on a per-feddan basis to connecting farmers over a 20-year period to defray the private operator's concession fee, additional capital expenditures financed by the operator, replacement costs, and a return on investment. The operator also will collect a volumetric tariff based on actual water consumption, which will defray the operator's cost of operations and routine maintenance, and provide a management fee.

Rationale

This hybrid option was regarded as the preferred approach for the proposed project because it balanced risks evenly between the public and private parties. The DBO model transferred as much project risk as possible from public to private. A pure public model or a management contract would have had a high probability for successful implementation but would have transferred few risks to the private sector. By comparison, a classic BOT concession would have transferred essentially all risks to the private sector. However, it would have been be too costly in the initial stage and likely would have received low interest from prospective private investors without sizable subsidy, as was recently demonstrated in the Guerdane Concession in Morocco.

Institutional and Regulatory Arrangements

Regulatory responsibilities would be shared between a Project Management Unit (PMU) within the Ministry of Water Resources and

Irrigation, a Regulatory Office (RO), and a Water User Council (WUC) representing farmers in the area. The PMU would manage the day-to-day business of the project, including financial management and disbursement functions. The PMU would also supervise the contractual arrangements for the initial construction and expansion of the irrigation system. The RO would regulate rate adjustments and tariff rebasing and oversee the contractual commitments of the operator with regard to prescribed service standards. Finally, an Independent Panel of Experts would be set up as needed to mediate disputes.

The WUC was established as an independent farmers' organization to take an active part in preparing the project and, ultimately, during implementation, in monitoring the relationships and potential conflicts among farmers on such matters as water entitlements, usage, and alternating hours of irrigation. The WUC also will monitor groundwater pumping in the area, along with the more official program that will be implemented by the PMU.

Conclusion

The challenge posed to the West Delta project was to provide quality irrigation services to a highly discriminating user group without significant public subsidy. The West Delta Project has responded by introducing a transaction concept that relies on *full cost recovery, volumetric pricing, a balanced risk framework, user participation, tariff regulation, and technical specifications to reduce the financial exposure of private operators*. The transaction would involve sharing the financing between GOE, a private operator, and farmers, with the debt portion underwritten by a government guarantee.

While the project has its own specificities, in particular, a preexisting community of commercial, successful, and technically savvy farmers, it provides useful lessons about the design of self-financing irrigation schemes. Whether the project's formula for apportioning risks and rewards will succeed in the market remains to be seen. Whatever the outcome, however, the project will be keenly observed by MNA countries looking for new approaches to meet the service demands of their irrigated farmers.

References

Tardieu, H., and others. 2004. "Public-Private Partnership in Irrigaiton and Drainage: Need for a Professional Third Party between Farmers and Governments." Eighth International Seminar on Participatory Irrigation Management: Emerging Trends in Public-Private Partnerships in Irrigation. www.inpim.org/leftlinks/Seminars/EighthSeminar.htm

World Bank. 2007. "Emerging Public-Private Partnerships in Irrigation Development and Management." Water Sector Board Discussion Paper 10. May.

Delegation

20

Participatory Irrigation Management and Cost-Sharing in Yemen

Naji Abu-Hatim and Ahmed Shawky Mohamed

Yemen is among the *poorest* countries in the world. Its agriculture is an important driving force of economic growth, contributing 14 percent–23 percent to GDP. Agriculture also makes very significant indirect contributions by providing employment and income to more than 55 percent of the active population. Nevertheless, poverty is spread mainly throughout rural areas, which are home to 83 percent of the poor. They derive their livelihoods and incomes mainly from agriculture-related activities.

Yemen is also one of the most *populated* among the Arab Peninsula countries. Yemen's 3.2 percent demographic growth puts high pressure on its natural resources.

Yemen is one of the most *water-constrained* countries in the world. With a per capita availability of 150m^3 a year, Yemen's water availability is 10 percent of the regional average and 2 percent of the global average. The country also has one of the highest sectoral water allocations to agriculture: more than 90 percent of total use.

With a largely arid to hyperarid climate and no perennial rivers, the country relies heavily on the exploitation of groundwater. *Groundwater reserves are being critically depleted*. Renewable resources, estimated at approximately 2,100 million cubic meters (m^3) a year, are being supplemented by groundwater mining from deep aquifers at a rate of approximately 1,300 million m^3 a year (with desalination and reclaimed wastewater accounting for a negligible percentage). In some areas, groundwater tables are dropping at 3 meters a year, and many farms are being abandoned. Spate flood is the second-order means of irrigation. However, as opposed to using groundwater, utilizing spate water proved costly to the government since it requires developing and maintaining spate-regulating, off-farm infrastructure.

Irrigation in Yemen has grown rapidly, both from groundwater and surface water. Traditionally, Yemenis had many ingenious techniques to husband their scant water. Early development of modern spate schemes in the 1950s successfully adapted traditional flood recession technology to a more controlled system. Later, in the 1970s, the introduction of the tubewell and motor pump revolutionized irrigation. Now, full or supplemental groundwater irrigation accounts for over two-thirds of the value of crop production. Irrigation efficiencies are low (nationwide average approximately 40 percent). Water consumption in the irrigation subsector continues to increase at an average annual rate of 30 million m^3, or 5 percent. Already by 1990, irrigated agriculture alone was consuming 130 percent of Yemen's renewable water resources, meaning that the overdraft beyond the "safe yield" was approximately 30 percent. By 2005, this figure had reached over 50 percent. If agricultural expansion continues, groundwater overdraft will reach 100 percent by 2025. However, many aquifers will be pumped dry long before then.

Water markets exist in Yemen but only on the margins of the water-related activities. The private sector and market mechanisms are found only in irrigation water sales to water tankers. However, these markets are informal. Yemen lacks clear groundwater rules. Third-party externalities are not accounted for, and there is no enabling or regulatory environment.

Water scarcity is exacerbated both by significant spatial and temporal variations and by significant water (rights) allocation problems. With the expected rapid population growth, by 2025, water availability per capita is estimated to decrease by 35 percent from 2005, well below levels generally reckoned to indicate severe water stress.

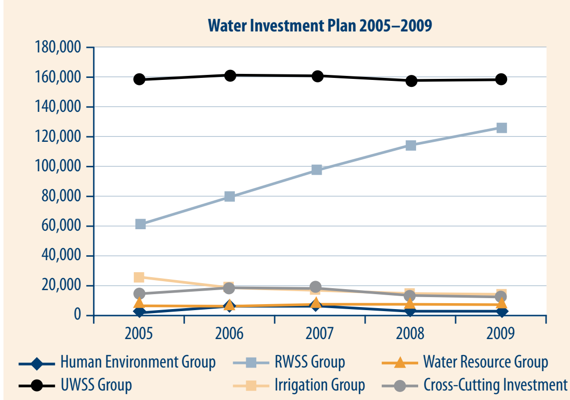
As a result, one challenge facing Yemen is to *reduce groundwater use in agriculture while maintaining the rural economy and farmers' incomes*. A compounding challenge is to improve the sustainability of spate irrigation infrastructure and to reduce the government's financial burden through strengthening farmers' self-reliance on financing and maintaining spate irrigation systems.

In the past, the government intentionally subsidized irrigation and drinking water to promote development, reduce the cost of living, raise farm incomes, and vest powerful influence groups with patronage. By the late 1990s, the government recognized that this pattern posed economic and environmental pressures and that new pricing regimes were needed to target cost recovery and—to a lesser extent—demand management.

Nevertheless, despite a decentralization program for cost-sharing in water investment programs, government remains the dominant financier. During 2000–04, water sector capital expenditures were financed mainly by budget transfers (41 percent) and loans (29 percent). User fees financed only 28 percent of the investment program. According to the 5-year government investment plan proposed for 2005–09 (figures 20.1 and 20.2), budget transfers are expected to represent only 30 percent of total financing for the water sector. Funds committed by donors (loans/grants) amount to 31 percent. Therefore, 39 percent of additional financing—the balance—is required by 2009. Self-financing may be needed to cover most of this balance. Furthermore, the government has developed an ambitious investment plan for the water supply and sanitation (WSS) subsectors to achieve the MDGs (figure 20.1). Thus, the government would prioritize its sovereign financing of these subsectors over the irrigation and water resource management subsectors.

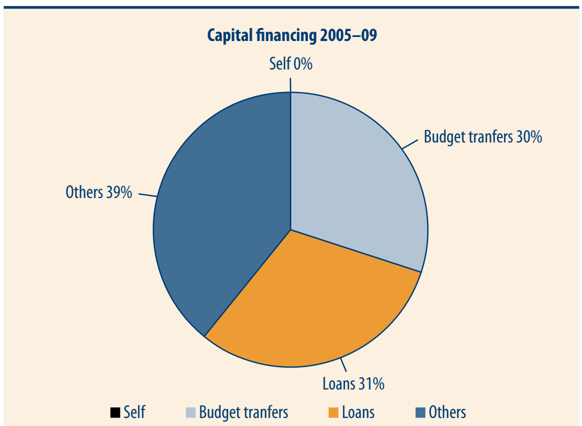
For the irrigation subsector, it can be concluded from the above that cost recovery and demand management policies need to be coupled and fostered, thus replacing the old patronage and supply-driven approaches. The government has set financial autonomy as a policy for rural decentralized water supplies and has started to work with water user groups (WUGs) toward cost recovery, particularly in spate irrigation.

Figure 20.1 WSS Subsectoral Five-Year Investment Plans, 2005–09



Source: DGGREE-Ministry of Agriculture and Water Resources, "Report on the Preparation of the Investment Project in the Water Sector," 2007.

Figure 20.2 Projected Sources of Capital Expenditures for Water Sector, 2005–09 *(%)*



This chapter presents success stories and lessons learned from the cost-sharing and water user-participation activities of the World-Bank-supported Irrigation Improvement Project (IIP) in Yemen. The chapter also presents comparable experiences from other demand-management-oriented projects in Yemen.

Experiences from the Irrigation Improvement Project (IIP)

To improve the use of spate irrigation in Yemen, the World Bank Institute (WBI) facilitated a review of the prospects for WUAs and the ultimate transfer of spate schemes to users. In 2001 this review envisioned the IIP: "…an Adaptable Program Loan to support physical rehabilitation and to move the reform agenda forward" (US$20 million). One IIP component aimed to establish water user organizations that would share investment/rehabilitation costs of the main irrigation system and gradually take over the operation and maintenance (O&M) of the secondary/tertiary system.

Formulation of Water User Organizations toward Cost-Sharing

The IIP was articulated around Participatory Irrigation Management (PIM). The project prompted the government to create enabling legal and institutional environments to establish two main irrigation-user organizations: water user associations (WUAs) and irrigation councils (ICs). Each WUA is in charge of implementing PIM in its respective irrigation command area.

The WUA was to (1) provide reliable and sustainable irrigation services, (2) perform maintenance and rehabilitation, (3) collect fees from beneficiaries, and (4) develop the capability for self-reliant O&M. At later, more advanced stages, ICs were established in both Wadi Zabid and Wadi Tuban with potent representation from the WUAs. The ICs act as the High Executive and Administrative Authorities in each wadi (riverbed). The ICs are responsible for (1) applying the IC's by-laws and implementing its executive procedures; (2) coordinating activities between government authorities that continue to be in charge of O&M of head works/primary canals and the WUAs in charge of O&M of the secondary and tertiary systems; (3) protecting water user rights and resolving conflicts and pending issues; and (4) monitoring the social, financial, and technical performance of WUAs. The ICs represent the local government, WUAs, and the Ministry of

Agriculture and Irrigation (through its Regional Development Authority/Agriculture Office).

The project initiated the PIM approach through undertaking a comprehensive awareness program to inculcate the concept of PIM in farmers' minds and to clarify the roles and responsibilities of irrigation beneficiaries within their representative user groups. The program targeted all relevant stakeholders, including farmers (owners, sharecroppers, and tenants), government officials, and local councils. As a result of the program, informal water user groups (WUGs) were formulated at the onset, which later metamorphosed into formal WUAs. ICs were formed at an advanced stage of IIP. The project then developed training activities to build the managerial and technical capabilities of the WUAs and ICs.

PIM called for farmers' participation in overall project activities starting from decisionmaking to completion of the rehabilitation and improvement works, as well as farmers' contribution of 10 percent of investment costs in kind. Thereafter, farmers would take over responsibility and financing for the O&M of secondary and tertiary canals.

IIP's Approach to Community Cost-Sharing of Off-Farm Investments

For the investment/rehabilitation works, as mentioned earlier, the IIP introduced an in-kind cost-sharing approach through community-implemented contracts. To enable low-income farmers to share the capital costs of the project, IIP divided civil works into two categories:

1. *Priority works* to be fully financed by the project (government funds and loans). These works include feeder roads and flood/environmental protection works, which are deemed public goods outside the canal system and thus require no earmarked user fees.
2. *Participatory works,* requiring a 10 percent farmer contribution to rehabilitation/improvement capital costs. This percentage was agreed between the project government team and farmer representatives (initially the WUGs; eventually the WUAs). Farmers were allowed to contribute this percentage in kind: labor and material. In this arrangement, each WUA would implement 1–2 small community contract(s) up to $10,000 per contract, to an aggregate $1.4 million per project. To further persuade irrigation end-beneficiaries to contribute 10 percent in kind, the project guaranteed

that the unit rates of the contracts awarded to WUAs would be 30 percent cheaper than those implemented by the national/regional contractors. (These rates otherwise would have embodied significant profit margins for the WUA contractors.) This percentage thereby represents the total contribution from end-beneficiaries and, intrinsically, from the WUA contractors.

Farmers' Response to Joining WUAs and Sharing Capital Costs

One major incentive for farmers to join WUAs was to vest the farmers with the authority to co-design and co-implement spate subprojects. Due to past, persistent centralized subsidies of irrigation in Yemen, farmers at first felt little incentive to buy in to the idea of forming WUAs under the project, especially since spate irrigation depends on erratic floodwater that is becoming ever more scarce and less predictable.

However, *through IIP's public awareness program*, many farmers have come forward and joined the WUAs. The farmers pay subscription and annual fees and play an active role in selecting the types of irrigation structures needed and contributing to subsequent implementation/supervision of civil works contracts.

Farmers became more interested after they were vested with the right to participate in decisionmaking and (as explained above) to directly implement small contracts in which they would cost-share the rehabilitation and improvement works. The project's Credit Agreement included a prerequisite that civil works could not start before establishing the respective WUAs.

Farmers also exhibited willingness to share costs of *on-farm improvements* after the project evidenced improved yields and profits. The IIP included a major component to demonstrate improved irrigation technologies and agronomic practices at the on-farm level.

The demonstrations were conducted with 360 farmers and 590 farmers at Wadis Zabid and Tuban, respectively. An additional 1500 farmers were involved in the associated awareness campaigns. As a result of the various on-farm interventions (table 20.1), some crop yields increased up to 100 percent! In the Rapid Appraisal Survey conducted in March 2005, farmers rated the overall outcome as highly satisfactory. They expressed willingness to share 25 percent and 50 percent of the on-farm costs of improved technologies for the spate and tube-well demonstrations, respectively.

Table 20.1 Yield and Farm Revenue Increases Due to Improved Farming Practices: Planned Project Estimates vs. Actual Measurements (%)

Crop	Planned yield increase (%)	Measured yield increase (end 2005) (%)	Internal rate of return (%)
Cotton	13 Zabid 15 Tuban	45–100	Up to 6
Sorghum grain	5	Up to 98	9.5
Sorghum fodder	4 Zabid–8 Tuban	Up to 44	4.5
Sesame	10	Up to 55	8
Maize	18 Zabid	62–97 Zabid	NA
Cucurbits	3 Tuban	Up to 200	Up to 90
Tomatoes	20	87	4
Onions	20	12 to 25	2
Eggplant	20 Tuban	44	13
Red chilies	20 Tuban	NA	NA
Banana	10–15	NA	NA
Mango	10	NA	NA
Okra	15	25	3
Water melon	NA	28 Zabid	NA

Backstopping the WUAs and Tackling PIM Implementation Difficulties

The project provided the needed training and necessary administrative, financial, and technical backstopping to WUAs. Primarily due to their weak legal and financial status at start-up, WUAs experienced various obstacles in actualizing their roles. These difficulties called for creating options to empower the WUAs in carrying out the community contracts. For instance, it proved difficult for the WUAs to issue bank/commercial guarantees for the community contracts. Alternatively, they were permitted to issue guarantee letters endorsed by the governors.

Backstopping the WUAs included the following five activities:

1. A training program has been carried out for each WUA Board of Directors and for their Auditing and Inspection Committees to enable them to understand the legal status, objectives, and administration/financial management of O&M activities. The emphasis has been sustainable O&M.

2. Irrigation Management Transfer (IMT) Agreements were prepared in Arabic and were endorsed by the governors.
3. The project team has trained the WUAs' construction managers on contracting procedures as well as procedures covered in the Project Operations Manual.
4. The WUA representatives have participated in three workshops at the regional and national levels on institutional assessment of the irrigation sector.
5. The draft by-laws for establishing the ICs have been approved by the project's interministerial Steering Committee, thus hastening the establishment of an IC for each of the two wadis.

Approximately 30 working papers and operational manuals have been prepared by the training consultants for the project's PIM component.

The cost of training and WUA-backstopping in the IIP has been considerable, amounting to approximately 20 percent of total project costs. The Yemeni government could seek to scale up the PIM concept after the completion of Bank-supported projects. If so, the government would need to secure financing for such software-type investments from the sovereign resources allocated to rural extension and research. From international experience, this is deemed one of the examples for "virtuous" subsidies that a "lean-and-mean" government (as opposed to the private sector or end-beneficiaries) could shoulder.

Status and O&M Roles of WUAs/ICs, and Expected Progress

Promising results have been observed thus far as irrigation stakeholders in the two wadis participated in the IIP design, cost-sharing, and implementation stages.

All WUAs in Wadi Zabid and Wadi Tuban have been established and become fully operational with active boards of directors, proper bookkeeping, and bank accounts. The WUAs have worked closely with the project management units (PMUs) and the project consultants during the design and implementation of the rehabilitation and improvement activities. As part of the WUAs, Farmer Design Committees (FDCs) have been elected (with the facilitation of existing Farmers' Organizations, or FOs) to determine priority ranking of rehabilitation needs and to participate in their design.

The WUAs have efficiently been implementing the participatory contracts and signing IMT Agreements for all secondary and tertiary canals. More importantly, they started to contribute to O&M costs of the secondary/tertiary system (as it has been agreed that the O&M costs of the main system be shouldered by the government). The IIP has prepared an O&M manual including a detailed inventory of required O&M items and a description of how WUAs could prepare O&M plans/budgets and collect O&M fees. The WUAs have been attending an extensive training program on how to use this manual and how to implement it. Thus far, WUAs have been collecting user fees for heavy-equipment rentals to carry out immediate O&M of the secondary/tertiary canals. The fees collected are deposited in WUAs' bank accounts and disbursed from these accounts. To date, O&M fees are being collected ad hoc since O&M of the IIP-introduced works have not been in effect. However, it is reported that farmers are paying their contributions and that the collection process is transparent.

The ICs also have started to hold regular meetings and discuss issues related to water rights and water distribution. The role of the WUAs and the ICs will become more obvious after completion of the rehabilitation/improvement works. *One sign of WUAs' effectiveness in Wadi Zabid was that they managed to persuade powerful farmers to restore canal cross-sections and to remove the control works that they had unilaterally placed in the canals to extend their irrigated areas.*

To summarize, thus far, IIP has been deemed a successful "process" project, in testing and scaling up the PIM concept. The beneficiaries formed grassroots-level WUAs and wadi-level ICs that have been successfully:

- Participating in decisionmaking and in selecting design options
- Contributing to capital investment costs and to implementation of civil works contracts
- Gradually taking over responsibilities for the recurrent financing and O&M of the secondary and tertiary systems.

The viability of this "process" project is to be assessed based on its far-reaching impacts. They include financial sustainability; natural-resource-base sustainability; reduction of avoidable transaction and overhead costs; and piloting, transferring, and scaling up best practices. Most of the off-farm rehabilitation and improvement activities are in progress. Thus, it is too early to draw conclusions on the quality of irrigation services provided by ICs/WUAs, as opposed to those previously provided by corresponding government entities.

Experiences from the Groundwater Management Projects

In the early 1990s, Yemen began tentative steps to reverse the groundwater water mining problem and improve cost-sharing. A major constraint was the very weak legal governance environment and the strong traditions of tribal and local autonomy and fragmented water institutions that had virtually no influence over the water-extraction decisions made by tens of thousands of independent-minded farmers. In response, a decentralized partnership approach was proposed. The following sections touch on the PIM and cost-sharing experiences obtained from a number of irrigation demand-management-oriented projects in Yemen.

Groundwater Management Called for Introducing PIM

As one building block for an integrated approach to the water problem, the Bank-supported Land and Water Conservation Project (LWCP 1994–99) was launched to demonstrate a package of technical improvements to reduce water use at farm level. LWCP targeted improving Yemen's very low (approximately 40 percent) overall irrigation efficiencies. The project offered a package of technical advice to groundwater irrigators on water-saving technology and financed capital improvements on a cost-sharing basis, typically 30 percent from farmers and the balance from government. Technology comprised predominantly piped on-farm water distribution systems and the use of drip or bubbler micro-irrigation. The project decentralized implementation to local specialist teams and required farmers' contributions up-front, with a credit facility available. The project was well received by farmers and achieved its water-saving objectives.

A second phase—the Groundwater and Soil Conservation Project (GSCP)—began in 2003. It is extending the technical and financial package from 11 to 15 governorates. GSCP builds on the LWCP exercise by adding a key element: a technical advisory service. It complements physical investment in water-use-efficiency equipment with improved water management (through better irrigation scheduling and agronomic improvements), adjusted cropping patterns, and crop husbandry—all toward raising farm returns per m^3 of water.

The project deepens the innovative partnership approach that LWCP introduced. The government has created a framework of rights, regulations, and basin planning that—in Yemen's weak governance context—can be implemented only through decentralized approaches and the cooperation of groundwater users. Ways to develop this cooperation through partnership approaches are being tested at two levels: the *basin level* through basin committees that are based on basin hydrological boundaries rather than on governorate boundaries; and the *local level* through WUAs similar to those introduced under IIP. Complementing the GSCP, a Japanese-grant-financed pilot program, the Community Water Management Project (CWMP), has been harnessed to test community self-management approaches to water conservation. CWMP groups the irrigators together for groundwater management and conservation, using participatory monitoring techniques ("peer monitoring").

Water Reforms Enable Coupling Demand Management with Cost-Sharing

Alongside these field approaches, the government is strengthening groundwater governance. A 2003 water law defined water rights and set up a regulatory system of permits. Created in 1996, the National Water Resources Authority (NWRA) is preparing basin plans, working with basin committees that bring together government and water users, and encouraging participatory and community-based solutions aimed at self-regulation and self-financing of recurrent costs by water users. The Sana'a Basin Water Management Project (SBWMP) is testing these approaches in the stressed basin around the nation's capital.

At the same time, government is fostering water conservation incentives by using macroeconomic measures, raising the price of diesel fuel, and phasing out border protection of irrigated commodities. Government doubled the price of diesel in 2005, a key demand-management measure.

Cost-Sharing Created Revolving Funds to Finance Water-Saving Practices

The LWCP piloted improvements for groundwater management and innovative approaches to watershed management. The adoption of cost-sharing proved the key to demonstrating farmer commitment.

Previously, projects had provided equipment free of charge, with disappointing results. Cost-sharing has created a revolving capital fund of approximately US$2 million to finance expansion of the LWCP. The project's decentralized and participatory approach to identification, design, and implementation brought farmer knowledge and commitment into partnership with the skills and resources of government. LWCP also laid the basis for the current GSCP/CWMP phase in which the government will partner increasingly with user groups rather than with individual elites.

Farmers jointly invested approximately US$250/ha to achieve water savings of approximately 2,300 m^3/ha/year. The investment costs thus are approximately US$0.11/$m^3$ of annual water saving. Savings in pumping costs averaged US$0.06/$m^3$. Thus, the investment cost is recouped by farmers in just two years, even without accounting for the opportunity value of the water saved in the aquifer.

Political Economy of Introducing PIM to Groundwater Users

Although combating groundwater mining generally seemed to be pro-poor in Yemen, the better-off may have been capturing most of the initial benefits. Under LWCP, a pro-poor filter was applied to the project's subsidized investments in water-use efficiency by applying a ceiling on the area that the project would co-finance. However, this mechanism proved weak, and there was certainly a bias toward the better-off, who had land/water privileges and could afford the cost-sharing. It was clear that the better-off farmers control the lion's share of groundwater. Therefore, Bank-supported actions to reduce mining inevitably had to deal with these farmers. However, WUAs are a means of helping the disadvantaged avail of the benefits.

Forgoing WUAs would have risked excluding the poorer farmers, the landless, and women. Incidentally, this risk was a hot issue in the preceding Bank-supported Ta'iz Rural Water Supply Project. In it, there was a debate on the ethics of a Bank project dealing directly with the "sheikhs," who controlled most groundwater, rather than with WUAs, who were poor but did not actually "own" much water. The design of the Japanese-financed CWMP (box 20.1) attempted to resolve this problem by promoting WUAs that integrate all water users, from big well-owners to those who own no resource at all, on the basis of common responsibility.

Box 20.1 Yemen Community Water Management Project

The Japanese government is providing a grant for a Community Water Management Project (CWMP). The project, which is executed by the World Bank, would test and develop replicable models for sustainable self-management of local water resources by poor farming communities in areas of Yemen in which water, particularly groundwater, is becoming increasingly scarce. The project would have three components:

1. *Participatory water management component*. Would (a) identify areas in which social conditions are appropriate for local community self-management of water resources, and (b) build the capacity of local user groups across a discrete hydrological unit to manage the resource
2. *Water management and monitoring component*. Would work with user groups to define the water balance and a hydraulic goal, to draw up and carry out water management plans, and to monitor progress against the plan
3. *Monitoring and evaluation component*. Would document the project in full, evaluate and disseminate results, propose ways of scaling up successes, and create and support a network of practitioners.

At the end of the 4-year grant period, the project is expected to have developed models and institutional capacity in at least 3 representative areas. In these areas, local user groups will have the capability to work in partnership with local and central government agencies. The groups also will be able to set, enforce, and monitor local water management plans that reduce both net water loss and losses from pumping from the aquifer, while sustaining incomes equitably. The project will have documented the proven models, created a network of practitioners capable of scaling up the models, and influenced the policies and practices of local and central government agencies to partner with communities on local water management.

Community-Based Monitoring and Evaluation System

To maintain sustainability, the IIP ensured that ICs closely monitor the performance of the WUAs. The project has established three broad performance indicators: (a) institutional, (b) financial, and (c) technical.

1. *Institutional performance indicators* include (a) representation (percentage of farmers subscribing to membership in each WUA); (b) transparency and accountability (whether the chair and members

of the WUA executive body were properly elected; whether the executive body meets and produces minutes of meetings; whether WUAs members are being timely informed of the executive body decisions; whether WUAs adopted proper Internal Rules and Regulations and bookkeeping concerning managerial, financial, and technical aspects); and (c) authority (the degree to which WUAs have the power to execute their decisions).

2. *Financial performance indicators* monitor whether WUAs are willing and able to collect/receive adequate funds to cover O&M and whether WUAs maintain proper bank accounts and accounting records.
3. *Technical performance indicators* monitor whether WUA members master the O&M and supervision plans and are well informed of their foreseen costs.

However, *WUAs and ICs may need to be empowered to fully undertake the M&E, and ICs may need to be bottom-up rather than top-down entities.*

The water law enacted in 2003 enunciated that WUAs and ICs need to be established and need to contribute to the Wadi Integrated Water Management Plans, which are adopted by the government. With technical backstopping from the regional line agencies and local authorities/councils, WUAs and ICs need to gradually take over the role of overseeing service provision and facilitating the application of water-related incentives and regulations. They also can be entrusted with more monitoring/benchmarking roles in coordination with the regional line agencies, and with more enforcement roles in coordination with local authorities.

Nonetheless, the best alternative for a monitoring/benchmarking/planning body would be the technical secretariat of a basin committee. The basin committee would be based on hydrological boundaries. Its board would be composed of water user groups/federations, local authorities, local line agencies, and NGOs. This composition would reduce the immense forgone resource-economic costs posed by the administrative boundaries; and would limit the transaction costs posed by assigning monitoring/benchmarking roles to mono-user water groups.

The technical secretariat for the SBWMP thus far has been the Sana'a branch of the National Water Resources Authority, which needs to be capacitated. Basin committees are mentioned in the recent water law. However, the law/by-law is silent on:

a. Whether the committee board would approve the basin plans (developed by its technical secretariat) by consensus or by majority.
b. An indispensable provision entailing that the board members be from user groups and local entities rather than from line agencies. (Sana'a's board is not in compliance with this by-law as its members include many top ministerial officials.)
c. A provision stipulating that the board members are to be elected rather than appointed, with the chairmanship of the board being rotated among them.

Conclusions

Five conclusions can be drawn from the cost-sharing and related PIM experiences in Yemen's irrigation subsector:

1. WUAs and ICs could play an important role in rendering (a) services responsive to farmers' demands, (b) easier expansion of irrigation coverage, and (c) more timely water delivery, thus matching crop water requirements.
2. Farmer participation and cost-sharing create a sense of ownership of irrigation schemes, since farmers (a) become more proactive in dealing with emerging problems and in resolving the long-lasting social and technical problems that the government failed to resolve; and (b) start to speak up openly about issues that were controversial in the past, such as revisiting water rights that no longer maintain equity between upstream and downstream users.
3. Without sound water rights, rehabilitation and improvement of the irrigation infrastructure would not contribute substantially to improve equity of water distribution between upstream and downstream users. In addition, the relationship between landlords and sharecropper/tenant farmers needs to be clearer on who does what and how much each should contribute, thus avoiding exploitation of poor farmers.
4. Government can provide farmers with three key incentives to participate in cost-sharing and to organize themselves in WUAs: (a) Producing public awareness activities prior to any physical interventions. Advance notice would ensure upfront transparency

and notify farmers of the benefits forgone by not opting into the PIM process; (b) entrusting farmers to participate in the design, implementation, supervision, and O&M activities of the feeder-level (as opposed to trunk-level) irrigation contracts; and (c) producing public awareness activities after the physical interventions have been completed so that farmers could witness the resultant increase in production and net revenue.

5. Beneficiaries' contributions to capital and O&M costs relieved pressure on government budget and contingent liability.

References

MNSRE (Rural Development Water and Environment Group). 2004. Yemen Water Sector Public Expenditure Analysis. Draft. World Bank.

____. 2006. "Local Action: Partnership Approach to Sustainable Groundwater Management in Yemen." Draft paper prepared for contribution to the 4th World Water Forum, "Groundwater Management in the MNA Region." World Bank.

World Bank. 2005. Yemen Country Water Resources Assistance Strategy.

21

Community Management of Rural Water Supply: Evaluation of User Satisfaction in Yemen

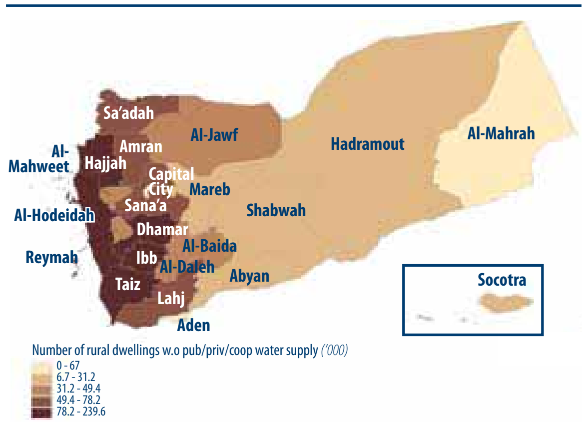
Susmita Dasgupta, Craig Meisner, Andrew Makokha, and Richard Pollard

Meeting the Millennium Development Goals (MDGs) in water supply and sanitation in Yemen is a formidable challenge for several reasons. First, the country is challenged by an inhospitable and dry geography. Second, the predominantly (75 percent) rural population is typified by small tribal communities dispersed in scattered settlements. Third, many of these approximately 100,000 villages are situated on rocky mountain tops, making service delivery and outreach difficult and expensive. Finally, only 41 percent of the population has access to health services, and less than 31 percent has adequate access to water and sanitation services (WSS) (figure 21.1).

These significant service deficit gaps obviously require substantial investments from the public sector, communities, and individuals. At the same time, many policymakers are concerned whether publicly financed investments are providing sustainable services to communities once the project investment is completed and support services are removed.

In recent years, the Government of Yemen, with support from the World Bank, the Government of the Netherlands, and UNICEF and other agencies, has initiated several projects and programs to improve WSS in rural communities. These programs

Figure 21.1 Rural Population Lacking Access to Public/Private/Cooperative Water Supply Networks in Yemen



Source: Project files.

have differing institutional and technical designs. Among other characteristics, they range from being strongly community-driven to strongly government-led programs in which communities are provided with infrastructure through centrally managed programs. Community-driven means that users are given extensive voice and choice in project planning, implementation, and water system management along with training and support to develop local water system management capacity. The World-Bank-funded Rural Water Supply and Sanitation Project (RWSSP) was perhaps the most community driven of the initiatives in that it provides users with a relatively open menu of choices of service levels (within the technical and resource limitations of the community) and management arrangements.

RWSSP was prepared during a period of reform and institutional uncertainty in Yemen's water and sanitation sector. As a result, one of the key elements built into the project was technical assistance to support the formulation of a national rural WSS strategy and the development of a subsector investment program based on the implementation experience of RWSSP.

Yemen now has comparatively streamlined water sector agencies. All the main government bodies working in the water supply and sanitation sector are located under the Ministry of Water and Environment. They include the General Authority for Rural Water Supply Projects (GARWSP), the National Water Resources Authority, the National Water and Sanitation Authority, the Technical Secretariat for Water Supply and Sanitation Sector Reform, and the Environmental Protection Authority.

The Government of Yemen (GOY) issued a policy statement agreeing to the guiding principles of the RWSSP, namely, a "decentralized, demand-responsive approach (DRA) to RWSS development, integrating sanitation and hygiene education with water supply in order to maximize health benefits and the sustainability of RWSS systems." The policy statement laid out three major principles of a demand-responsive approach:

1. Communities self-select to participate in the project by applying for assistance and meeting project conditions for local contributions and organizing for local management.
2. Communities participate in the design of their water supply and sanitation system and in the selection of the technology and service level that they consider suitable for their needs and for which

they are willing and able to pay partial investment costs and full operation and maintenance costs (O&M).

3. Communities create formal water user associations (WUAs) to manage their water and sanitation systems.

A number of major investment projects and programs that were either underway or prepared in the early 2000s adhere, to varying degrees, to these principles. The main investment programs include the Social Fund for Development, the Public Works Program, the national RWSS program executed by GARWSP, and UNICEF's Water, Environment and Sanitation (WES) Programme in Yemen.

User satisfaction with RWSS services provides a useful measure of the success or failure of a WSS investment program and the likelihood that the infrastructure will be sustained through its design life. An analysis of user satisfaction therefore can enable comparisons among the different approaches. The comparisons can indicate the relative sustainability of the WSS services that were constructed through the different programs.

Yemen RWSSP Household Survey

From October 2007 to September 2008, a household survey was conducted in the Abyan, Hajjah, and Ibb Governorates of Yemen to evaluate water users' satisfaction with water and sanitation services. The objectives of the survey were to (1) assess the performance of the RWSSP with respect to several indicators of user satisfaction with the services provided and their ability to operate and maintain water systems, and (2) compare the RWSSP's performance with that of other ongoing RWSS projects in Yemen. As mentioned above, the outcomes of this survey were to guide the design of rural water and sanitation interventions.

Table 21.1 breaks down the total number of community water systems established through RWSSP and four other projects included in the survey as of June 2007.

Survey Sample

Sample selection for the survey was carried out in three stages. First, a record of all existing water supplies was culled from different sources and stakeholders. Next, with support from local governments and

Table 21.1 Number of Rural Water Schemes, June 2007

Governorate	Total	RWSSP	GARWSP	Public works (PWP)	Social Fund (SFD)	UNICEF
Ibb	423	38	315	27	41	6
Abyan	248	33	153	38	8	23
Hajjah	176	19	96	28	34	1

Source: General Authority for Rural Water Supply Projects (GARWSP).

social workers, a field review was carried out at the district and *Uzla* (subdistrict) levels to establish which supplies were operational. Third, operational water suppliers were arranged by source of funding (donor or government). A sample of water schemes by each donor and governorate was then selected for the detailed survey (table 21.2).[1] A random sample of households was then selected from each of the 168 selected water schemes. In total, 5,035 households covering 41 districts and 152 Uzlas participated in the survey.

Table 21.2 Sample Composition

	No. of water schemes surveyed *(no. HH surveyed)*				
Governorate	**RWSSP**	**GARWSP**	**PWP**	**SFD**	**UNICEF**
Abyan	7 (210)	29 (870)	6 (180)	4 (120)	6 (180)
Hajjah	4 (120)	20 (600)	4 (120)	6 (180)	0
Ibb	17 (510)	38 (1140)	11 (330)	10 (295)	6 (180)
Total	**28 (840)**	**87 (2610)**	**21 (630)**	**20 (595)**	**12 (360)**

Description of Projects to Be Compared

Rural Water Supply and Sanitation Project (RWSSP)

In 2000 the Republic of Yemen received a US$20 million credit from the International Development Agency (IDA) for the Rural Water Supply and Sanitation Project (RWSSP). The project's overall objective is to expand sustainable rural water supply and sanitation service coverage

[1] The initial selection of the number of water schemes was not necessarily representative of all schemes.

to approximately 400,000 mostly poor rural dwellers in 6 governorates: Abyan, Hajjah, Ibb, Amran, Lahje, and Al Dhalea. In 2007 the project was extended for one year to December 2008 with additional financing to expand coverage to a total of approximately 800,000 people (including the original target population) through approximately 150 rural water supply systems. Table 21.3 summarizes rural water supply and sanitation service coverage within the six governorates covered by the project as of 2004, at which time the project had completed only a few water systems.

Table 21.3 Rural Water Supply and Sanitation Coverage in the Six Governorates of Yemen Included in RWSSP

Governorate	Rural population	No. of dwellings	No access to water network *(%)*	No sanitation *(%)*
Ibb	1,748,126	259,492	69.8	44.0
Abyan	321,026	43,446	71.9	42.5
Hajjah	1,346,407	169,586	87.7	71.4
Lahj	657,652	104,882	71.6	40.1
Amran	728,562	80,408	86.1	53.2
Al-daleh	409,391	52,640	86.8	52.4
Average for rural Yemen			76.1	50.4

Source: CSO-Demographic Census 2004.

The project was to achieve these targets by:

- Introducing demand-responsive, decentralized, community-managed RWSS approaches
- Building and strengthening governorate, district, and local-level RWSS systems' implementation capacity
- Providing a platform for a national RWSS implementation strategy based on the principles of demand-responsive, community-owned RWSS services
- Enhancing a learning process for RWSS systems sustainability
- Implementing RWSS development schemes and expansion of service coverage.

The project is managed by a central Project Implementation Unit (PIU), which operates through governorate PIUs in each of the administrative areas in which the project is active. The PIUs are independent of existing sector agencies to enable the units to develop and use decentralized, demand-responsive, community-managed approaches.

Nonetheless, the project is relatively "embedded" within government institutions. All major decisions pertaining to geographic priorities or changes in the project implementation strategy require approval from the Project Steering Committee, which is chaired by the Minister of Water and Environment.

Subprojects are planned and managed with extensive water user group (WUG) involvement guided by social mobilization teams. However, design and construction are carried out by private firms contracted by the PIUs. Communities contribute a minimum of 5 percent of subproject costs. Communities co-sign the contracts and payment authorizations. RWSSP schemes tend to be large, piped, pumped water systems aimed at providing continuous or near-continuous water services through metered house connections. The project does not fund groundwater exploration or borehole drilling. Nonmechanized technologies such as hand pumps are supported only in cases in which piped services would not be feasible. The project uses existing water sources, or it coordinates with GARWSP, which locates water sources and drills and develops the boreholes that can be the sources of water for RWSSP systems. Table 21.4 summarizes the number of RWSSP schemes completed and incremental coverage achieved by June, 2007.

Table 21.4 Coverage of RWSSP, June 2007

Governorate	No. of RWSSP water schemes	No. of villages served	Population coverage	
				% of total
Ibb	38	184	117,508	6.7
Abyan	33	262	50,568	15.8
Hajjah	19	274	64,302	4.8

Source: RWSSP.

General Authority for Rural Water Supply Projects (GARWSP)

The General Authority for Rural Water Supply Projects (GARWSP) is the national agency that manages the Government of Yemen's national rural water supply program. In addition to national funds, it receives sector budget support from the Netherlands.

The program is highly centralized. Bulk procurement of raw materials (pipes, pumps) is carried out in Sana'a. Governorate offices of GARWSP coordinate with local governments to identify, design, and construct subprojects. As a national program, GARWSP is under considerable pressure to spread resources across all parts of the country, rather than prioritize regions or respond to community self-selection. Budget allocations are usually insufficient to enable individual subprojects to be completed in a single fiscal year. As a result, individual subprojects are implemented in phases so may require several years to be completed.

Just as does Public Works Project (PWP), GARWSP has tended to focus on implementation rather than on community capacity building for O&M. However, in recent years, GARWSP has begun to support the establishment of water user groups (WUGs) for water scheme management.

Public Works Project

The Public Works Project (PWP) has an institutional and financial setup similar to that of the Social Fund for Development (SFD). PWP is autonomous, financed through a special account, managed by a Project Management Unit (PMU) in Sana'a and six regional suboffices, and implemented through private contractors and consultants. PWP also is a multisector initiative with approximately 30 percent of funds going to water and sanitation subprojects. Beneficiaries contribute at least 5 percent of subproject costs. However, project financing is only for civil works, such as constructing a reservoir or pumping house station.

PWP's focus is on creating labor-intensive employment. This focus has led to financing only labor-intensive civil works rather than comprehensive infrastructure systems. This policy creates institutional constraints when communities apply for a mechanized water supply system. PWP then becomes reliant on other partners (GARWSP, UNICEF) to finance and implement the capital-intensive components of these subprojects. Conversely, communities often ask PWP to complete civil works components in unfinished community water supply schemes or to implement scheme designs prepared by other agencies.

PWP has developed a reputation for rapid and efficient implementation. However, it rarely offers communities much participation in planning, choice of technology, service level, or user contributions. PWP focuses on implementation and does relatively little capacity building.

Social Fund for Development

The Social Fund for Development (SFD) was established in 1997 by law, which granted SFD a great degree of autonomy. In essence, and despite the managing director's being a government minister, the law enables SFD to be managed as an independent body The fund's approach is to provide services in response to communities' demands and needs. Communities decide on their key priorities, contribute to the capital costs, and take a role in operation and maintenance (O&M) of the facilities.

Now in its third phase, SFD has grown from a US$30 million project in 1997 to a $400 million national program supported by 10 multi- and bi-lateral donors. It is an "open menu" project providing funds for a wide variety of community-prioritized investments., Approximately 20 percent of the funds provided for community investments are spent on water subprojects. The subprojects designed are simple systems (standposts, rainwater collectors). SFD water projects are limited to water-harvesting schemes and water supplies based on shallow wells and springs. SFD does not have the same degree of flexibility as the RWSSP in responding to community demands for piped systems with or without house connections. Therefore, the fund does not finance drilling for boreholes or mechanized systems. Activities with an environmental focus include wastewater management and solid waste management.

SFD has been expanding community contracting in its subprojects, and most construction is undertaken by private contractors. Cash community contributions amount to approximately 15 percent of subproject costs. Contributions in kind in the form of labor and local materials are growing. The project aims to provide only technical assistance and material inputs that are not available locally.

UNICEF

Through its Water and Environmental Sanitation (WES) Program, UNICEF also finances water supply systems on a grant finance basis, although not on the same scale as the other projects.

RWSSP and SFD have much greater sustained engagement with communities than PWP or GARWSP. One thus could hypothesize that user satisfaction would be greater in RWSSP and SFD than in the other two projects.

Survey Findings

Household connections and water use

The percentage of households with connections in each subproject ranges from 100 percent in the RWSSP to approximately 80 percent for the other projects (table 21.5). The reasons for the range are that (a) not all technologies are amenable to piped house connections and (b) some of the projects (such as SFD as explained earlier) concentrate

Table 21.5 Surveyed Households with Connection to Piped Water Network *(%) (no. of HH in parentheses)*

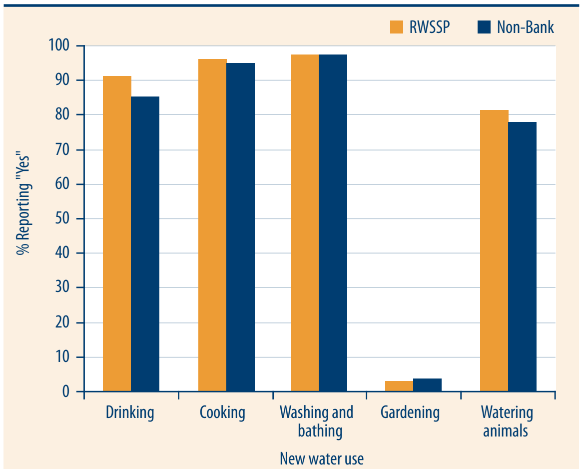
	%	RWSSP	GARWSP	PWP	SFD	UNICEF	Total others
Abyan		***100.0***	***85.8***	***83.3***	***75.0***	***40.6***	***78.4****
	Connection	(210)	(870)	(180)	(120)	(180)	(1350)
Hajjah		***100.0***	***100.0***	***100.0***	***0.0***	—	***100.0***
	Connection	(120)	(600)	(120)	(180)		(900)
Ibb		***99.8***	***94.6***	***88.2***	***30.5***	***87.8***	***83.1***
	Connection	(510)	(1140)	(330)	(295)	(180)	(1945)

Note: * = Sum of GARWSP, PWP, SFD, and UNICEF projects.

on low-cost rainwater harvesting and other nonmechanized technologies.

Irrespective of the manner of access and type of water scheme, almost all HH used the water provided through the subprojects primarily for drinking, cooking, washing-bathing, and watering animals (figure 21.2). Very little of the water was used for irrigation.

Figure 21.2 Various Uses of RWSSP and Other Subprojects Water in Yemen, 2007–08



Adequacy of water

All water users reported a level of dissatisfaction with the extent to which the projects met all household needs (table 21.6).

Reasons for inadequacy

The four main reasons for inadequacy of water relate to water resource constraints (table 21.7) Due to seasonal variations, WUAs are forced to regulate availability of water in order to maintain service to an acceptable number of users. This regulation leads to intermittent nonavailability of project water. In addition, there also are a substantial number of cases in which water is inadequate because of breakdowns.

Comparison of actual and scheduled water service provision

The survey compared perceptions of the users of RWSSP to the perceptions of users of the other projects. In governorates—Hajjah, and

Table 21.6 HH Reporting That "Project Water" Was Not Meeting Their Entire Household Needs *(%) (no. of HH in parentheses)*

	RWSSP	GARWSP	PWP	SFD	UNICEF	Total others
Abyan	***40.0*** (84)	***44.4*** (386)	***23.3*** (42)	***44.2*** (53)	***75.6*** (136)	***45.7**** (617)
Hajjah	***25.8*** (31)	***31.5*** (189)	***50.0*** (60)	***67.8*** (122)	—	***41.2*** (371)
Ibb	***16.3*** (83)	***36.7*** (418)	***51.8*** (171)	***69.8*** (206)	***16.1*** (29)	***42.4*** (824)

Notes: * = Sum of GARWSP, PWP, SFD, UNICEF projects.

Table 21.7 Top 7 Reasons Why "Project Water" Is Not Sufficient to Meet Entire Household Needs *(%) (sample surveyed in parentheses)*

Reason	RWSSP	Total others
Seasonal variation	4.9 (41)	14.6 (612)
WUA regulates water consumption	4.5 (38)	8.9 (374)
Quality of project water not good enough	4.5 (38)	9.2 (390)
Project water not available all the time	4.0 (33)	3.1 (130)
Frequent breakdowns in water delivery due to poor O&M	4.0 (32)	8.1 (338)
Inadequate capacity of delivery network	2.0 (15)	5.2 (218)
Project water not sufficient in dry season	1.5 (12)	2.0 (85)

Ibb—RWSSP's actual water delivery schedule was reported to be better than the other projects' (tables 21.8a and 21.8b). The difference held good for both "dry" and "wet" seasons. All of the regions, particularly Abyan, needed much improvement. Such improvement would bring the ratio closer to 1.0 and increase the number of water days available.

Scheme failures

Even though respondents reveal that RWSSP performed better than the others, the need to reduce service failures is evident in all projects (table 21.9).

Performance of water user associations (WUAs)

On average, over 90 percent of consumers can contact their WUAs about services and bills and get attention (table 21.10a). This percentage is higher than for most urban systems in the region. However, approximately 10 percent of water users believe that the WUAs are just

Table 21.8a Actual vs. Scheduled Water Supply in Dry Season *(no. of HH in parentheses)*

Governorate		RWSSP	GARWSP	PWP	SFD	UNICEF	Total others
Abyan	Avg. no. of days/wk	*5.3*	*4.9*	*4.3*	*5.1*	*3.9*	*4.7**
	Range: Days/wk	(210)	(870)	(180)	(120)	(180)	(1350)
	(Actual/ scheduled)	**0.11–7.0**	**0.25–7.0**	**0.25–7.0**	**1–7.0**	**0.25–7.0**	**0.25–7.0**
		0.82	**0.84**	**0.85**	**0.94**	**0.96**	**0.87**
Hajjah	Avg. no. of days/wk	*5.7*	*3.5*	*2.2*	*7.0*	—	*4.0*
	Range: Days/wk	(120)	(600)	(120)	(180)		(900)
	(Actual/ scheduled)	**1–7.0**	**0.25–7.0**	**1–7.0**	**6–7.0**	**—**	**0.25–7.0**
		0.97	**0.82**	**0.75**	**1.0**	**—**	**0.85**
Ibb	Avg. no. of days/wk	*2.1*	*1.6*	*1.7*	*2.6*	*2.5*	*1.9*
	Range: Days/wk	(509)	(1106)	(328)	(285)	(169)	(1888)
	(Actual/ scheduled)	**0.125–7.0**	**0.083–7.0**	**0.125–7.0**	**0.083–7.0**	**0.25–7.0**	**0.083–7.0**
		0.93	**0.78**	**0.80**	**0.83**	**0.90**	**0.80**

Note: * = Sum of GARWSP, PWP, SFD, and UNICEF projects.

Table 21.8b Actual vs. Scheduled Water Supply in Wet Season

Governorate		RWSSP	GARWSP	PWP	SFD	UNICEF	Total others
Abyan	Avg. no. of days/wk	*5.3*	*5.1*	*5.4*	*5.1*	*5.1*	*5.1**
	Range: Days/wk	(210)	(870)	(180)	(120)	(180)	(1350)
	(Actual/ scheduled)	**0.11–7**	**0.25–7**	**1–7**	**1–7**	**0.25–7**	**0.25–7**
		0.82	**0.87**	**0.92**	**0.94**	**0.88**	**0.88**
Hajjah	Avg. no. of days/wk	*5.8*	*3.5*	*2.3*	*7.0*	—	*4.1*
	Range: Days/wk	(120)	(600)	(120)	(180)		(900)
	(Actual/ scheduled)	**1–7**	**0.25–7**	**1–7**	**7 -7**	**-**	**0.25–7**
		0.98	**0.82**	**0.78**	**1.0**	**-**	**0.85**
Ibb	Avg. no. of days/wk	*2.3*	*1.8*	*2.3*	*3.8*	*2.5*	*2.2*
	Range: Days/wk	(509)	(1108)	(328)	(285)	(169)	(1890)
	(Actual/ scheduled)	**0.25–7**	**0.083–7**	**0.125–7**	**0.25–7**	**0.25–7**	**0.083–7**
		0.94	**0.80**	**0.83**	**0.86**	**0.91**	**0.82**

Note: * = Sum of GARWSP, PWP, SFD, and UNICEF projects.

looking out for themselves. Although small, this percentage points to a need to carry out even more community campaigns before project implementation.

Nearly 50 percent of all users say it takes less than 1 day for project staff to fix a service problem; 28 percent say it takes 1–5 days; and 23 percent say it takes more than 5 days. In all cases, RWSSP users have the most positive responses: 56 percent report that RWSSP takes less than 1 day to fix problems (table 21.10b).

Table 21.9 Record of Service Failure on Scheduled Days in Past Year *(% reporting)*

	RWSSP	GARWSP	PWP	SFD	UNICEF	Total others
Abyan:						
Several times	21.4	32.6	18.3	26.7	27.2	29.5*
Few times	16.2	22.5	25.0	18.3	13.9	21.3
Once	10.5	20.1	16.1	16.7	39.4	21.9
Never	52.0	24.7	40.6	38.3	19.4	27.3
No. HH	210	870	180	120	180	1,350
Hajjah:						
Several times	3.3	29.2	50.8	1.7	–	26.6
Few times	0.8	17.7	20.8	2.2	–	15.0
Once	32.5	29.7	16.7	20.0	–	26.0
Never	63.3	23.5	11.7	76.1	–	32.4
No. HH	120	600	120	180	–	900
Ibb:						
Several times	8.8	26.4	24.5	18.0	3.0	22.7
Few times	10.0	13.1	19.5	17.0	2.4	13.8
Once	28.7	25.5	22.6	7.8	21.0	21.9
Never	52.5	35.1	33.4	57.2	73.7	41.5
No. HH	509	1,110	323	283	167	1,883

Note: *"Total others" = Sum of GARWSP, PWP, SFD, and UNICEF projects.

Table 21.10a RWSSP and Other Projects: Users' Perceptions Regarding Their WUAs *(% reporting)*

	HH reporting WUA cannot be contacted about services and billing and have not received assistance	HH reporting WUA does not take complaints seriously and makes no attempt to improve service	HH reporting WUA is just looking out for itself
RWSSP:			
Abyan	1.9	3.8	3.8
Hajjah	9.2	11.7	21.7
Ibb	12.9	13.5	14.5
Other:			
Abyan	9.6	12.3	13.6
Hajjah	11.7	15.7	16.7
Ibb	17.5	21.4	23.3

Users' satisfaction with water services

In general, all respondents expressed increased satisfaction with the frequency and duration of water supply and water pressure, and reduced overcrowding near public standposts (figures 21.3a and 21.3b). However,

Table 21.10b RWSSP and Other Projects: Average Time for WUA to Fix a Problem

	HH reporting *(%)*		
	Less than 1 day	**1–5 days**	**5+ days**
RWSSP			
Abyan	66.7	19.5	9.5
Hajjah	56.7	23.3	12.5
Ibb	46.9	35.5	13.3
Others			
Abyan	53.6	23.3	18.0
Hajjah	40.3	20.7	22.7
Ibb	35.5	28.0	25.9

respondents from water schemes other than RWSSP have expressed dissatisfaction with the current water charges. Their complaints contrast with the responses received from areas served by RWSSP schemes.

Concerning water service, the survey reveals greater satisfaction with RWSSP schemes, compared to schemes supported by other programs in frequency of supply (days/week), duration of supply (hours/day), water pressure, and crowding near public standposts (table 21.11).

The study also assessed consumer perceptions of the direction of change in water network maintenance after project completion. RWSSP communities showed a greater perception of change for the better than communities served by other projects (figures 21.4a and 21.4b). When the categories of "Satisfied," "Changed to well,"

Figures 21.3a & b Satisfaction with Water Services before and after RWSSP and Other Projects

Figure 21.3a Satisfaction with Water Services before and after RWSSP

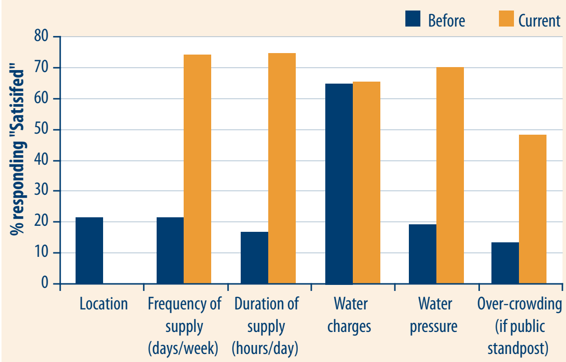
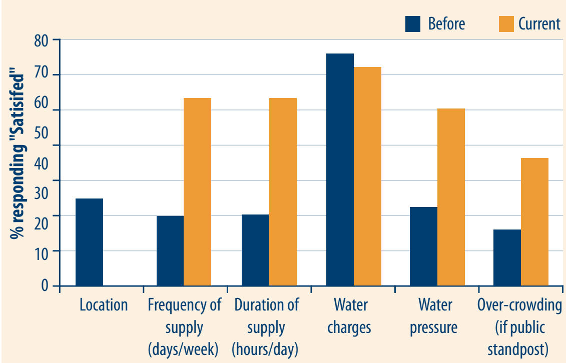


Figure 21.3b Satisfaction with Water Services before and after Other Projects



Note: Services = Location, frequency, duration, water charges, water pressure, and overcrowding.

Table 21.11 Differences between RWSSP and Other Projects in Service Satisfaction

	RWSSP		Non-Bank	
	Before	Current	Before	Current
Location	21.0	—	24.6	—
Frequency of supply (days/week)	17.4	73.7	20.1	53.1
Duration of supply (hours/day)	16.4	73.9	20.2	53.1
Water charges	64.4	64.9	65.8	62.0
Water pressure	18.8	69.6	21.6	49.9
Overcrowding (if public standpost)	12.9	48.0	15.7	35.9

Figures 21.4a & b Consumers' Perceptions of Direction of Change in Water System Maintenance after Completion of RWSSP and Other Projects

Figure 21.4a Consumers' Perceptions of Direction of Change in Water System Maintenance after RWSSP Completion *(%)*

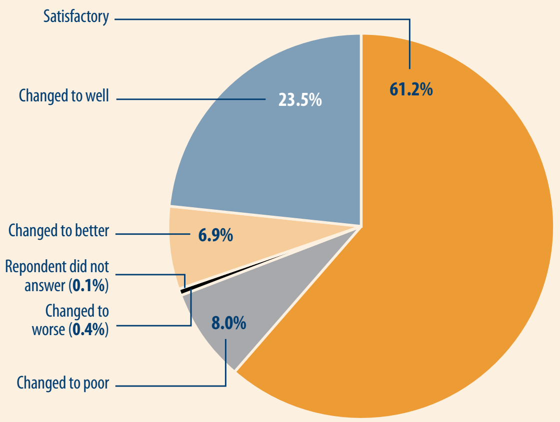
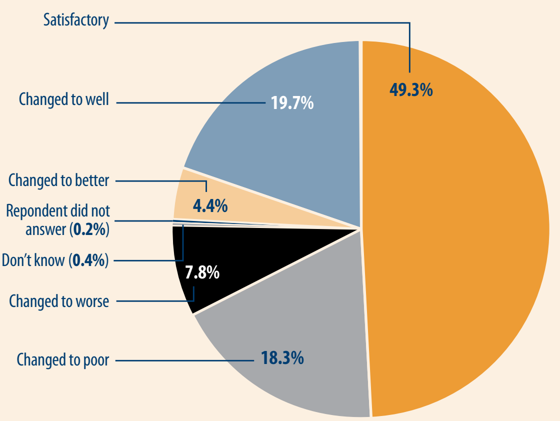


Figure 21.4b Consumers' Perceptions of Direction of Change in Water System Maintenance after Completion in Projects Other Than RWSSP *(%)*



and "Changed to better" are combined, RWSSP project HH are more satisfied with the maintenance of their water network after project implementation.

Levels of water network maintenance satisfaction are also higher for RWSSP projects.

User preference for management of water schemes

To elicit users' preferences for the management of water schemes, survey questions included the current and preferred arrangement for ownership of water scheme, revenue collection, water allocation, budgeting, expenditure control, O&M, major repairs/replacements, and investments in the expansion of the system. Potential choices included WUA, WUA chairperson, all consumers, operating staff, water scheme manager, the sheik, district committee, GARWSP branch office, the government, and other.

Survey responses for all projects (table 21.12) revealed clear preferences for:

- Ownership of water schemes: By *consumers*.
- O&M scheme, revenue collection, and water allocation: By *operating staff.*
- Budgeting, expenditure control, and investments in the expansion of the system: By *WUA*.
- Major repairs and replacements: Respondents served by RWSSP schemes are content with the lead role of the WUA. Respondents from "non-Bank" schemes expressed preferences for a dominant government role.
- Budgeting and expenditure control and investments to expand the system: Although a plurality of both RWSSP and other respondents expressed a preference for *water user groups* to manage these 3 processes, the percentage was much higher for RWSSP respondents (46.8 percent) than for non-RWSSP beneficiaries (27.7 percent). These data suggests RWSSP communities' comparatively high

Table 21.12 User Preferences for Management of Water Schemes *(% of HH reporting)*

Mgmt. alternatives:	Ownership		Revenue collection		Water allocation		Budgeting and expenditure control		Operation & maintenance		Major repairs and replacements		Investments to expand system	
	RWSSP	Other	RWSSP	Other	RWSSP	Other	RWSSP	Other	RWSSP	Other	RWSSP	Other	RWSSP	Other
WUA	28.5	7.4	27.6	11.3	29.6	17.9	46.8	27.7	19.9	9.4	42.3	20.6	46.1	25.3
WUA chairperson	7.5	0.8	6.4	1.4	12.2	5.1	19.0	3.4	5.5	0.6	16.6	2.0	17.2	2.4
All consumers	44.0	58.3	3.2	3.7	4.3	10.8	6.6	8.6	4.0	7.6	3.4	7.0	3.3	5.5
Operating staff	0.3	1.0	46.6	48.8	40.6	33.5	5.2	6.6	57.6	58.3	2.4	3.2	2.0	3.3
Water scheme manager	3.8	5.6	5.0	10.2	3.8	12.9	8.1	16.0	3.5	7.3	7.1	15.4	8.2	16.6
Sheik	3.5	7.5	1.5	4.4	1.3	5.3	2.2	8.4	1.5	4.1	3.3	8.6	3.3	8.6
District committee	2.8	3.2	1.3	2.3	1.1	2.5	2.3	5.6	1.3	2.5	3.8	4.6	3.3	4.6
GARWSP branch office	3.1	5.5	2.8	3.7	2.2	4.3	2.8	5.2	2.7	3.3	6.8	11.4	5.4	9.2
Government	6.5	9.6	5.1	5.7	4.7	5.8	6.6	8.5	4.0	5.8	13.5	22.9	10.9	16.8
Other	0.0	1.2	0.6	8.5	0.2	1.8	0.3	10.0	0.0	1.0	0.7	4.4	0.5	7.6

levels of confidence in the technical and financial management capabilities of the WUAs.

Cost of water

Table 21.13 portrays the change in average monthly water service charges paid by consumers. WUAs in RWSSP schemes are provided with training and technical support to determine the actual tariffs that need to be charged to cover operation, maintenance, and rehabilitation costs for their water systems. Table 21.13 shows that post-completion water payments for metered connections in RWSSP villages in all three districts are significantly higher than in other projects. The higher payments can be attributed to more accurate calculation of full costs, higher per-household water consumption (due partially to more reliable service), and limited but highly subsidized nonmetered access for the very poor.

Table 21.13 Cost of Water Bill per Month in Unmetered and Metered HH, 2007–08 *(YR)*

	RWSSP		Other	
	Before	After	Before	After
Abyan				
Unmetered (YR)	846.2	335.7	696.9	1095.0
Metered (YR)	71.4	962.5	51..0	724.0
Hajjah				
Unmetered (YR)	293.3	261.7	278.2	437.0
Metered (YR)	0.0	1523.0	14.9	555.8
Ibb				
Unmetered (YR)	234.7	0.0	118.5	158.8
Metered (YR)	11.0	1178.0	39.4	724.5

Note: YR = Yemeni Rial.

Conclusion and Lessons

The Government of Yemen's National Water Sector Strategy and action plan espouses four policies:

1. Decentralizing implementation mechanisms
2. Enhancing beneficiary community roles and responsibilities
3. Adopting a demand-responsive approach to identify communities for inclusion in sector programs and making this approach standard practice

4. Improving cost effectiveness by identifying means to implement projects that meet basic needs at lower costs.

The RWSSP was designed to develop and test approaches for sector programs that operationalize these policies. More than other projects that support rural water supplies and sanitation in Yemen, *RWSSP has focused on developing the capacity of communities to take on the delegated responsibilities of planning and managing their own water and sanitation systems*. The RWSSP invested considerable resources in establishing and building up the technical and financial management and planning capabilities of democratically elected water user associations (WUAs). The consumer satisfaction survey findings suggest that the project's strategy for developing communities' capacity and meaningful involvement in planning and managing their own water and sanitation systems is effective. The strategy has resulted in relatively high levels of beneficiary satisfaction and has increased the likelihood that the communities will sustain the systems over their design lives.

RWSSP beneficiaries enjoy relatively reliable water systems. Over 60 percent of residents had one or no service failures within the past year. Confidence in WUAs as governing and management bodies for water schemes also is high. Beneficiaries are agreeing to and paying tariffs that cover O&M costs. In fact, they are paying the full costs and spending more per month, on average, for water service than they did before RWSSP was completed. Through their WUAs, communities are developing a range of mechanisms to prepare to finance major repairs.

In addition to all of these positives, progress is needed in two areas:

1. The RWSS subsector still lacks a clearly agreed strategy.
2. All programs need to follow this strategy and other water policies consistently. GARWSP and the other projects and agencies working in the subsector increasingly are cooperating. Nevertheless, further development of procedures for joint programming and for aligning their respective approaches to conform to national policies is still needed.

22

Rural Sanitation within an IWRM Framework: Case Study of Application in the Delta Region, Egypt

Ayat Soliman, Ahmed Shawky Mohamed, Maged Hamed, Wendy Wakeman, and Mohammed Mehany

Case for a New Approach to Rural Sanitation in Egypt

At the macroeconomic level, the analysis of public spending on water in Egypt concluded that spending more on wastewater collection and treatment would boost GDP by at least 1 percent. The antipollution measures in the 2003 National Water Resources Protection Plan would benefit Egypt by LE 2 billion. Adding community-based and self-financed sanitation programs would add an extra LE 1 billion in net benefits. Public spending is best focused on public goods: nonexcludable items that benefit many. However, in Egypt, much public expenditure has been on "private-like" goods (irrigation and urban households). The government therefore should shift resources toward controlling water pollution, which is a public health hazard; and away from subsidies for irrigation and urban water supply, which provide private benefits.

Rural Poverty and Public Health Issues Are Correlated with Lack of Sanitation Services and Lack of Water-Quality-Management Solutions.

In Egypt's rural areas, there is a huge gap between water supply and sanitation coverage. Currently, 80 percent of the rural population relies on piped water supply, whereas only 4 percent is connected to sanitation systems. Even when HH are connected, the collected sewage is not always safely disposed of. Due to the narrowness of the Nile Valley in which the rural inhabitants live, the interconnection of

Figures 22.1a & b Poverty-Sanitation Link

Figure 22.1a Poverty Correlated with Lack of Water and Sanitation Services

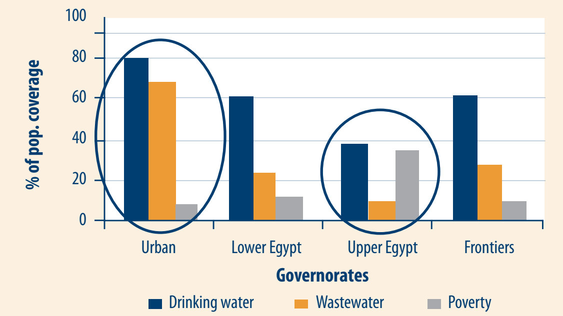
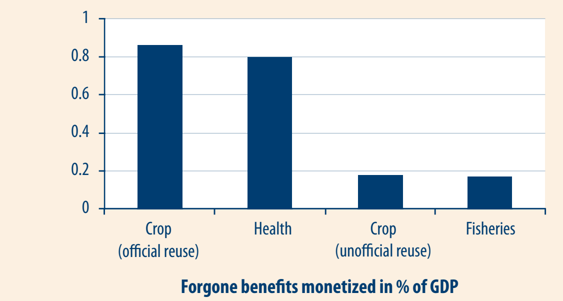


Figure 22.1b Socioeconomic Losses Due to Lack of Sanitation and Treatment

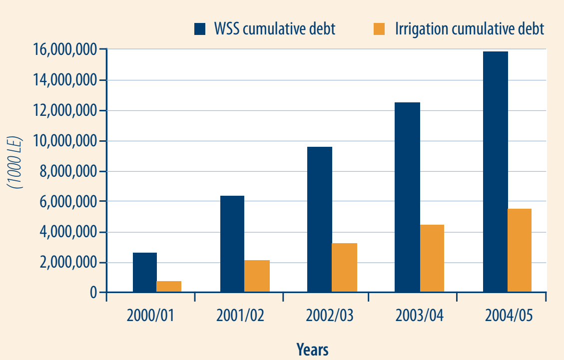


the irrigation/drainage system, and the extensive (often unofficial) reuse of agricultural drainage water, the semi/maltreated sewage diffuses into the waterways and reaches the food chain. This diffusion negatively affects public health, crop production and quality, and poverty (figure 22.1). Extending the "conventional" sanitation and treatment services to a larger share of the rural population would be prohibitively expensive. Low water tariffs undermine both the public and private sectors' capability to maintain existing water supply and sanitation (WSS) facilities, let alone expand coverage.

Conventional/Centralized Approaches to WSS Contributed to Fiscal Deficit.

The efficiency of Egypt's public spending on water falls short of international norms. Egypt's WSS services are less financially efficient than their developing-country peers. They are possibly on a par with utilities in Eastern Europe and Sub-Saharan Africa regarding public management. The Integrated Sanitation and Sewage Infrastructure Project (ISSIP) design envisages that entrusting the decentralized institutions to take over part of the WSS services could reduce such inefficiencies. Public spending on water would be more equitable and efficient by gradually transferring finance and management from the centralized/public agencies to decentralized/autonomous utilities.

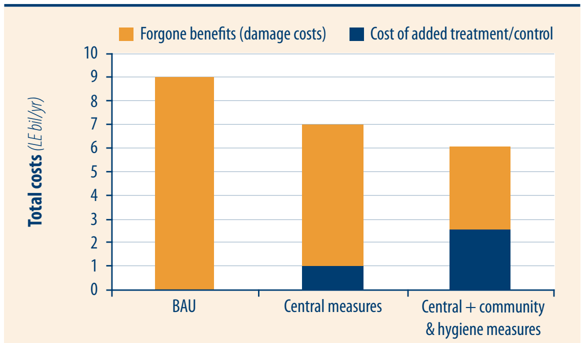
Figure 22.2 Consequence at National Level: Escalating Public Debt, 2000–05



Box 22.1 Untreated Sewage Results in National Economic Loss

The latest Country Environmental Analysis of Egypt (World Bank 2005) estimated that the socio-economic cost of maltreated or untreated wastewater is higher than LE 9 billion, or 2% of GDP. These costs represent the harm caused to human health, agriculture, and fisheries.

Cost-Benefit Analysis of Improving Wastewater Disposal



Environmental Damage

The absence of proper wastewater collection and treatment, combined with inadequate solid waste disposal is causing severe environmental sanitation problems in the rural areas of the Nile Delta. These problems affect the life expectancy and morbidity of the population, cause health costs for treatment and care, reduce the possibilities for agricultural reuse, influence the costs of drinking water supply, and have an adverse effect on fisheries. In addition, families are forced to incur costs for sludge evacuation of their cesspits, provided they can afford them.

New Approach Based on IWRM

Providing sustainable sanitation solutions in rural areas faces three inherent challenges:

1. Higher unit cost per capita due to the topography and dispersed population
2. Limited ownership and voice of the local communities in influencing planning processes and decisionmaking at the central level
3. Limited ability of many developing countries to provide sustainable O&M over a large number of small systems, particularly in view of low cost-recovery ratios.

Addressing these challenges can be assisted by applying the key principles of integrated water resource management: *treating water as a*

Box 22.2 Local Context

The ISSIP area in the three Governorates of Gharbeya, Kafr El Sheikh, and Beheira can be characterized as mostly flat agricultural land with a high water table (less than 5 meters). Most development is fairly recent in origin, and rights of way, other than through roads, are not raised much above the natural ground surface. The high water table in the area can pose problems. Annual rainfall is low, ranging from approximately 50mm per year in the south of Gharbeya to 100mm or more per year in the north of Kafr El Sheikh and Beheira.

Villages in Gharbeya tend to be urban in character with many buildings rising to three stories or more. As a general rule, villages in Kafr El Sheikh and Beheira are more rural in character, but even in them, many buildings have more than 1 story and are occupied by more than 1 household. Rights of way tend to be narrow, often less than three meters, with houses built up to the road.

Water use varies considerably among villages but is often in the range of 100–140 l/cd. Most households in the three governorates covered by the project already have water-flushed sanitation, although few are connected to sewers. Most houses that are not connected to sewers discharge wastewater to cesspits; a small percentage discharge directly to nearby drains. The high water table exacerbates existing inadequate sanitation arrangements, often resulting in very unhealthy environments. In many cases, this threat to human health has led to a very high demand for improved sanitation services.

holistic resource, *management at the lowest appropriate level*, and *stakeholder participation*. In addition, lessons from global implementation in several countries, including Brazil and India, provide helpful examples of how to manage the community interface and enhance local ownership.

This chapter presents a recent case example in the Delta region in Egypt in which these principles have been integrated in the planning, management structures, monitoring arrangements, and community participation framework for rural sanitation service provision. The resulting methodology has been reflected in the design of the World Bank's Integrated Sanitation and Sewerage Infrastructure Project (ISSIP), which will be implemented by the Government of Egypt (GOE) during 2009–14.

Egypt has lacked a separate clear national strategy for addressing rural sanitation due partly to the priority in recent decades of increasing coverage for urban centers. With the more recent increased attention given to the problems resulting from poor sanitation infrastructure in rural areas, the rural sanitation issue moved to the forefront of the political agenda. The president has declared a national program for rural sanitation to increase the sewerage coverage in rural areas from 4 percent to 40 percent. In addition, in 2007 a national strategy for rural sanitation was initiated that incorporates several of the principles presented below. It is hoped that the lessons from ISSIP implementation will refine the methodology and provide lessons for wider replication.

Planning around a Hydraulic Basin and the Concept of Clustering

A number of challenges face the planner when a fragmented top-down approach to planning wastewater service delivery based on individual population centers is applied to rural areas. Planning for single cities or towns can yield clear results based on large urban population centers. However, when it comes to the rural setting, it is harder to prioritize investment allocations and establish the link between the inputs and desired outcomes. The example of the rural areas of the Delta in Egypt illustrates the need to shift the planning framework to a bottom-up approach based on a number of technical, environmental, and social criteria and considerations.

Historically, central planners focused on providing services to the large cities and towns. Mother villages were included only if they were near planned urban systems. Hence, only 4 percent of Egypt's rural areas were served with sewerage systems. The remainder often relied on failing on-site solutions that compounded water logging and groundwater pollution problems in the dense areas.

Moreover, Egypt is a hydraulic society. Its historic system of irrigation canals and drains has shaped the rural landscapes and livelihoods for millennia. Thirty-seven percent of the population relies on surface water irrigation for agriculture. Increasing water quality deterioration in both canals and drains is due in large part to the discharge of untreated effluents (both domestic and industrial) into the waterways.

Box 22.3 Egypt's Rural Villages

Egypt's villages range in size from small remote hamlets with 200 inhabitants to larger "mother villages" that have up to 80,000 inhabitants. Of the 5,633 villages (main and satellite), 73% have populations of fewer than 10,000; 25% have population between 10,000 and 30,000; and 2% have populations exceeding 30,000. The average population density in rural areas is 1,500 persons/km^2.

The following were the considerations for putting in place a strategic sanitation plan for the Delta region.

Planning Rural Sanitation Provisions around a Hydraulic Basin Increases Environmental Benefits.

The first planning consideration is the need to shift from administrative planning boundaries to integrating the hydraulic boundaries in the planning process. These boundaries are defined by hydraulic basins, or sub-basins in the case of Egypt, since the whole Nile valley can be considered one large interconnected basin. Within this basin, well-defined irrigation command areas include smaller sub-basins, typically around secondary drains with reaches in the range of 15–20 km. (Figure 22.3 illustrates the example of the Mahmoudia Canal Command Area in the western Delta, including its sub-basins.) This use of hydraulic boundaries enables the planner to select and group target villages based on their locations vis-à-vis existing water bodies and to prioritize these village groups/waterways in which a combination of current water quality conditions *and* expected improvements from implementing rural sanitation in these areas would yield the highest environmental benefits. The tools and criteria elaborated in the following sections of this chapter are proposed for such prioritization: (1) clustering villages (2) water quality modeling, and (3) applying multicriteria prioritization.

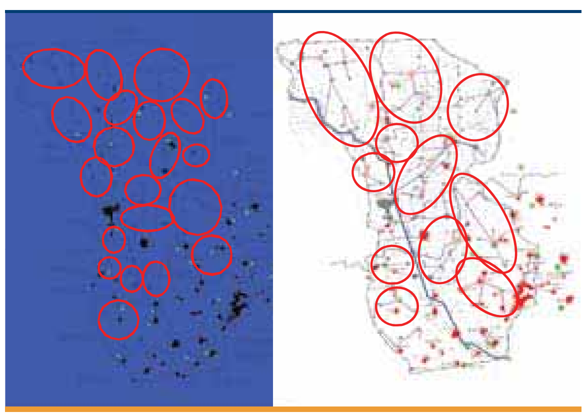
Figure 22.3 Mahmoudia Canal Command Area Sub-Basins

The use of hydraulic boundaries also enables the mobilization of integrated water resource management institutions. Local institutional mechanisms for WRM, such as farmer groups and water user associations (WUAs), can be integrated with water supply and sanitation management within one monitoring framework. These aspects are further elaborated in the last two sections of this chapter.

Clustering Concept Provides a Comprehensive and Cost-Effective Approach That Maximizes Technical Feasibility Based on Pollution Abatement Objectives.

To facilitate planning, the grouping of villages around a hydraulic sub-basin needs to integrate several additional considerations. In this context, a cluster can be defined as a geographical unit of planning and implementation that provides comprehensive and cost-effective sanitation solutions for almost all villages falling within this unit, thereby maximizing the feasibility of technical solutions. Grouping villages into one cluster along hydraulic boundaries and taking into consideration technical criteria and administrative boundaries enable linking sanitation service provision with final environmental improvement impacts. Hence, the planner needs to set the final cluster boundaries to minimize expensive crossings, such as main canals and railways, and the number of administrative units for each cluster. Simultaneously, the planner needs to maximize the use of existing facilities and maintain a manageable overall cluster size from a technical and financial point of view. Too small a cluster would result in a very large number of small-scale sanitation solutions. In the case of the dense Delta areas, small-scale solutions would not be not cost effective, and would increase the management burden of water utilities. On the other hand, a cluster size that is too large would lead to crossing a large number of administrative boundaries and would bring the scale closer to those in urbanized settings. In addition, an over-sized cluster would limit the ability to apply small-scale, community-managed solutions and reduce the ability for community oversight and financial cost recovery.

Figure 22.4 Applying Two Scenarios for Varying Cluster Sizes: Mit Yazid Command Area



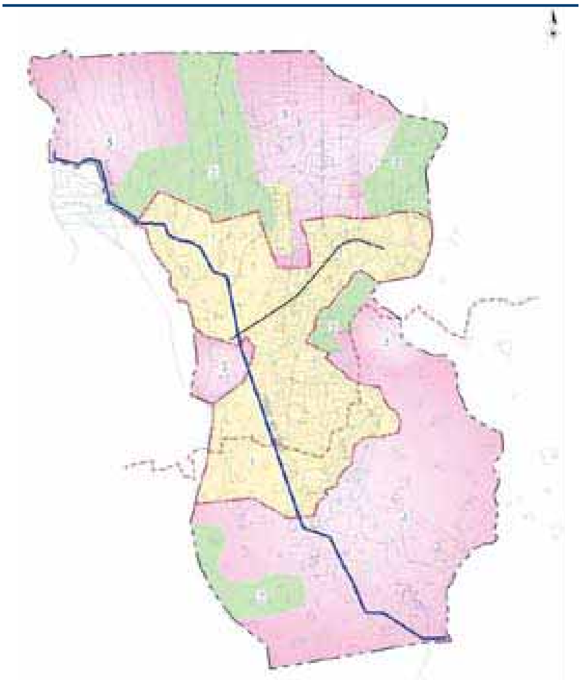
The iterative planning and cluster-sizing process for the Mit Yazid Canal Command Area in the Delta (figure 22.4) illustrates this case. The first scenario, with an average cluster diameter of approximately 5 km, resulted in approximately 41 new proposed wastewater treatment plants with an average treatment capacity of approximately 3,000m^3/day. The second scenario, with an average cluster diameter of approximately

10 km, reduced the number of new treatment plants to approximately 10. The average treatment capacity per plant of approximately 6,000 m^3/day resulted in an overall investment plan that was deemed a more appropriate scale for the Egyptian setting.

Applying Multicriteria Assessment to Prioritizing Village Clusters Targets Interventions at Areas in Which the Largest Impacts Can Be Achieved.

In developing a strategic sanitation plan for a region, existing service needs should be compared with available funds to determine the extent of required prioritization. For the case examples of Mahmoudia and Mit Yazid in the Delta, a methodology for selecting priority areas/clusters was developed based on multicriteria analysis of the most relevant factors. The criteria were population served, reuse potential of the irrigation canals, potential health benefits, and water quality improvement potential (see section below), potential for tie-in to existing treatment works, and proximity to water treatment plant intakes.[1] These factors are implicitly based on the *key principle that interventions should target areas in which the largest impacts can be achieved*. The result of the analysis constitutes the strategic sanitation plan, with prioritized ranking of clusters, so that a forecasting financing plan can be agreed by the decisionmakers. The result for the Mit Yazid Command Area is illustrated in figure 22.5, which ranks the areas (1 being the highest priority) that receive ISSIP financing. Furthermore, the application of advance (ex-ante)

Figure 22.5 Priority Ranking within the Mit Yazid Command Area



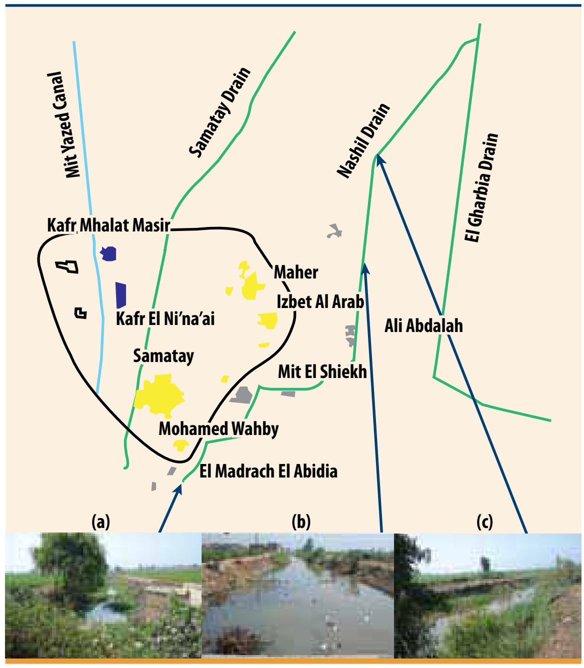
[1] These criteria and the relative weighting for each should be a dynamic process, to be modified and updated based on implementation progress and emerging considerations.

economic analysis, with consideration of national scale-up options, is elaborated below ("Assessing the Results of Water Quality Management Investments in Egypt" section) and provides additional information to policymakers in making final investment allocation decisions.

Water Quality Modeling Is an Indispensable Tool in Identifying Which Groups of Villages to Serve Using Decentralized Treatment Approaches and Which Drains Have Enough Self-Purification Capacity to Enable Them to Assimilate the Partially Treated Rural Sewage.

Limited financial resources often are a major constraint facing rural sanitation coverage expansion. In the case of ISSIP, limited funds lead to a trade-off between (a) implementing secondary wastewater treatment for a few villages, thus complying with Law 48 (the law that regulates discharges to inland waterways) effluent standards; and (b) implementing advanced primary treatment for a larger number of villages, allowing natural attenuation in the drains to reach ambient standards, even if falling short of Law 48 effluent standards.

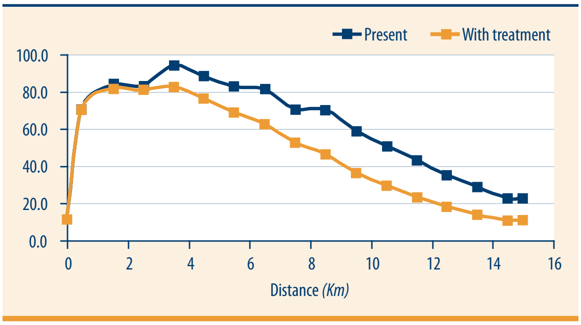
Figure 22.6 Example of Nishil Drain



Notes:
a First stretch: Upstream of the villages wastewater effluent, unpolluted water in stream.
b Middle stream: Water is polluted due to disposing the untreated village sewage.
c Downstream: Significant improvement in the drain's water quality.

Mathematical modeling was used to make a judgment call on whether option (b) is possible and for which drains. Visual observation showed that, for some drains, self-purification processes can and do improve the water quality. Figure 22.6 illustrates three locations along Nishil drain in the ISSIP study area and shows water quality improvement along the downstream direction. Mathematical modeling confirmed that if the villages along this drain's reach are served with advanced primary treatment, then the water quality of the drain can achieve Law 48 requirements downstream from the discharge points (figure 22.7).

Figure 22.7 Simulation Results for the Self-Purification of BOD along Nishil Drain before and after the Decentralized Treatment



Notwithstanding the ambient water quality legislation, decisionmakers can accept the aforementioned decentralized treatment approach introduced by ISSIP as a transitional measure so long as:

- ***A "free zone" without any domestic-wastewater point sources*** is enforced along the drain, downstream of the ISSIP-introduced treatment point (with a free length of approximately 5 km–8 km for most drains). This free zone will enable the self-purification to function as modelled.
- ***Predominance of the diffuse source, the agricultural drainage water***, is maintained. The modelling results showed that the agriculture drainage water provided an overall "net dilution" factor along the drain. Achieving the necessary dilution rate requires a typical drainage catchment for third-order drains of 5,000–10,000 feddans. Another necessary factor is to have discharge flows along the drains no less than the following range: 0.6 mm/day (from Cairo up to Tanta City) to 7.5 mm/day (north from Tanta City up toward the coastal areas).
- There is ***minimal upstream pollution load (headwater quality):*** with dissolved oxygen (DO) no less than 5 mg/l, biological oxygen demand (BOD) not exceeding 12 mg/l, and coliform bacteria not exceeding 8,000 most probable number (MPN)/100ml.
- ***The point-source villages and hamlets are small,*** up to 500–1,500 capita each. In them, domestic wastewater would be much smaller than the agricultural drainage water, hence enabling sufficient dilution by the latter. An acceptable ratio between domestic and agricultural return flow would be 1:10 (or, to be on the safe side, a more conservative ratio of 1:20).

Within-Cluster Optimization Based on Available Sanitation Options Balances Service Coverage with Financial Feasibility.

The final step of the planning process concerns the selection of the applicable sanitation solution(s) within each cluster. It is important to emphasize that part of the integrated cluster approach maintains that the planner

Box 22.4 ISSIP Intervention Categories

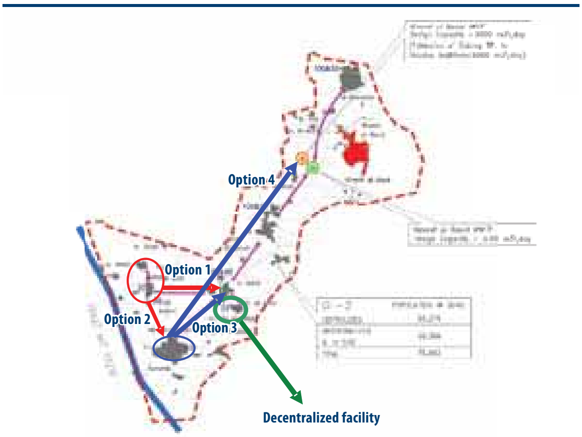
The following three broad categories of sanitation solutions have been considered in the Egypt case study and related investment program:

1. *Centralized systems:* For villages with populations greater than 1,500 inhabitants and smaller villages in their proximity. These villages would be served by a sewerage collection network leading to a single central wastewater treatment plant. Smaller villages would be connected if the cost of doing so does not exceed the cost of decentralized treatment solutions.
2. *Decentralized systems:* For settlements with 500–1,500 inhabitants, not located along the networks serving larger villages. These villages would be served by local collection systems discharging into simple treatment works providing advanced primary treatment, typically consisting of a communal septic tank followed by a series of anaerobic baffled reactors (ABRs). Effluent is then discharged into a nearby drain. Pumping should be avoided if possible.
3. *Onsite systems:* For settlements with fewer than 500 inhabitants. These will continue to use onsite sanitation systems based on cesspits or septic tanks. The capacity of the central treatment plant would take into account the septage resulting from these onsite systems.

should seek to provide a type of sanitation service for 100 percent of the population living within the cluster, so that the anticipated resulting benefits can be achieved. However, given the varying typography and conditions for the individual villages within each cluster, a one-size-fits-all approach to the technology and proposed solution would not be feasible.

The proportion of villages falling under each of the solution categories is determined by an optimization process within each cluster, by which the cost comparison and technical feasibility of the different solutions is applied. Figure 22.8 illustrates the technical solutions, within an ISSIP sample cluster, based on consideration of the different project intervention options. The options compared include tying remote villages to the central treatment plant, with stages of pumping along the way

Figure 22.8 Within-Cluster Optimization



(option 4), versus establishing decentralized facilities for 1 or 2 villages (options 1, 2, and 3).

Assessing the Results of Water Quality Management Investments in Egypt

Ex-ante Economic Assessment Used Cost-Benefit Analysis.

The economic analysis of the ISSIP has been performed via a cost-benefit analysis (CBA) approach (see the logical framework for the economic analysis in appendix A22.1), rather than the cost-effectiveness approach commonly applied to assess sanitation projects. The CBA has been conducted by factoring in the following considerations:

- For phase 1, the weighted average of the unit capital cost is approximately \$130 per target inhabitant (year 2040). Hence, the (amortized) capital cost per household/month is approximately 45 LE/month/family at maximum, and O&M costs are approximately 10 LE/month/family.
- The private benefits are estimated as the non-income-constrained willingness to pay (WTP), per the "contingent valuation" method. A proxy for this WTP is the upper bound of the current payments that households pay vacuum trucks to empty their cesspits in some of the ISSIP command areas. Hence, approximately 50 LE/month/family.
- The public benefits associated with fully improving rural sanitation are estimated at approximately 81 LE/month/family. This is the summation of the monetized, incremental benefits accruing (or damages avoided) to the following subsectors:
  - Health (avoided morbidity and mortality, plus avoided medication costs)
  - Reuse of agricultural drainage (reduced BOD improves the reuse potential)
  - Fisheries (increased DO increases fish production and quality)
  - Recreational activities related to waterways and northern lakes.

These incremental benefits have been calculated by estimating the impact of reducing the baseline concentration of sewage-related pollutants such as BOD, fecal coliforms, ammonia, and dissolved oxygen toward their ambient and user-specific standards. Using the aforementioned (capital and recurrent) unit costs and (private plus public) unit benefits, the project's economic rate of return (ERR) has been performed against (a) 2 strategic scenarios, which adjusted the valuation of the incremental public benefits as these benefits correspond to 2 alternative assumptions on 1 of the project's major externalities: the "headwater quality" in the drains served by ISSIP; and (b) 3 sensitivity tests. The two strategic scenarios are:

1. ***"Low" scenario.*** This scenario assumes that ISSIP is not followed by a country-wide program that can scale up the ISSIP model. In that (unlikely) case, within ISSIP command areas, it is assumed that only 40 percent of ISSIP area drains will be cleaned. Factoring in the centralized systems' secondary treatment along with the advanced primary treatment provided by the decentralized systems, the overall improvement in these drains would only be "partial." This partial improvement in the in-stream quality is estimated at 60 percent (incremental improvement of the baseline Water Quality Index, or WQI, toward the standards). The remaining drains (60 percent) cannot be sufficiently cleaned because of the already poor headwater quality. The "dose-response" relationship in this case has been estimated at 60 percent:70 percent (due to the "increasing returns to scale"). Under this scenario, the central estimate of the ERR would be approximately 10 percent.
2. ***"High" (or optimistic) scenario.*** This scenario assumes that this area eventually would be considerably cleaned, with the ISSIP concept being fully replicated (that is, through the nation-wide sanitation program for which 20 billion LE has been earmarked by the GOE). In this case, the incremental public benefits would be the product of 70 percent and 81 LE/month/family, hence 56 LE/month/family. The total (public cum private) benefits therefore would be 106 LE/month/family. The resulting ERR would be on a safer side: 15 percent.

Sensitivity tests have been performed to work out the ERR switching values (or strategic "flags") that could bring ERR down to 10 percent or less:

1. Marginal increase in unit costs (due to price escalations and/or physical contingencies and contract variation orders)
2. Marginal postponement of the benefits stream by a number of years, for example, due to delays in construction/implementation

3. Marginal reduction in public or private benefits (for example, due to changes in unit prices or in other conditions or assumptions).

The low/high scenario analysis and the sensitivity tests demonstrated that the project interventions can be socioeconomically viable. The "switching values" indicate that the ERR has some limited scope of accommodating marginal cost escalation, benefits reduction, and delays in implementation. However, both the sanitation (private) benefits and the water quality (public) benefits need to be fairly guaranteed.

Ex-Post M&E Framework Needs to Reflect and Validate the IWRM Approach.

Monitoring outcomes and impacts is a key focus of any project as it establishes the link between inputs (sanitation services in the case of ISSIP) and objectives (such as improvements in water quality and environmental conditions). The results-based M&E system under ISSIP will focus on monitoring outcomes and reporting on impacts of the implemented sanitation services, thus evaluating these impacts against the project development objectives (PDOs). The monitoring arrangements will, for the first time in Egypt, include the quantification of benefits occurring due to improved sanitation and feed into decisionmaking on allocating new funds and prioritizing investments. Many of the M&E activities will make use of the M&E tools/models, laboratories, and analysis results already existing per the mandate of the Ministries of Water Resources and Irrigation; Health and Population; and Housing, Utilities and Urban Development.

Supplementing an ongoing irrigation improvement project being implemented in the same area, ISSIP's development objective is to contribute to the sustainable improvement in (a) sanitation and environmental conditions for the resident communities and (b) water quality in the selected drainage basins within the served project areas. This ambitious objective entails looking beyond typical physical measures, such as service coverage ratio and the number of households connected. Instead, the project targets interacting with the community to evaluate satisfaction levels with local environmental conditions associated with improved wastewater management (local ponding, canal water quality), and conducting qualitative research to identify households practicing improved hygiene behavior. Improvements in water quality are another key objective of the project. To this end, an innovative M&E

Box 22.5 Water Quality Index M&E Application

In the case of the ISSIP, there will be several subcatchment-specific water quality indexes. Each index is to be weighted by population served and by proximity to the (surface or groundwater) potable-water supply off-takes and drainage-reuse locations within each project subcatchment.

The index can be based on in-stream ambient concentrations of fecal coliforms and BOD, as well as on any other user-specific in-stream concentrations (as applicable for each subcatchment) such as DO for fisheries and ammonia for potable water and for reuse of agricultural drainage.

Provided that a water-quality-modeling tool will be used by the M&E unit (similar to what has been used for project preparation), monitoring and compliance regarding the "in-stream" concentrations would take precedence over the "at-effluent" concentrations. "In-stream concentrations" would take priority, especially for the drains/canals that used to be polluted by the untreated sewage from adjacent villages rather than from project externalities (effluents upstream of ISSIP's command area). This approach would make use of the self-purification occurring along the monitored streams.

application based on developing site-specific water quality indexes to be monitored has been adopted for ISSIP (box 22.5).

To monitor intermediate outcomes under the centralized investments, the M&E unit will coordinate with the mandated central organization, the National Organization for Potable Water and Sanitary Drainage (NOPWASD), and with the respective subsidiary WSS utilities. As for monitoring intermediate outcomes under the decentralized sanitation systems, the M&E unit will coordinate with the respective subsidiary WSS utilities and with the beneficiary community development associations (CDAs).

Community Participation Framework

As noted earlier in the chapter, two key principles of integrated WRM are *management at the lowest appropriate level*, and *stakeholder participation*. A participatory, demand-driven approach is used to help ensure sustainability by putting in place sanitation systems that users want and are willing to pay for and maintain. The Community Participation Framework (CPF) summarizes the concepts and principles for community participation, mobilization, and awareness-raising techniques; roles of individual actors; and plans for community capacity building.

Three overall steps are crucial to this process: *information-sharing, demand verification,* and *institutional arrangements for community participation in implementation*.

- Initially, communities being considered for interventions need to be informed about the project and proposed options so that they can make informed choices about whether to participate.
- During the demand verification, communities' willingness to participate (their demand for the project) can be verified. Confirming demand is crucial to ensure that communities will use and pay toward the operation and maintenance (O&M) of the systems so that investments will not be wasted.
- Institutional arrangements need to be designed carefully, so that management of systems is at the lowest appropriate level—the level at which systems are the most likely to be managed well and thus sustained. Institutional arrangements need to be as clear and simple as possible. In addition, the various stakeholders need to receive adequate capacity building and any ongoing support needed to ensure that they can fulfill their roles.

An important part of the stakeholder participation principle includes identifying and addressing the needs/preferences of various groups of stakeholders. At the community level, this includes various community sub-groups such as men and women, youth, and the poor. The CPF should be implemented so that the needs and preferences of these sub-groups are addressed and so that they can play appropriate roles in implementation.

Community Participation Implementation Framework

While community participation will be more extensive in decentralized systems, in both centralized and decentralized systems, community participation in the project will cover the following phases:

- Information dissemination to communities
- Community-level discussions on the project
- Demand verification
- Community selection (based on criteria)
- Communication with communities during construction
- Capacity building of community organizations (as appropriate)

- Involvement in hygiene promotion activities
- Involvement in O&M (decentralized systems)
- Involvement in participatory monitoring and evaluation (M&E).

Information Will Be Disseminated to Communities and Community-Level Discussions on the Project.

The first step will be for Rural Sanitation Unit (RSU) staff, working in some cases with an NGO or staff of a consulting firm, to disseminate project information to communities that have been targeted for inclusion in the project. The information will include the type of system proposed (centralized or decentralized, type of technology), expected amount of monthly charges, expected level of community involvement, implementation timeframe, and possible land acquisition requirements.

Schemes should be presented to the communities as an opportunity to participate in a public-private partnership (PPP) in which the government will be committing a huge amount of capital funds for infrastructure development (WWTPs and networks). ISSIPs will undertake to build necessary infrastructure in areas in which villagers are willing to pay for sewage disposal and treatment.

RSU staff (in some cases, working with an NGO or local consulting firm) can present the basic project information to community members and then have a general discussion to answer questions. Meetings could take several forms:

- An open, public meeting
- A meeting with the CDA and/or local unit staff
- Separate meetings for community men and women, with steps taken to ensure that other subgroups such as the poor and youth are involved.

The goal is to spread information about the project as widely as possible in the proposed communities, discuss the proposed project with community members, and answer any questions they may have.

Demand Verification and Community Selection

After the community meetings have been held, verification of demand for the project can take place in communities that have indicated an initial interest in the project (that is, communities in which, after receiving information at the community meetings, either the CDA or the local government unit has expressed an interest in the project).

In both types of systems, the CDA or the local unit will need to send an initial letter indicating its interest in the project. In centralized communities, RSU staff working with consultants (or an NGO) can perform a simple willingness-to-pay survey, confirming that households would be willing to pay expected monthly tariffs. After this confirmation, a memorandum of understanding (MOU) can be signed between the CDA or the local unit and the project (RSU), agreeing to the conditions of the project.

Demand verification will be more extensive in communities being considered for decentralized systems, as these communities will have larger roles to play in implementation. In the decentralized communities, a more extensive willingness-to-pay survey will be conducted. It will include focus group discussions with various groups of community members to ensure that they understand all that will be expected of the community (concerning community management of systems) and that they are willing to undertake these roles. In this case, the MOU can be accompanied by a list of households agreeing to pay the monthly charge and willing to participate in the project.

Construction

During construction, RSU staff (working with the NGO/consultants) will keep communities informed of construction activities and answer any questions/address any complaints that arise. With decentralized systems, communities (CDA) may help monitor some construction activities.

Capacity Building

Communities will need capacity building related to their roles in the project. In centralized communities, CDAs/local units will receive capacity building in participatory monitoring and evaluation (M&E) during construction to enable them to help monitor the contractor as the system is being built and afterwards to help monitor system functioning and provide feedback to the RSU. There can be training in proper system usage (ways to prevent blockages).

In decentralized communities, CDAs/local units will receive in-depth training before system start-up in how to operate and manage the system (financial, administrative, technical, and social aspects) as well as training in M&E. This training can be provided by the NGO/ consulting firm, supervised by the RSU. Communities will be provided with manuals to assist them in their work.

Hygiene Promotion

The hygiene promotion campaign will be pivotal to convincing community members to change hygiene and waste management behaviors. Hygiene promotion activities will target children as well as mothers and fathers of children under five (there may be other target groups as well). Hygiene promotion activities will take place during and after construction activities.

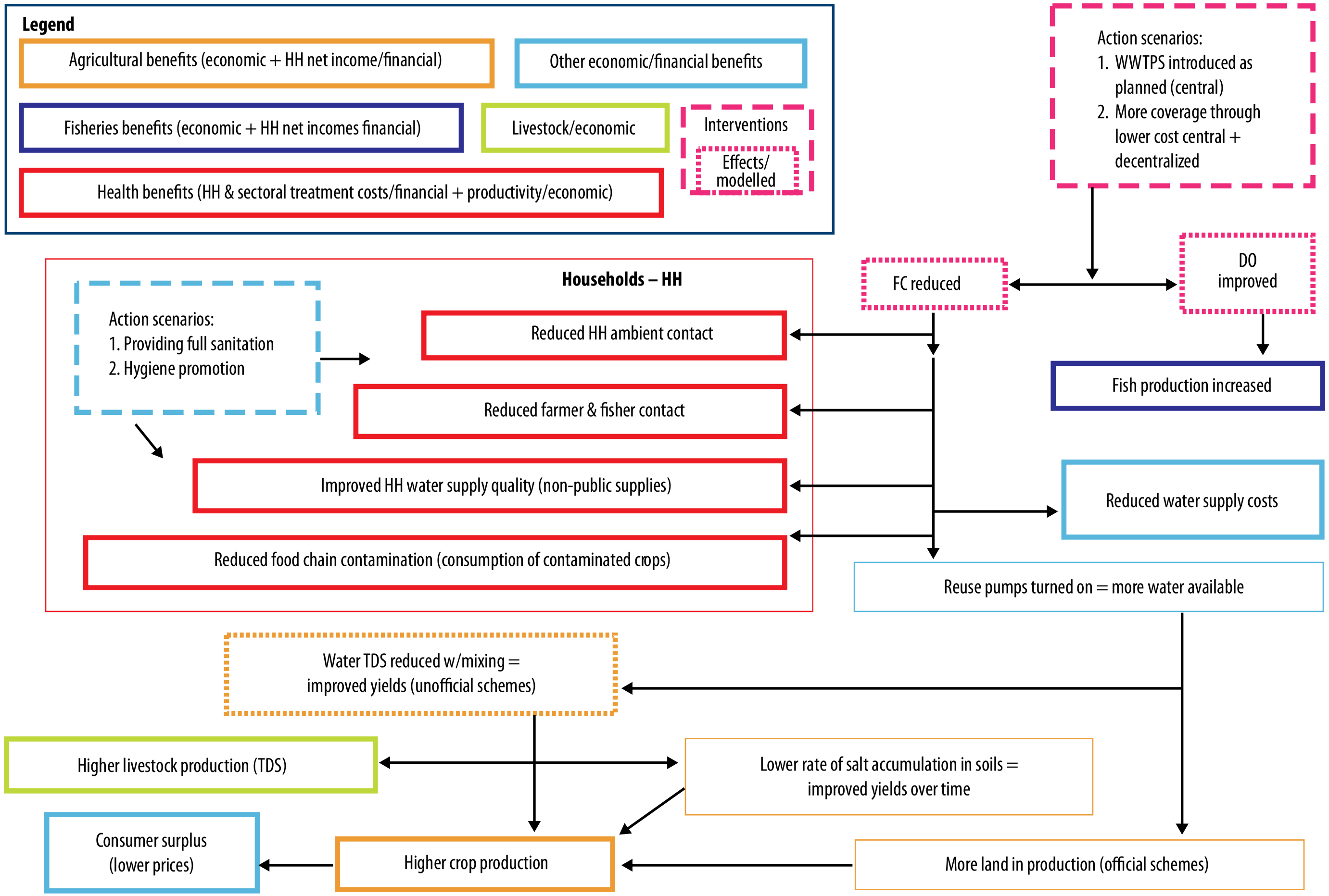
Operation and Maintenance (O&M)

In centralized systems, CDAs/local units will provide community feedback on system functioning to the RSU and alert the RSU to any problems that occur (system blockages) With decentralized systems, the CDA/local unit will manage the system, receiving back-up technical support from the RSU as needed.

Participatory Monitoring and Evaluation (M&E)

In centralized and decentralized communities, CDAs/local units will be involved in participatory M&E, assessing project progress and then system functioning through monitoring specific indicators and related targets. Various community sub-groups can be involved in this monitoring, such as women and men and youth.

Appendix A22.1. Assessment and Monetization of the Private and Public Benefits from Improving Water Quality: Taking Fecal Coliform Regarding Health and Food Chain, Dissolved Oxygen Regarding Fisheries Production, and TDs Regarding Crop Production



23

Water Management in Spain: Highlights Relevant for MNA Countries

Ahmed Shawky Mohamed,
Abdulhamid Azad and Alexander Bakalian

The Middle East and North Africa (MNA) water team, along with counterparts from the various MNA countries, spent two weeks in July 2008 on a study tour of Spain. The tour included participating in the Zaragoza Water EXPO, and visiting Spanish institutions responsible for water resource management, water supply, irrigation, and desalination.

The significance of Spain's water sector to the MNA region is three-fold:

1. They share similar climatic and hydrological conditions.
2. They share many common cultural and historical links dating back to the Moorish period.
3. Perhaps most importantly, in many areas of water services, Spain appears to have transitioned its Integrated Water Resource Management (IWRM) practices to more decentralized decisionmaking and successful implementation of public-private partnerships (PPP).

The first part of this chapter discusses the MNA water team observations from the field visits. The second part summarizes the key messages on climate change from the Water EXPO deliberations that the team attended.

Observations from Field Visits

Ebro River Basin Authority (Confederation Higrografica del Ebro) at Its headquarters in Zaragoza

Spanish river basin authorities use reliable data, drought and flood control tools, as well as coordinated operations of reservoirs and aquifers.[1]

An advanced hydrological information system manages real-time data on meteorology, hydrology, and water resources (level of reservoirs, state of main water control gates, and discharge at control points) in the basin. This advanced information system enables good management and prediction, and supports an alarm system for flood prevention and drought management.

One of the highlights of the tour was the visit to understand how Spain's *hydrological information system* works. The operations room does real-time monitoring of data (*Sistema Automático de Información Hidrológica,* or SAIH).[2] The data comes through sensors in some 620 remote stations (dams, rivers, canals, rainfall measuring stations) and is processed for decisionmaking through a software developed for this purpose (decision support system, or *SAD* in Spanish). SAD allows real-time flood management and provides flow forecasts along the different stretches of the rivers in the basin as well as simulates the operation of the existing infrastructure.

In addition, the *automated Water Quality Information System* monitors water quality in rivers and discharge points of industries and towns. The availability of reliable, easily understood (by stakeholders), real-time data has been a key factor behind the success of the governance structure.

Canal de Isabel II by Water Supply and Sanitation Group

Canal de Isabel II is the water utility for the Madrid autonomous region.[3] This utility is considered one of the oldest in the world. It was founded 150 years ago (1858). It serves 6 million people and has approximately 2250 employees. Unlike many countries' water utilities, this canal manages the full water cycle:

- Water reservoirs (14)
- Conveyance systems
- Water treatment plants (11)
- Distribution networks
- Wastewater collection treatment (140 plants of all sizes, the largest with 16 m^3/sec capacity).

[1] www.chebro.es
[2] www.saihebro.com
[3] www.cyii.es

Wastewater reuse

The company reached the level of 100 percent wastewater treatment in 2006. Currently, it is implementing a treated wastewater reuse program that will provide irrigation water for 40 percent of the green areas in the Madrid region. (As a reference point, the MNA team was informed that the price for reused water is 0.15 Euro per m^3).

Water supply

The company provides different levels of service to the some 140 municipalities and towns in the Madrid autonomous region under different arrangements: full concession contracts covering all activities; operations and maintenance (O&M) contracts; and contracts for commercial activities only (billing and tariff collection).

Some key indicators given were (a) unaccounted-for-water (UFW): 22 percent, of which 11 percent is physical losses; and (b) tariff for water and wastewater: 1.3 Euro per m^3 for the consumption of less than 25 m^3 (per 2 months).

It is noteworthy that the company has created a subsidiary that works as a successful private operator in a number of countries in South and Central America.

Lessons for MNA countries.

The Madrid utility could be considered as a "mature" organization, that is, one that has adapted over time to the local political realities and emerging environmental priorities. More fundamentally, the utility appears to have transitioned into an organization that is implementing IWRM while maintaining internal and external accountability.[4]

Almeria

Almeria is a desert area. The team visited two examples of conjunctive use of desalinated water with groundwater in the coastal areas of Nijar and Balerma (for irrigation through distribution networks extended to greenhouses). In addition, some of this desalinated water is supplied to coastal communities for household use and to the booming tourism industry. The desalinated water helps to both reduce the burden on depleted groundwater and counteract the sea-water intrusion in the

[4] See Jagannathan, "Principled Pragmatism: Lessons from the "MNA Development Report on Water" in this volume.

water-supply wells. The models were quite similar to the conjunctive use models being developed in Morocco's Guerdaine project (financed by IFC) and Egypt's West Delta Project[5] (with surface water). The primary driver in both situations is the water demand from farmers who grow high-value crops for international markets. In addition, as most farmers are smallholders (<2 ha.), the model of technical assistance (TA) and marketing support has direct relevance to the project design in Egypt's West Delta. For example, the water user commercialization association in Balerma has developed a very interesting auctioning system for marketing the farm produce to the local/EU markets.

The difference in the case of Almeria is that the production cost per unit of water is subsidized by the state budget and by EU subsidies. This subsidy was designed to function in a relatively targeted/objective manner. It was designed to achieve desired outcomes, for example, by writing off the interest on the state loan to farmers upon proof of improving the productivity per unit of water. The average water productivity is very high: 12 Euro/unit of water for vegetables such as tomatoes and peppers.

In summary, Almeria's approach has enabled scaling up the supply-side investments that are tied to the water user demand, thereby ensuring financial sustainability. The administration sees the subsidy as justified because it contributes to financing a regional/state "public good," namely, that water availability has promoted a booming tourist industry along the coastline. Compared with MNA countries, Spain's public subsidy comes at a lower social cost because public social spending (notably health and education) is at a higher level.

Observations on irrigation model

Given its geographical position, Spain is vulnerable to climate change. However, Spain finds itself in a situation that may facilitate the adaptations needed for the supply, demand, and management of water resources. Regarding supply, two favorable circumstances are the (1) high level of regulation of the rivers and sufficient water control infrastructure and (2) current program to build desalination facilities. Demand is the subject of a series of programs for making improvements, such as the National Irrigation Modernization program.

The visit to Almeria, officially Europe's only desert, is instructive in this regard. Its 30,000 hectares (ha) are intensely farmed. This area is dedicated primarily to horticultural crops under greenhouses.

[5] See Baietti and Abdel-Dayen chapter on West Delta Project in this volume.

The water supply is from surface water, groundwater, rainwater, and desalinated water. The greenhouses are very labor intensive—on the order of 700 person days/ha/year. The Almeria type of greenhouse is a low-cost structure of light materials. Plastic is used for the enclosure, and a two-layer cover captures the rainwater for irrigation. Under greenhouses, 1 to 2 crops per year are obtained. Production is interrupted in June and July, when there is considerable production of fruits and vegetables in other parts of Europe. Water productivity under greenhouses is approximately 12 Euro/m^3.

Assessment of water user associations

The team visited two water user associations (WUAs) with very different situations. The first was the Campo de Nijar WUA, which has 1,826 members and an irrigated area under greenhouses of 8,200 ha. Irrigation is by (deep) groundwater (200 m). The expansion of the irrigated area since 1970 has resulted in overexploitation of the aquifer and sea-water intrusion. Because of the highly saline water, many farmers started capturing the rainwater that falls on the greenhouses, mixing it with the well water. Since this solution was inadequate, they are now using desalinated seawater from the Carboneras plant. The desalinated water is provided on demand with a limit of 0.3 l/s/ha for 23 hours a day. The average investment cost to distribute this water is approximately 6,700 Euro/ha (using only water conveyance distribution systems). This cost is subsidized by the European Union, the central government, and provincial authorities. In addition, farmers obtain certain subsidies, up to 50 percent, for their private on-farm drip irrigation systems. The technologies used in this area can serve as a good example for the recently approved West Delta irrigation project in Egypt.

The second visit was to the Solponiente WUA. It has 1454 members and an irrigated area under greenhouses of 1,800 ha. Irrigation is done conjunctively by surface and groundwater. The irrigation water is distributed on demand by a pressurized system. Irrigation water is allocated daily and administered using a sophisticated real-time control and monitoring system. Irrigation modernization recently was completed. It consisted of implementation of water metering and remote management (Supervisory Control and Data Acquisition, or SCADA) of these meters, as well as an irrigation advisory service. The water metering and SCADA investment cost was approximately 3,000 Euro/ha. As a result, it was estimated that savings of 16 percent of irrigation water were achieved. The irrigated area was not increased due to modernization. The average cost of irrigation water is approximately 0.18 Euro/m^3. In future, this area also will be served by desalinated seawater, which will be used conjunctively with groundwater and surface water.

Spain's irrigation areas vary considerably. Nevertheless, the WUAs share many common characteristics:

- Constitution and legal status.
- Organization and selection of leaders and functions.
- Sharing the financing costs as well as participating in the management of water resources.
- Water users being obliged by law to join a WUA (*comunidad de usarios)*. When most members are farmers, it is called an irrigators association (*comunidad de regantes)*.
- Rules of the associations written and approved by users. The rules must be approved for compatibility with the law but may not be otherwise changed by the River Basin Agency. WUAs with a common interest can form a general association around that issue.
- Existence of a National Federation of WUAs with the objective of studying irrigation-related issues and presenting proposals to government.

WUAs are managed by (1) a General Assembly composed of all members, (2) a Board of Governors elected by users to carry out directives of the General Assembly, and (3) an Irrigation Jury, responsible for resolving conflicts between farmers.

Observations on the desalination plants

The team visited two desalination-supported water schemes in Nijar and Balerma that provide water not only for household water supply and tourism but also for irrigation (via distribution networks extended to greenhouses). The desalinated water also helps reduce the burden on the depleted groundwater and helps counteract the seawater intrusion in the water-supply wells.

The Carboneras desalination plant started operation in 2005. It uses reverse osmosis technology and has a treatment capacity of 120,000 m^3/day. The desalinated seawater is used for irrigation of the greenhouse crops in Campo de Nijar (27 million m^3/year), household supply (15 million m^3/year), and industries (1 million m^3/year). The desalination process is very energy intensive: it uses 4–8 kWh/m^3.

Additionally, the desalinated water must be pumped to a reservoir with a dynamic head of 280 m. Thus, desalination does not appear to be an economically viable option. Because desalination costs are approximately 0.52 Euro/m^3 (3,000 Euro/ha), only highly profitable crops can be irrigated.

Economies of scale (scaling up the desalination and water distribution works) and the ongoing technological advances have helped to dramatically reduce unit costs. In the past, the KWH per unit of desalinated water in the Canary Islands was as high as 40 KWH/m^3, whereas, in the Nijar Desal plant (visited during the tour), it is only 4 KWH/m^3. With improved developments of membranes, these costs already are reduced further to 2KWH/m^3. The effluent brine is a negative externality that often is the environmental concern in scaling up desalination schemes in some countries. This brine is mitigated by dilution with the water used for the energy plants before being disposed to the sea.

Role of subsidies

As in the case of irrigation, the production cost per unit of water is subsidized by the state budget and by the EU. However, these subsidies are made in a relatively targeted/objective manner. The subsidy is relatively outcome-based (for instance, by writing off the interest on the state loan to farmers when they present proof of improving the productivity per unit of water). The water productivity is as high as 12 Euros/unit of water (for example, with tomatoes and peppers).

Lessons Learned from the Field Visits

The main lessons from the visit are:

- Overall management of water resources requires active participation from users. In addition, reliable, user-friendly, hydrological information that monitors the stocks and flows of water plays a key role in resolving various conflicts of interest. The Spanish river basin agencies have been able to play a critical role in sustainable water resource management, but these institutions have evolved over several decades.
- Irrigation improvements that enhance water productivity are likely to lead to higher evapotranspiration (ET). Under these circumstances, desalination offers sustainable solutions to coastal farmers who are already producing high-value crops.

- The Almeria model of providing small farmers with technical assistance at three levels (on the farm, for meeting EU phytosanitary regulations, and for marketing) has interesting lessons for World Bank projects in Egypt and Morocco.
- Irrigation system modernization needs to attend to both physical and operational aspects. Good water-level control and communication facilities are essential to good irrigation management. In particular, there is a need for good water balance assessment, good understanding of internal system processes, and high flexibility in water delivery arrangements.
- Desalinated water could be put to conjunctive irrigation use *provided* there is a high-value use (such as tourism) that can *pay* for cross-subsidies. However, this model is not replicable in MNA because the Spanish farmers benefit from a variety of subsidies available through EU agricultural policies.
- In general, desalinating costs are declining, and the costs of surface water and groundwater are increasing. Therefore, desalination is becoming more competitive for urban uses. Reverse osmosis is the preferred desalination technology due to the cost reductions driven by improvements in membranes in recent years.
- For water-scarce regions similar to Almeria, such as coastal communities in MNA countries, a hybrid solution may be relevant to enhance productivity of periurban agriculture for local markets. Such a hybrid would blend the relatively cheaper treated wastewater (once public acceptance is achieved through adequate environmental and social safeguards) with desalination plants, Technologies for tertiary wastewater treatment and desalination have very much in common. However, the cost of treatment varies depending on the type of treatment and the intended final use of the water.
- Spain has evolved a system whereby the state pays for major construction works for water resource development and recovers the costs through water tariffs. Equally important is the availability of a strong legal framework that has empowered the WUAs. It takes many years for WUAs to evolve. Project designs need to recognize the long gestation periods before WUAs can become fully empowered.

The Almeria experiences of conjunctive water use for growing vegetables are replicable in MNA in areas in which the farmers *already have worked* out supply chain/logistical issues essential to connect to the export market. Examples of such areas in MNA are Agadir in Morocco, parts of Tunisia, Algeria, and possibly Gaza (once normalcy returns).

Zaragoza Water Expo: Summary of Messages for MNA Countries on Climate Change

- Developing countries will be the most affected, notably those in the MNA region.
- Climate change is 1 of the 4 causes of the *escalated water demand-supply imbalance (water scarcit*y). The other three causes are *population growth, improved living standards,* and *increased system losses due to under-budgeted O&M*. In some countries, these last three causes may dwarf the importance of climate change. In other countries, the incremental effect of climate change will be significant. Diversification and trade are key adaptation solutions, namely, "virtual water" to maximize net exports per unit of renewable water.
- In general, in MNA, climate change will:
  - Increase irrigation-water demand per ha (due to increased temperature).
  - Alter the flood and drought extremes, and shift the seasonal rainfall and surface-water flow hydrographs. The Nile basin likely will encounter increased precipitation (and hence increased, rather than decreased, flows).
- One major challenge is the high uncertainty (of the demand and supply forecasts to 2050 or 2070). High uncertainty means that, for designing and executing the adaptation interventions, MNA countries inevitably will take risks:
  - Higher-income countries need to take some *capital-cost risk*. For instance, they could design the water interventions to adapt to the most extreme (that is, highly unlikely) flood or drought (such as a 1-in-200 year flood/drought).
  - Lower-income countries need to take some *damage risk*. For instance, they could design the water interventions to avoid only the more probable floods/droughts.
- The adaptation options, including several supply augmentation and demand management measures, need to be assessed by multiple criteria, including, importantly, the sustainability criterion. The cost-benefit ratio should not be the sole factor. MNA made a presentation at the EXPO emphasizing that the assessment and

implementation of adaptation options should be performed through the ABCDE approach, elaborated in chapter 1, as opposed to the common top-down engineering approach. In Algeria and Yemen, for example, the latter approach resulted in costly/oversized trunk works without real bottom-up societal demand.

- In some cases, the mitigation and adaptation agendas could overlap. The planner needs to address this possibility to ensure a harmonized overlap. Examples include:
  - Cropping shifts that save water (adaptation measure) without resulting in increased greenhouse gases (GHGs) (mitigation measure)
  - Reusing treated wastewater (adaptation measure) while sequestering the emitted methane (mitigation measure)
  - Capitalizing on the storage of bulk-waters (adaptation measure) to develop clean solar-thermal energy (mitigation measure, as planned for Balerma reservoir, which the team visited during the tour).

Engineering

24

Egypt: Irrigation Innovations in the Nile Delta

Jose Simas, Juan Morelli, and Hani El Sadani

Introduction and Statement of the Problem

Egypt depends almost entirely on 55.5 billion m^3 per year of water from the Nile River. This allocation represents 95 percent of the available resource for the country. Approximately 85 percent of the Nile water is used for irrigation. Demand for water is growing while the options for increasing supply are limited. Egypt faces the challenge of improving the productivity and sustainability of water use. To respond, the Ministry of Water Resources and Irrigation (MWRI) has been implementing an Integrated Water Resource Management (IWRM) Action Plan. Its *key strategy is to improve demand management*. This plan has had the support of the World Bank, Germany's KfW, the Netherlands Development Cooperation, and other donors.

The Integrated Irrigation Improvement and Management Project (IIIMP) is an important measure of the IWRM action plan. IIIMP is implemented on 500,000 acres (*feddans*) in the Nile Delta covering the command of 2 main canals, Mahmoudia and Mit Yazid. The project aims at improving the management of irrigation and drainage in the project area and increasing the efficiency of irrigated agriculture water use and services. The main interventions of the project are improving irrigation and drainage systems and improving the water management institutional structure.

† This chapter was prepared in close collaboration with the staff of Egypt's Ministry of Water Resources and Irrigation (Irrigation Improvement Sector; IIIMP Management Unit; Water Management Research Institute) and Ministry of Agriculture and Land Reclamation (Executive Authority for Land Improvement; Soil, Water and Environment Research Institute; Center of Agricultural Economic and Statistics).

The IIIMP interventions in irrigation modernization are based on the experience gained from several preceding and ongoing projects. The original concepts of irrigation modernization were developed in the early 1980's and since then have received support from UNDP, USAID, Japan, World Bank, KfW, the Netherlands Government, and others. In 1996 implementation started on the World Bank/KfW-financed Irrigation Improvement Project (IIP). It was the first large-scale application of the irrigation modernization program in Egypt. The project closed in December 2006. By that time, 50 percent of the tertiary and secondary systems of the command areas of the main canals of Mahmoudia and Mit Yazid had been modernized.

The IIP included three types of improvements/innovations:

1. *Introduction of continuous flow.* The mode of operation of secondary distribution canals was changed from rotational (for example, 5 days on/5 days off during the summer) to continuous flow (that is, water flows continuously in the secondary canals). The purpose of continuous flow was to improve water delivery services to the farmers. It has given more flexibility to the water management system to make it more suited to growing high-value crops.
2. *Providing a single lifting point*. The low-lying tertiary water systems (*mesqas*) were replaced by pressurized/elevated systems. Water is lifted from the secondary canal into the tertiary network through a single-point lifter rather than the old system. The latter allowed farmers to lift the water through several formal/informal control points without adequate control measures. The old system caused tremendous inequity in water distribution between upstream and tail-end users. The new system has led to better water distribution equity and reduced operation cost.
3. *Piping tertiary canals*. Earthen open tertiary canals were converted into piped canals. Piped canals allow for pressurized water delivery, reduce seepage losses, prevent discharge of solid waste and sewage into the tertiary system, and save approximately 2 percent of the total command area.

The IIIMP widened the approach of the previous Irrigation Improvement Project (IIP). The initial driver was based on the economic analysis of various technical irrigation improvement options, including the IIP approach. Average IIP improvement costs were exceeding LE 6,000 per feddan (extreme cases reached 12,000 LE/fed), due mainly to over-design. In addition, IIP's economic rate of return (ERR) was lower than expected at appraisal time.

In addition to reducing the cost side of the interventions, a number of innovative measures were considered to maximize the benefit side of the project from both economic and financial points of view. For example, at this time, the Egyptian government was implementing diesel fuel cost increases. These increases not only have increased the operational cost of nonimproved systems but also would have increased operational costs for improved systems if the original choice of IIP of diesel single lifters had been adopted. The proposed response was to take advantage of the relatively good electrical transmission and subtransmission infrastructure in the Nile Delta and the economic efficiency, life span, and capital and running costs of the electro-pumps.

In general, IIIMP adopted a three-point strategy:

1. Proper sizing of the improved infrastructure to optimize capital costs
2. Technical innovations to increase cost-savings and functionality
3. Extension of the improvement package to the whole system (including tertiary and on-farm improvements).

Both (2) and (3) would have resulted in maximized benefits compared to the associated costs.

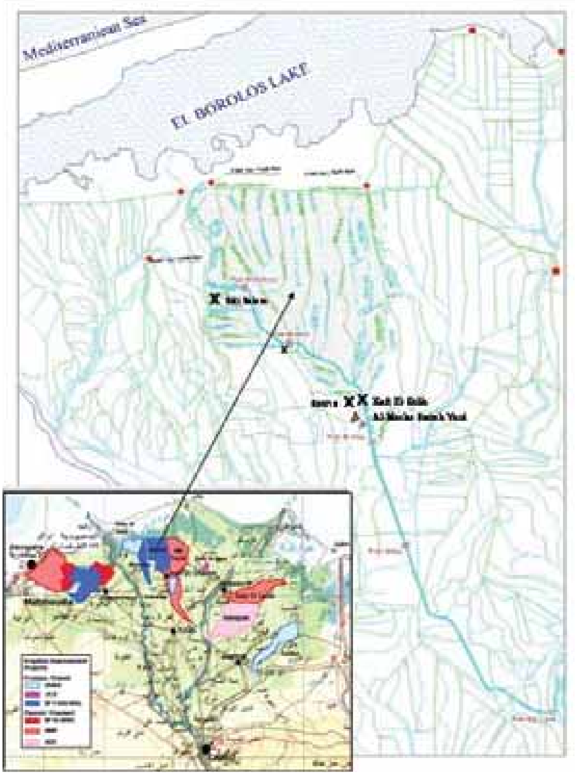
Government engineers were reluctant to endorse the elements discussed during preparation for two reasons. First, this strategy had never been implemented in Egypt. Second, there was concern regarding possible rejection by farmers of innovative elements with which they may not have had experience before. It was clear that only a "sizeable pilot" could clarify the large number of issues and fine-tune the appropriate technology before scaling up to the national level.

The objective of this chapter is to document the process of developing the pilot and to provide an interim evaluation based on real measured data. There is a real need for this evaluation at this time due to the fact that the irrigation modernization package implemented in this pilot has never been tested before under Egyptian conditions.

Selection of Pilot Area

The W-10 area in Kafr El Sheikh Governorate was selected to serve as the "sizeable pilot" for the new approach. It comprises approximately

Figure 24.1 Layout Map for Northern Part of Mit-Yazid Canal Showing W-10 Subproject Area



6,000 acres in the most downstream tail-end command area of the Mit Yazid main canal. It is supplied by 3 branch canals and 2 sub-branch canals (table 24.1). The area was selected solely because it was the only subarea in which no IIP interventions had ever been made.

As a tail-end area, W-10 has restricted water supply in the peak summer season and therefore reuses drainage water. The water shortage and low farmer incomes meant that W-10 was a more difficult working environment than the IIIMP overall.

On the positive side, the W-10 area is close to the Sakha Experimental Station.[1] This fact, together with the support of the GTZ-MALR Agriculture Water Management Project, was considered a plus, because it would enable the provision of technical assistance and materials to implement the pilot actions.

Package of Actions to Test for Scaling Up

Substantial differences existed between the old design criteria implemented under IIP and the new approach applied in W-10. The latter featured 12 innovations:

1. Electrification of single-point lifters (mesqa pump sets) rather than diesel pumps. While this measure has had the benefits mentioned above, a new dedicated distribution grid was needed, and the MWRI was to take care of it.

[1] Sakha is a subsection of the Soils, Water and Environment Research Institute (SWERI) of the Ministry of Agriculture and Land Reclamation (MALR).

2. Adoption of prepaid electrical cards to avoid delinquent payments and facilitate supply logistics to user farmers. This measure was adopted because the electric utility companies were reluctant to accept the new users based on risks of delinquent monthly payments from farmers. The IIIMP team proposed a "new deal" through the use of modern "prepaid credit cards." This was a win-win option for both farmers and utilities.
3. New and cheaper equipment for the tertiary distribution systems (mesqas): increased irrigation application time in the peak month from 12 hr to 20 hr; substantial reduction of pipe diameters; direct pumping rather than costly concrete standpipes; more compact pump houses equipped with smaller pump modules: 20, 40, and 60 l/s, instead of 60 and 90 l/s units (reducing water duties from 4–6 l/s/ha in extreme cases to 2 l/s/ha or 0.82 l/s/acre in Egyptian customary units).
4. Improvement of head works control gates of branch canals through telemetric instrumentation and remote operation of gates with Supervisory Control and Data Acquisition (SCADA) system.
5. Improvement of quaternary distribution systems (*marwas*) including the testing of two options: lining by brick and mortar or piping by low-pressure pipes up to the on-farm gate. MWRI had not been involved before in the improvement of marwas. However, the Soil, Water and Environment Research Institute (SWERI) of the Ministry of Agriculture and Land Reclamation (MALR) was implementing a pilot program to line marwas using bricks and mortar. Thus, an interministerial agreement was made to enable SWERI to implement the marwa improvement activities, although MWRI would be responsible.
6. Testing low-pressure pipes for marwas (class 2.5 bar instead of 4 bar).
7. Testing different types of valves for the mesqa-marwa interface (ball, gate, and butterfly), different brands and specifications, optional manufacturing materials (metallic, polyvinyl chloride or PVC), PE, and different installation lay-outs.
8. Developing and testing different individual farm-gate hydrants for on-farm use allowing future use of hoses and gated pipes—all provided with pre-set constant flow and pressure.
9. Application of laser land-leveling (LLL) practices to improve allocation efficiencies (recently initiated).

10. Introduction of rotational operation schedules of pumps, valves, and hydrants to harmonize farmer needs and efficient use of water, labor, and energy.
11. Introduction of on-farm water management improvements including irrigation scheduling (to begin soon).
12. Testing and introduction of modified/controlled drainage (tested at station level and to be expanded soon).

By 2009 the approach tested in the W-10 pilot area was being expanded within IIIMP to more than 500,000 acres in the Delta.

This expansion depended on the collaboration among the specialized agencies of the MWRI and MALR, working together with water user associations (WUAs) and informal farmer groups. The cooperation between MWRI and MALR in the W-10 area provided the framework for MALR participation in the implementation of marwa and on-farm improvement programs. These programs included piped marwas, laser land-leveling, and training and capacity building of beneficiary farmers.

The completion of the W-10 took more than four years due to contractors' inexperience in implementing some of the new interventions and failures of some contractors to comply with the contractual schedule. The marwa implementation schedule was delayed because of delays in agreement on procedures for interagency transfer of funds and materials and other accountability mechanisms. After the project management unit (PMU) took over responsibility for completing the W-10 area project, the marwa improvement program began to accelerate.

As noted above, the new W-10 approach was strongly resisted during the first few years. However, after the results of the W-10 pilot became evident, many of the skeptical parties became convinced that the project's technical and organizational innovations could succeed.

Evaluation of the New Approach

The IIIMP Project Appraisal Document (PAD) envisaged (a) an average increase in farmers' annual income of approximately 15 percent, (b) water savings of approximately 22 percent, and (c) an overall ERR of 20.5 percent.

An interim evaluation of W-10 pilot was conducted in late 2008. The aims were to:

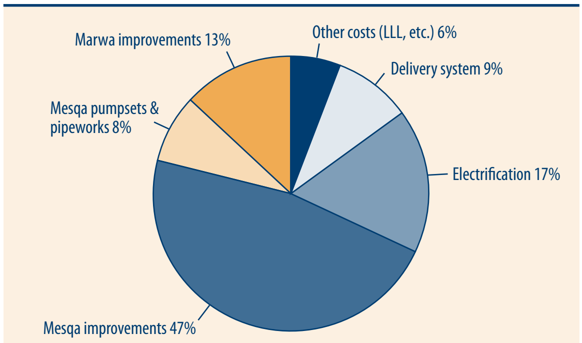
- Verify whether the new approach was feasible and whether the PAD forecasts were accurate
- Inform the design of a results-oriented monitoring and evaluation system.

Investment Costs

Most of the W-10 improvement costs were financed by IIP, which closed on December 31, 2006. The improvements at the quaternary and on-farm levels were taken on by the IIIMP. Despite having an estimated cost of approximately LE 120 per acre—less than 2 percent of the total improvement costs—laser land leveling is expected to have a significant impact.

Figure 24.2 shows the breakdown of the main components of the improvement costs in the W-10 pilot. Mesqa improvements represent 47 percent of all W-10 improvement costs.

Figure 24.2 Breakdown of W-10 Investment



Source: Authors based on data from official records.

Improvement in Physical Performance of Irrigation System of the W-10 area

At the time of writing of this report, the authors could not assess the full range of enhancements in irrigation system performance because the improvement package had not yet been implemented in full (for example, the crucial laser land-leveling improvement). However, through a number of ongoing M&E studies, the following preliminary observations have been evident:

Impact of marwa improvement

- The *sufficiency indicator*, which expresses whether enough water is diverted by the marwa to its served area, is the highest for pipeline marwas compared to lined and earthen marwas (earthen is the lowest).
- The *equity indicator*, which measures adequacy of water distribution, is the highest for pipeline marwas, compared to lined and earthen.

- The *conveyance efficiency indicator* depends on calculating water losses due to seepage, percolation, and evaporation from marwas between the source and the farm. This indicator was highest for piped marwas. Piped marwas resulted in substantial water saving compared to other interventions.
- The *irrigation time indicator* indicates the superiority of improved marwas over earthen marvas.
- *On-farm* (application, crop water use, and field water use) *irrigation efficiency* is highest for piped marwas.
- *Water table depths* were deeper for improved marwas compared to earthen ones, indicating less water loss and lower drainage coefficients.
- The s*ocial assessment* indicated that most farmers prefer piped marwas. The farmers perceived four benefits from improving marwas: equity enhancement, land-saving, reduction in maintenance costs, and reduction in irrigation time.

Impact of mesqa improvement

- The average total operating cost was significantly lower for W-10 compared to the IIP regular improvement package.
- The average irrigation time was higher for W-10 compared to the regular IIP-1 due to reduced pump size and pipe diameters in W-10 area.
- Relative water supply is better for the W-10 area compared to the nonimproved areas, thus indicating better water availability.

Benefits in W-10 Pilot Area

Appendix 24.1 shows which irrigation improvements produced which benefits.

Benefits could be summarized for one or several of the improvements by the following actual production parameters:

- *Crop yield increases* (due to enhanced flexibility under continuous flow operation, timely irrigation, equity for tail-end farms, improved water quality and quantity, improved drainage and reduced water table and water and soil salinity, and reduction of weed infestations)
- *Change in cropping pattern* (due to improved reliability and timely access to water)

Table 24.1 Average Incremental Yields and Incomes by Crop

Crop/activity	Crop yields *(kg/fed)* Without project	With project	Increase *(%)*	Income *(LE/fed)* Without project	With project	Increase *(%)*
Maize	3.100	3.500	13	3,355	4,042	20
Rice	4.100	4.600	12	3,140	3,928	25
Seed cotton	1.130	1.330	18	1,769	2,602	47
Summer vegetable	15.000	18.000	20	3,450	5,254	52
Wheat	2.800	3.200	14	4,871	5,868	20
Broad beans	1.400	1.600	14	2,131	2,666	25
Winter vegetable	19.000	22.000	16	6,805	8,729	28
Berseem long season	25.000	28.000	12	2,504	3,085	23
Berseem short season	12.000	15.000	25	1,067	1,748	64
Sugar beet	18.000	21.000	17	2,332	3,186	37
Citrus	10,000	12,000	20	8,995	11,528	28

- *Land gains* for communal service space (due to replacement of open mesqas and marwas by buried pipes)
- *Reduced irrigation costs*
- *Increased water productivity* (due to reduced water losses, conveyance efficiency, controlled drainage, laser land-leveling, higher yields, lower irrigation costs).

The improved production parameters recorded above all are measurable and easy to introduce into crop and farm representative budget models.

To estimate the benefits of the W-10 pilot package, the authors worked closely with officers of MALR's Center of Agricultural Economics and Statistics[2] to update with- and without-project crop patterns and budgets. Such figures were obtained primarily by field-sampling yields and some estimates based on qualified experts. Table 24.1 summarizes the resulting yields and net income parameters of the main crops cultivated in W-10.

As can be seen from the physical quantities and values detailed in table 24.1, yields are increased by 12 percent–25 percent. Net incomes per cultivated acre are increasing by 20 percent–64 percent as a result

[2] Engineers Bayoumi Abd El Megued Bayoumi, Abd Elmahab, and Mohamed A. El-din Mustafa (MALR).

of the combined effects of increased productivity and reduction of the irrigation costs (depreciation and O&M of pumps).

Table 24.2 summarizes three typical *farm models*. All models confirm the financial feasibility of the proposed improvements and the positive impact on beneficiaries' family income. Through integrated on-farm and off-farm investments, the project not only saves approximately 20 percent–30 percent of water but also significantly increases household income by 8 percent–14.5 percent (table 24.2). As W-10 pilot area investments are completed with laser land-leveling and other on-farm improvements (training, irrigation scheduling), additional income gains will materialize.

Financial and economic prices have been estimated using 2007–08 data. Conversion factors (CFs) for shadow pricing are based on estimates prepared for this quick illustrative analysis. Conversion factors for wheat (1.1), cotton (0.95), sugar beet and maize (0.9), and citrus fruits and tomato (0.8) were used. Given the high levels of existing subsidies to Egypt's energy market prices, CFs of 4.0 and 2.5 were used for diesel and electricity, respectively. For nontraded commodities, such as berseem and other forages, financial prices are assumed to be in line with economic prices. According to the most recent forecasts of commodity prices prepared by the World Bank (November 2008), future economic prices for traded inputs and outputs are not expected to show major variations. The WB forecast made no adjustment for labor costs.

Due to the short time available for preparing the analysis, no economic value was estimated for water saved. The farm model estimated that water consumption in W-10 was reduced by 30 percent from 49.6 million to 34.8 million m^3 as a result of the new improvement package being tested. However, water is gaining an increasing opportunity cost as irrigated area continues to expand in Egypt and water becomes more and more scarce.

Table 24.2 Farm Models: Estimated Income Increases *(LE/farm)*

	Income increases *(%)*	Model *(feddan)*	W-10 Area per model *(feddan)*	No. of farms	Farmer's net income: Without project	Farmer's net income: With project
W-10 pilot area			6,000	5,583		
Model 0.75 feddan *(50% of area)*	8.0	0.75	3,000	4,000	18,658	20,151
Model 1.5 feddan *(33% of area)*	11.9	1.50	2,000	1,333	23,222	25,988
Model 4 feddan *(17% of area)*	14.5	4.00	1,000	250	38,198	43,754

The ERR for W-10 investments was estimated at 15.2 percent and the net present value (NPV) at LE 11 million at 12 percent discount rate. These numbers were achieved even without assigning any value to (1) the water being saved or (2) the significant reduction of carbon emissions due to substituting the more than 5,500 individual diesel pumps with approximately 100 single-point electric pump houses.

Conclusions and Recommendations

This analysis uses empirical data to confirm that the W-10 pilot improvements are economically viable. It produced this positive result despite the fact that the project was in its start-up phase. There were cost overruns as staff became familiar with the new approach, and not all project benefits had yet materialized.

The exercise is a valid first approximation of an evaluation procedure that should be followed routinely. It should be updated regularly on the basis of systematic data collection.

Other additional preliminary conclusions that could be drawn from the analysis are:

1. As crop yields improve, the new designs introducing continuous flow and significantly reducing the capacity of single-point mesqa irrigation pumps are proving to be adequate for crop and farm needs. These designs are showing the way to improve equity in the irrigation distribution systems, which, by design, have a limited water conveyance and delivery capacity. With the new improvements approach, tail-end farmers should be in a better position to obtain the water they need. Farmers located in the head will neither need, nor be able to capture, water in excess of their crop consumption needs.
2. Electrification of the system also enables significant reductions of the costs of irrigation. The reductions result from both the reduced depreciation and maintenance costs of electric pumps as opposed to the diesel pumps, and the lower cost of electricity as compared with diesel fuel. Electrification also substantially reduces a significant source of carbon emitted from the thousands of individual diesel pumps by substituting more efficient and environmentally friendly shared electric pump houses.
3. There is still a great possibility to reduce costs of irrigation improvement works, as implementation partners (Irrigation Improvement

Sector of MWRI; Executive Agency for Land Improvement of MALR) and private contractors learn about the innovative approaches. As investment costs are reduced with experience, the impact of the improvements will increase.

4. Integrated irrigation improvements up to the marwa and the on-farm levels are possible due to the institutional collaboration and strong support from MWRI and MALR that were developed during IIMP. These arrangements should be reinforced and more training provided.
5. With the new approach, it is possible both to save approximately 20 percent–30 percent of the water used for irrigation and to achieve a significant increase in the value of production.
6. The evaluation exercise showed that the productivity of water increases by more than 80 percent when comparing the total net economic value of production per 1000 m^3 used for irrigation at project maturity with the pre-project productivity.

Appendix A1 Monitoring and Evaluation Framework: Integrated Improvements Components and Expected Impacts

Table A1.1 Monitoring and Evaluation Framework: Integrated Improvements Components and Expected Impacts

Infrastructure networks levels			Relevant users organizations	Improvement subcomponents (inputs)	Impact results expected (outputs): Intermediate outcomes	Impact results expected (outputs): Final outcomes
On-farm			Water User Associations (WUAs)	Laser land-leveling	Efficient on-farm water management	■ Labor savings for farmers ■ Incremental crop yields ■ Incremental energy and water savings at farm level ■ Fertilizer savings ■ Land market-value appreciation
				Calibrated farm hydrants and irrigation scheduling training	Increased crop yields	
				Salinity control agronomic packages		
Off-farm improvements and actions	Minor networks	Quaternary marwas		Marwas improvement (piping/lining)	Efficient, timely, and equitable water distribution to farms	■ Assurance of water adequacy, equity, and timeliness to farms ■ Pump energy savings ■ Increased yields ■ Water and energy savings ■ Incremental increase of land value ■ Labor savings
				Hydrants harmonized rotational scheduling		
				Controlled drainage pits	Water and pumping savings on rice crops	
				WUAs training on O&M	Effective and sustainable O&M	
		Tertiary mesqas		WUA establishment and effectiveness	Enabling condition to all actions/ improvements	■ Sustainable use of water distribution water adequacy, timeliness, and equity of distribution to marwas ■ O&M cost recovery to mesqas ■ Water and energy savings ■ Increase of land value ■ Emissions reduction
				Piped mesqa + single lifter	Enabling condition for equity and saving	
				Electrification	Reduction on pumping costs, emissions, and noise	
				Training on pumps and valves O&M and rotational scheduling	Sustainable use	
				Adoption of continuous flow at peak times	Equity and water savings	

Continued on next page

Table A1.1 Monitoring and Evaluation Framework: Integrated Improvements Components and Expected Impacts *(continued)*

Infrastructure networks levels			Relevant users organizations	Improvement subcomponents (inputs)	Impact results expected (outputs)	
					Intermediate outcomes	Final outcomes
Off-farm improvements and actions	Major networks	Secondary branch canals and surface drains	Branch-canal water user associations (BCWUAs)	Improvement of BC and related structures	Enabling conditions for mesqa improvements	■ Water adequacy, timeliness, and equity of distribution to mesqas
				BC headworks improvement and volumetric metering	Enabling condition for continuous flow	
				Renewing subsurface drains	Enabling conditions for controlling salinity and water logging	■ Sustainable crop productivity and yields: water savings on rice crops
				Modified/controlled drainage	Rice water savings	
		Surface drains (main)	District Water Boards (DWBs)	Main surface drains and related structures rehabilitation	Enabling conditions for controlling salinity and water logging	■ Sustainable crop productivity and yields
		Main canals		Main canal and related structures rehabilitation	Enabling condition for continuous flow for tail-end BCs	■ Overall equity, adequacy, and timeliness of water distribution to BCs
		Pump stations		Major pumping stations and related structures overhauling		

25

Water Reuse in the MNA Region: Constraints, Experiences, and Policy Recommendations

Claire Kfouri, Pier Mantovani, and Marc Jeuland

The scarcity of freshwater in most countries in the Middle East and North Africa (MNA) region is an increasingly acute problem, particularly as populations continue to grow and place higher demands on water resources. Fourteen of 20 MNA nations are in water deficit (less than 500 m^3 of renewable water supply per capita per year) (FAO 2006). Due to demographic growth, countries that are relatively well endowed with water resources, such as Egypt, Lebanon, Morocco, and Syria, may join the water-deficient nations by 2050. As rapid urbanization continues, water scarcity will create pressure to shift water from agricultural to domestic and industrial uses.

According to the latest collection of simulation results reviewed by the Intergovernmental Panel on Climate Change, consensus is strong that precipitation will decrease substantially in MNA countries (IPCC 2007). Higher temperatures will lead to greater evaporation from surface water storage reservoirs and losses in soil moisture. Higher evapotranspiration rates in vegetated areas likely will decrease runoff and groundwater recharge rates and could increase crop-water requirements in agriculture (IPCC 2007, Trenberth and others 2003, Schneider and others 1990).

In this context, the development of nonconventional resources such as desalinated water and reclaimed wastewater is increasingly relevant.

Water Reuse

On paper, water reuse, or the recycling of reclaimed wastewater for planned beneficial uses, is particularly attractive. It can limit or eliminate effluent discharges, while generating an alternate resource. Reuse indirectly allows both the preservation of freshwater resources for higher quality uses (such as potable water supply) and the postponement of potentially more costly water supply approaches (storage, transfer, or desalination schemes). These and other environmental, public health, and economic benefits of water reuse are widely documented (Scott and others 2004, Asano and others 2007, Mantovani and others 2001). Water reuse is emerging as an established water management practice in several water-stressed countries and regions.

Despite the perceived potential advantages for a region ranked as the most water-scarce in the world, the spread of water reuse across MNA countries is surprisingly uneven and slow. To date, few countries in the region have achieved the implementation of substantial reuse programs.

To better understand the context of wastewater reuse in MNA and to assess its future and potential, this chapter addresses three key questions:

1. Given the scarcity of water, why have many governments been slow to promote wastewater reuse?
2. What insights for the future of wastewater reuse can be gleaned from regional and international experiences?
3. How should policymakers adapt the wastewater management agenda to their country's economic context?

This chapter argues, first, that the development and implementation of water reuse strategies in MNA are impeded by four factors:

1. Insufficiency of economic analysis
2. Relatively high cost of wastewater treatment and conveyance, coupled with pricing of irrigation water that does not adequately reflect its scarcity value
3. Technical and social issues affecting the demand for reclaimed water
4. Difficulty in creating financial incentives for safe and efficient water reuse.

Second, the chapter asserts that only the most extreme scarcity or institutional discipline pushes countries to adopt widespread water reuse.

Water Reuse Constraints

Many water reuse experiences in MNA are pilot projects. As such, their sustainability and replicability are uncertain. With some exceptions, most of the remaining (nonpilot-scale) projects involve the planned reuse of wastewater that is not treated to meet World Health Organization (WHO) standards or *unplanned* reuse. Some locations have a policy climate favorable to wastewater reuse. However, even there, serious obstacles remain before many of these projects can become self-sufficient, both operationally (timely delivery of water), financially (cost recovery), and environmentally (salinity risks).

The obstacles to wastewater reuse in MNA are discussed below:

Constraint #1: The Need for More Complete Economic Analysis of Treatment and Reuse Options

The decision to promote wastewater reuse should depend on a full accounting of the economic costs and benefits of projects. Economic assessment rarely encompasses all relevant aspects of reuse and rarely goes beyond financial feasibility analysis.

The economic impacts of reusing wastewater depend on the degree of treatment and the nature of the reuse. A large number of costs and benefits should be considered in the context of the specific reuse approach (table 25.1).

When considering the demand for the water that is being reused, one needs to pay careful attention to whether this water is replacing water from other sources. In such instances, the important measurement is the increase (or decrease) in benefits associated with using reclaimed water instead of the replaced alternative. There is therefore a risk of double-counting when considering changes in crop yields, cropping patterns, fertilizer savings, salinity impacts, and property value changes (IPCC 2007).

In addition, project planning tends to overlook many of the costs of planned reuse (opportunity cost of water to be reused, regulatory costs, education and training of irrigators). For example, when treated or untreated effluents already are reused for some purpose (either indirectly or unplanned), their opportunity cost must be included when considering planned new uses. In many cases, the main impact of reuse will be to move a given supply of water from one place to another.

Table 25.1 Economic Impacts of Wastewater Reuse: Examples of Costs and Benefits

Costs	Benefits
Value-added from displaced water (if any)	Value-added from reused wastewater (varies based on quality and reliability differences)
Opportunity cost of reused water (if any)	Alternative use of displaced water (if any) Value of sanitation improvements
Collection and treatment of wastewater, final disposal costs	Reduced environmental degradation
Conveyance/storage of reused water, including water losses (evaporation, leakage) and retrofitting costs for participating farmers	Aquifer recharge, or value of reduced aquifer depletion
Salinity-related impacts	Increases in property values
Other pollution (nitrates, heavy metals, toxic substances)	Increased crop yields
Health, odor, and nuisance costs	Savings in fertilizer
Ecological impacts (opportunity cost of reused water for minimum flow or other purposes)	Value of improvements or reform in the water sector due to water reuse

Some of these various costs and benefits may fall disproportionately on certain stakeholder groups affected by the project. For example, farmers may have nonzero demand for untreated wastewater, to which they may lose access. Economic analysis therefore needs to consider the distributional impacts of reuse projects and address compensation.

Similarly, irrigators are likely to face higher prices as a result of water-pricing reforms to promote reuse. In addition, the quality of the reclaimed water they receive may prevent unrestricted agriculture or present them with long-term productivity costs.

Constraint #2: High Cost and Lack of Wastewater Treatment in MNA, and Their Impacts on Reuse

The first major cost of water reuse development is the upfront investment and cost-recovery challenge associated with wastewater collection and treatment. Although MNA countries have made significant progress in extending sewerage to most of their urban populations, important gaps remain, and treatment capacity is very uneven.

The applications and potential for wastewater reuse differ greatly depending on whether wastewater is managed through local or municipal sewerage systems or in on-site sanitation systems. The latter case, which is prevalent in small towns and across rural areas, is usually

Table 25.2 Cost of Wastewater Collection, Treatment, and Reuse

Component	Cost/m³ *(US$)*	Notes	Source(s)
Conveyance to treatment works	Highly variable[a]		
Nonmechanized secondary treatment	0.10–0.22	Necessary for restricted reuse	WHO 2005, Shelef 1996, Haruvy 1997, Amami 2005
Aerated secondary treatment/activated sludge	0.22–0.27	Lower land requirement	Kamizoulis 2003, Shelef 1996, Shelef 1991, Haruvy 1997
Tertiary treatment (in addition to secondary)	0.07–0.18	Necessary for unrestricted reuse	Shelef 1996, Haruvy 1997, Shelef 1994
Distribution	0.05–0.36		Shelef 1994
Total	0.16–0.53		Shelef 1994, Lee 2001

Note:
a Costs come from a variety of sources and have not been standardized to a specific reference year.

incompatible with the types of reuse systems considered in this chapter. However, fully successful reuse agendas need to consider all possible options.

The rate of treatment of collected wastewater is low in many MNA countries.[1] Much of the wastewater collected in MNA is discharged untreated into the sea or other surface water bodies, or on land. While much progress has been made in defining the risks associated with such practices, enforcement of regulations prohibiting them in MNA is patchy.

Furthermore, to treatment costs must be added the cost of collection and conveyance to treatment facilities from locations in which such infrastructure does not exist. Treatment facilities vary from location to location based on the infrastructure needed and the quality of the wastewater. Nevertheless, a review of costs indicates that the numbers are at the low end of the 0.46–0.74 US$/m³ range and average at 0.53 US$/m³, as presented in Lee and others (2001): capital (0.10–0.16 US$ (2001 US$)/m³), operation (0.25–0.40), maintenance (0.08–0.15), and miscellaneous (0.03).

Many analysts argue that economic calculations for reuse projects require that "…only the marginal cost of wastewater recycling (additional treatment, storage, and distribution) be considered, excluding

[1] See appendix A25.1.

the cost of wastewater collection and treatment" (Lazarova and others 2001).

Similarly, some analysts argue for subtracting the cost of safe disposal of treated wastewater from the cost of reuse. However, it only makes sense to exclude the cost of wastewater collection and treatment from the economic analysis *if* these services *would have been in place and functioning in the absence of the recycling investment*. This condition often is not satisfied in MNA.

Indeed, many treatment plants are plagued by poor operation and maintenance (O&M) and are operated well beyond their design capacity. These conditions will result in degraded treatment reliability and diminished reuse possibilities. In such a situation, the cost of bringing wastewater collection and treatment up to the required standard is part of the cost of a reuse project.

Constraint #3: Low Demand for Reclaimed Wastewater

Robust evidence from numerous projects suggests that the demand for reclaimed water generally is lower than it is for alternative sources of freshwater, among farmers as well as households. This statement is true despite reused water's potential to reduce fertilizer costs and promote higher yields (Benabdallah 2003). In MNA, many people remain suspicious of reuse since they are uncertain about the quality of the water (WHO 2005). The availability of untreated wastewater free of charge may make it difficult to convince irrigators to pay anything for reclaimed water that is not of high quality.

This distrust is apparent in Tunisia, for example, where, besides being well below cost, the price charged to farmers for reclaimed wastewater (0.02 US$ (2007)/m^3) reflects the lower demand for this water. Conventional water costs approximately 0.08US$ (2007)/m^3 (WHO 2005; Lahlou 2005; Shetty 2004). Similarly, in Syria and Yemen, recycled wastewater is provided free of charge to farmers (Bazza 2003 and Baquhaizel 2006).

Constraint #4: Under-Value Water Pricing

The fourth obstacle to the development of wastewater recycling is the fact that the prices of water tend not to reflect its scarcity value, especially in the agricultural sector. In fact, in no MNA country does the price of freshwater delivered to irrigators reflect even the cost of supply. The best that some countries (Morocco and Tunisia) do is to charge sufficient rates to cover O&M (Bucknall and others 2007; Bazza and others 2002). Most countries make no charge for or take no control of groundwater abstractions other than the private cost of pumping and the permitting process (Morocco, Palestine (Seibh 2003), Tunisia, and Yemen (Bassa 2003)).

Tariff structures for irrigation and other water vary substantially. In Israel, the block tariff designed to promote conservation among farmers charges only the full *average* cost of delivering water in the final block: the *average* cost of water supply is 0.29 US$ (2002)/m^3, corresponding to the final 20 percent of each farmer's allotment (Becker 2002).

Table 25.3 Prices for Irrigation Water in Select MNA Countries

	Irrigation water price *(US$/m^3)*			
Country	**Low**	**Average**	**High**	**Source**
Algeria		0.14		(Bazza 2002)]
Egypt				(Bazza 2002
Jordan	0.01	0.049	0.05	(Bazza 2002, Dinar 2004)
Morocco	0.02		0.053	(Bazza 2002
Syria		Annual fees		(Bazza 2002
Tunisia	0.025	0.066	0.08	(Bazza 2002, Dinar 2004)
Yemen		None		(Bazza 2002
Israel	0.18		0.29	Becker 2002
Cyprus		0.108		(Bazza 2002

Constraint #5: Wastewater Recycling in MNA Usually Requires an Indefinite Government Commitment to Provide Subsidies

We have seen that freshwater is sold at below cost, that recycled water costs more to produce than freshwater, and that recycled water is seen by users as inferior to freshwater.

In addition, households (HH) do not directly perceive the environmental benefit of wastewater treatment. So long as wastewater is collected and conveyed away from urban areas, householders consider that their service is adequate. Governments therefore find it easier to collect fees for connection and wastewater service than for eventual treatment. On the agricultural side, the seasonal nature of demand for irrigation water does not match the year-round supply of wastewater.

Thus, it often is impossible for governments or utilities to recover the financial cost of additional treatment or distribution (typically 0.05–0.25 US$/m^3, depending on the chosen level of additional treatment), let alone full treatment. Regulatory and monitoring costs also must be acknowledged.

For all of these reasons, wastewater recycling in MNA usually requires a long-term government commitment to provide subsidies. Only with very widespread pricing and sector reform will there be any possibility of self-financing wastewater recovery investments.

MNA Opportunities and Innovations

Despite these obstacles, *some countries have moved aggressively to promote wastewater reuse*. In *Israel, Jordan, and Tunisia*, each country has taken a slightly different path, but they also are similar in important ways.

MNA Experience #1. Reuse in Israel: Centralized Government Control and Technological Promotion

One of the best-documented and analyzed experiences of wastewater reuse is that of Israel, where much innovation has taken place, particularly over the past three decades.

Reuse proved a politically attractive means of increasing water supply. The severe drought of 1990–91 brought dramatic cuts in freshwater allocations to agriculture. Consequently, it also stimulated the start of major increases in wastewater reuse (Shelef 1996) as government sought to postpone costly desalination projects (Becker 2002).

Today, Israel has some 400 wastewater reuse projects, mostly highly subsidized (Libhaler 2007). Examples are the Dan Region Project (irrigating 16,000 ha with 120 mcm/yr of effluents from Tel Aviv) and the Jezreel Valley Project (reuse of 20 mcm/yr of high quality effluents from the Haifa area) (Shelef 1994; Hidalgo 2004; and Friedler 1999).

As late as 2002, the state subsidized approximately 60 percent of infrastructure costs of reuse wastewater projects. Economists and the Finance Ministry in Israel long have pushed for pricing reforms and more extensive demand management, although with little success due to opposition from the agriculture sector (Becker 2002; Feitelson 2005; Menahem 1998; and Mizrahi 2004).

The institutional organization of the water sector in Israel has played a critical role in allowing for the development of reuse. The

Water Commission wields enormous power over water resources and strictly limits irrigators' withdrawals. Israel has no private wells; all such infrastructure belongs to the government. The Water Commission has full control over the planning of storage basins and other needed infrastructure. Within the zones that use reclaimed wastewater, irrigators have no alternative water source for irrigation. The price they pay for this water is only somewhat reduced (roughly 20 percent lower) from that of National Water Carrier water (Libhaber 2007). This governance structure largely solves problems of reduced demand while ensuring a regular supply of water.

Another aspect that distinguishes Israel from most MNA countries is the fact that, for years, the proportion of collected wastewater that is treated has been relatively high (nearing 80 percent). Municipalities are responsible for financing this compulsory treatment, and are expected to treat wastewater to meet national standards. Approximately 6 percent of the remaining wastewater is disposed of on site in central septic tank systems. The remaining 15 percent receives no treatment.

The fact that secondary treatment is so widespread greatly expands opportunities for reuse. In 1996 Israel had nearly 500 treatment plants, most of which were oxidation ponds (77 percent) or mechanical biological systems (14 percent) (Shelef 1996). A third type is the "Third Line" conveyance and distribution system, so called because it was the third major water artery linking the center of Israel to the arid south. The Third Line enables a supply of soil-aquifer treated (tertiary) reclaimed wastewater to reach southern Israel, thus lowering the infrastructure burden for new projects. Other infrastructure financed with government assistance includes small water conduits and sequential storage reservoirs or aquifer recharge systems that enable additional polishing treatment as well as regularization of water supply to irrigators (Juanico 2004).

The country's long history of reuse has enabled it to develop national expertise. As early as 1953, *Israel drafted the world's first set of standards for wastewater reuse*, which have continued to evolve to reflect the latest scientific findings on microbiological and chemical risks (Tal 2006). During the 1970s, a major health effects study in 81 agricultural communities was carried out (Fattal 1981). Through this experience, Israel has largely perfected the use of simple technologies for reuse (oxidation ponds, soil-aquifer treatment, simple storage schemes) (Juanico 2004; Libhaber 1987).

Recirculation of water in oxidation pond systems has lessened odor problems (Shelef 1994). Water scarcity and tight quotas have pushed irrigators to adopt highly conserving technologies such as underground drip irrigation schemes, which also reduce salinity risks (Feitelson 2005; Oron 1998).

The microbiological and nutrient composition of treated wastewater is satisfactory in Israel and generally within the WHO norms for unrestricted reuse. Nevertheless, some technical concerns remain. As in other water-scarce countries, Israel has a substantial risk of long-term salinization of groundwater. Wastewater becomes more saline during municipal use and treatment. This concern has led to expanding research on developing more salinity-tolerant crops.

The Dan Region treatment plant faces additional maintenance costs (for application of chlorine-based compounds) due to periodic bio-fouling of effluent pipelines. Bio-fouling also has proven to be a problem in Jordan, as it significantly increases energy needs for pumping (McCornick 2004; Icekson-Tal 2003). Nevertheless, Israel's experience in wastewater reuse shows that the technical concerns associated with this management strategy generally can be addressed, although at a high cost.

Experience #2. Reuse in Jordan: Flexible Policy Framework Coping with Rapid Demographic Change and Increasing Water Scarcity

Jordan's foray into the development of wastewater reuse capacity has been motivated by ever-tighter freshwater supplies (approximately 150 m^3/capita/yr) (FAO 2006), combined with a degradation in the quality of groundwater sources. Indeed, Jordan is one of the most water-deprived countries in the MNA region, and has some of the highest groundwater depletion rates, valued at 2.1 percent of GDP (Bucknall and others 2006). Agriculture has partially adapted to water scarcity: 62 percent of irrigated lands today use drip irrigation methods (Khouzam 2003). Few good options for augmenting water supply remain. Recent projects have been the Al Wahda dam, begun in 2004; construction of the costly $600 million Disi-Amman aqueduct; and desalination works on the Red Sea (Henry 2005). The government is privatizing the operation of municipal water utilities to cut down on high unaccounted-for-water ratios (50 percent nationwide) (Quna 2006).

However, water policy is somewhat inconsistent with agricultural policy. Master plans continue to discuss and present options for expanding irrigation and investing in costly conveyance infrastructures. Furthermore, even as water supplies become tighter, there is no consideration of options to discourage the irrigation of water-intensive crops (banana and citrus, which consume 35 percent and 21 percent, respectively, of JV irrigation water) (McCornick and others 2001b; 2001a).

Well-defined policy, standards, and institutional structures governing reuse exist in Jordan (McCornick and others 2001b; Baquhaizel 2006; and Nazzal and others 2000). However, its experience is different from Israel's in that most reuse projects have been much less strictly regulated and planned. Reclaimed wastewater accounts for nearly 10 percent of the total water supply in Jordan, which is only slightly lower than the percentage in Israel.

McCornick and others (2001a) describe three categories of reuse in Jordan: (1) planned direct use within or adjacent to wastewater treatment plants, (2) unplanned reuse in wadis, and (c) indirect reuse after mixing with surface water supplies (mainly in the Jordan Valley).

Projects in the first category—planned direct reuse—generally are under the jurisdiction of the authority responsible for wastewater treatment plants, the Water Authority of Jordan (WAJ). With strong government support, WAJ has made a strong effort to reuse wastewater from all treatment plants, although much of the reuse remains indirect.

Farmers involved in direct reuse have special contracts with the WAJ formalizing their rights to effluents. In addition, the National Wastewater Management Policy requires that prices cover at least O&M costs of delivery (McCornick and others 2001a), but not treatment or collection. Some projects supply private enterprises (such as the date palm plantations near the Aqaba treatment plant). A few are experimental pilot projects cosponsored by international donors such as USAID. In most of these direct reuse projects, users have no alternative water supply besides reclaimed wastewater (McCornick 2007).

The second and third categories stem from mixing wastewater discharged into streams that either is first treated (indirect reuse); or not collected in sewers; or collected but not treated (unplanned reuse). In some streams (most notably the Wadi Zarqa near Amman), overpumping of groundwater and decreased flow from natural springs has led to indirect and unplanned reuse water becoming an important and reliable augmenter of base flows. As a result, farmers in these zones have increased irrigation and pay little more than the costs of pumping river water to their fields. After receiving seasonal contributions from runoff, and treated effluents from the Khirbet As-Samra plant (Amman's treatment works), the Wadi Zarqa flows into the King Talal Reservoir. King Talal water is then mixed into the King Abdullah Canal, which supplies irrigation water to the southern Jordan Valley.

Upstream of the King Talal reservoir, the Ministry of Health and WAJ enforce agricultural restrictions based on reuse standards wherever possible. These authorities use fines, destroy irrigation lands, or impose restrictions as necessary. Once in the King Abdullah canal, however, the water is no longer legally considered reclaimed and can be used without restrictions (McCornick and others 2001). McCornick states that indirect reuse will continue to dominate since demand for water in the Jordan Valley is generally greater than the supply of treated wastewater.

The steady evolution of the wastewater policy framework suggests that *flexibility and the ability to accommodate pressures for change have been useful in Jordan's experience* (Nazzai 2001). Standards are regularly reassessed, with contributions from technical experts, government agencies, the Jordan Valley Authority (JVA), and the WAJ. Standards governing reuse have moved through four iterations, from those of the original WAJ (enacted in 1988) to updated versions of standards for the Discharge of Treated Domestic Wastewater (893/1995 and 893/2003) (McCornick and others 2001a) (Nazzai 2001).

Jordan's water standards are adapted to the needs of a severely water-constrained nation. The wastewater management policy of 1998 emphasizes such assertions as:

1. "Wastewater shall not be disposed of, instead it shall be a part of the water budget"
2. "There shall be basin-wide planning for wastewater reuse"
3. "Fees for wastewater treatment may be collected from those who use the water." (Nazzal and others 2000).

All three of these policy statements are unique and innovative in the region. Although the government has not achieved full success in implementing them, they represent a different way of thinking about wastewater reuse policy. Jordan also has extensive research on regional reuse planning in MNA, as evidenced in master plans and the general literature (McCornick and others 2001b; Al-Jayyousi 1995).

The role that the As Samra plant (30 km from Amman) plays in Jordan's reuse experience deserves special mention. It demonstrates both the potential and the hazards of the Jordanian management approach. The plant is very large. In 2000, prior to the much needed expansion, it consisted of 32 ponds sitting on 200 ha. It processed approximately 55 mcm of wastewater each year, corresponding to approximately 75 percent of the country's annual reclaimed wastewater (Nazzal and others 2000). The secondary-treated effluent flows into the Wadi Zarqa and then to the King Talal Reservoir. An expanding treatment plant also represents a potential gain for irrigators, who are willing to use reclaimed wastewater even as they lose rights to other sources of freshwater.

However, the potential of using Amman wastewater to meet these demands must be considered carefully. In 1996 Shatanawi and Fayyad showed that the massive amount of wastewater released from As Samra into surface water bodies created major salinity threats during the dry summer season. Moreover, overloading the plant (which was designed to handle a mere 25 mcm/year) or poor operation (also pointed out by Bazza 2003) led to concerns over the quality of treated effluent. McCornick and others 2001b) state that fecal coliform counts exceed Jordanian standards 1 month in 4. As a result, confidence in the safety of recycled water among the general population, farmers, and agricultural exporters has suffered (Pasch 2005).

Others suggest that the plant design itself may have been inadequate, due to a delayed awareness of low per capita water use in Amman and the resulting concentrated nature of its wastewater (Nazzal 2001). A third set of critics has emphasized what it perceives as a dangerous change in balance between natural and effluent flows in the Wadi Zarqa and King Talal Reservoir (Mrayyan 2005).

Jordan's development of wastewater reuse demonstrates that wastewater reuse has great potential in highly water-scarce areas; but that reuse planning must be integrated coherently with water resource planning, environmental management, and financing arrangements.

Experience #3. Tunisia: Partial Steps, Experiments, and Commitment to Reuse

Tunisian reuse policy has been tentative. Many experts state that there is strong government support for using treated wastewater in agriculture (Bahri 1996; Benabdallah 2003; Shetty 2004; and Bahri 2007), but this support has not translated into widespread reuse. Most analyses have focused on the social constraints to the use of recycled water in Tunisia. The logical question to ask is: What makes Tunisia different from Jordan and Israel such that lower demand becomes an obstacle to reuse?

The differences between Tunisia and the other two countries appear to stem from two key factors, which are interrelated and important when considering reuse in the MNA region as a whole.

First, despite the fact that Tunisia is considered to be in water deficit, this country has much more renewable freshwater per capita (450 m^3/yr) than does either Israel (250 m^3/yr) or Jordan (150 m^3/yr) (FAO 2006). Indeed, of the three countries, only Tunisia's per capita water withdrawals are less than its available renewable freshwater. In 2002 Tunisian withdrawals were roughly 58 percent of renewable resources, whereas Israel and Jordan were at 122 percent and 116 percent, respectively.[2]

Second, as a consequence of the wider availability of alternative water sources, irrigators and other users have many more choices about which type of water to use. Specifically, in distinct contrast to Israel and Jordan, in Tunisia reclaimed wastewater has not been mixed into or replaced alternative sources of freshwater. Recall that in Israel, this mixing occurs via controlled aquifer recharge, and in Jordan via mostly planned disposal into surface water bodies. As a result, in Tunisia, irrigators' (as well as other users') demand for reclaimed wastewater becomes vital for the success of reuse projects.

There is ample evidence that Tunisian farmers prefer not to use reclaimed water. In many cases, irrigators continue to use groundwater after large efforts have made reclaimed wastewater available to them. Shetty (2004) details a number of problems of social acceptance, regulations concerning crop choices, and other agronomic considerations that affect these decisions. Farmers in the arid south express concerns about the long-term impacts of *saline wastewater* on their crops and soils. Such problems have been documented around the city of Moknine, where compensation for farmers' damages today is provided through the delivery of free surface water from the Nebhana dam.

There also appears to be a general inability to match the timing of supply and demand for the water due to inadequate storage of treated effluents. The reliability problems associated with reuse erode the confidence of farmers who would like timely irrigation water. Perhaps most importantly, the fact that reclaimed water cannot be used for

---

[2] These percentages have probably increased somewhat since then.

high-value vegetable crops is discouraging to nearly half of all eligible farmers (Bahri 1996 and 2002).

In response to the reluctance to use wastewater, a 1997 presidential decree set the price of treated wastewater (0.01 US$/m^3, down from 0.03–0.07 US$/m^3) well below that of other freshwater (0.08 US$/m^3). Even so, the use of reclaimed wastewater has hardly changed (Shetty 2004 and Bahri 2007). Surveys also have shown that the demand for reclaimed wastewater is insensitive to price in a range between 0.01 and 0.04 US$ (1998)/m^3, the previous average rate (Bahri 1996).

Tunisia's geography creates an economic alternative to recycling. Most wastewater facilities in Tunisia are near the population centers along the Mediterranean coast, so effluents can be disposed of relatively easily in the sea after secondary treatment. From a wastewater management perspective, dumping effluents from existing treatment plants into the sea rather than in surface waters or on lands (where demand for reuse is low) has always been the simplest solution. It also may be the most economic one, in contrast to Israel and Jordan, in which water is already insufficient to meet existing demands.

The planning of irrigation with reused water in Tunisia has not been sufficiently coordinated or demand driven. Some 7300 ha are equipped for wastewater reuse (Atiri 2005), but only a fraction of these lands actually receives treated effluents (Bahri 1996; Madi 2002). *As a result, the predicted economic benefits from projects have not been realized*. In one particularly poorly coordinated project, supply to a reuse scheme was interrupted just as it was scheduled to go into operation due to an upgrade of the associated treatment plant (Boubaker 2007). Conscious of these issues, *Tunisian planners are starting to pay more attention to demand issues* (Bahri 2007).

Despite these many problems, consumption of reclaimed wastewater has increased substantially. Consumption grew from approximately 4 mcm to 18 mcm between 1996 and 2002, with annual increases of 23 percent, 3 percent, 19 percent, and 41 percent between 1999 and 2002 (Atiri 2005).

Restrictions for reuse designed to protect public health have received considerable attention and are in line with WHO recommendations. There have long been a large number of reuse schemes throughout the country. Some projects such as La Soukra—irrigation of citrus orchards—have enjoyed longstanding success and few demand problems (the unavailability of alternative sources is probably a factor). In areas along the northern coast with saltwater intrusion problems (Borj

Touil District), resistance to using reclaimed water for irrigation has been relatively low despite higher-than-average rainfall (600 mm/yr) due to the lack of reliable alternative water sources (Shetty 2004), In addition, the country is involved in experiments to promote technical innovation. Tunisia is investigating shallow groundwater recharge, urban beautification and recreation applications, and the improvement of crop yields (notably, olive trees and fodder) by using high-quality, stored, reclaimed water (Benabdallah 2003; Bahri 2002).

Finally, and perhaps most importantly, as in Jordan and Israel, Tunisian policymakers today treat reuse as an essential aspect of strategic water and wastewater sector planning, influencing such decisions as the location of wastewater treatment plants (Bahri 1998).

Lessons Learned

Based on the set of experiences with reclaimed wastewater reviewed in this chapter and the constraints described above, it is possible to draw attention to key messages that should be helpful in advancing the reuse agenda in MNA:

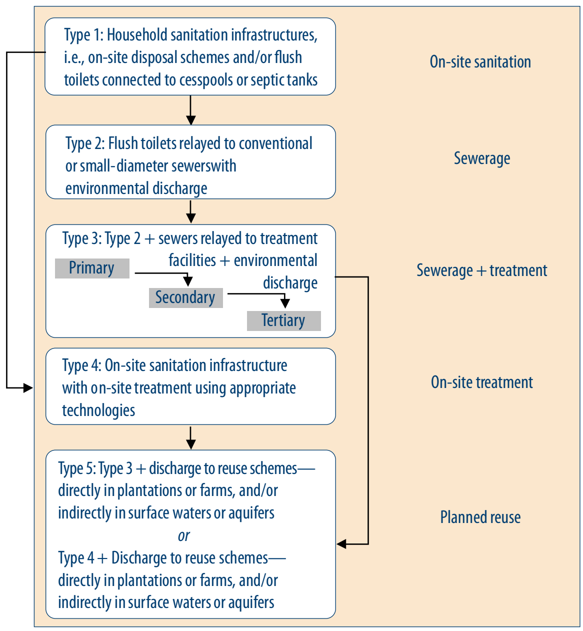
1. The countries that have expanded reuse most are those that ***explicitly consider reuse opportunities as part of the planning of wastewater collection and treatment projects***.
2. ***The state of wastewater collection and treatment is a critical issue in evaluating the economics of reuse projects***. Countries or sites with little or poorly functioning wastewater collection and treatment infrastructure will find it impossible to justify investments in reuse (figure 25.1).
3. ***If there are alternative water sources, users usually will prefer them to recycled water***. If irrigators' or other users' access to conventional sources of water is not restricted and water prices do not reflect costs of water delivery and resource scarcity, it generally will be be difficult for reuse applications to be competitive, unless conventional sources become overly degraded.
4. ***MNA countries in general lack* demand-driven *planning of reuse projects***. Too often, reuse projects are high-level decisions made by well-meaning governments, water sector institutions, and/or the international donor community that do not incorporate the preferences of future users.

5. Thus far, ***pilot projects have been useful in solving many technical issues. However, they offer little help with scaling-up and strategic planning***. This history of nonreplication is due largely to the lack of sustainability of pilot projects, the difficulty of interpreting costs and other management data related to pilot efforts, and/or the low demand for the water.

Recommendations

Given these key messages, five recommendations for the MNA water reuse agenda emerge:

Figure 25.1 Recommended Steps in Wastewater Infrastructure Development



1. **Implement reuse projects for which *known demand exists* for treated wastewater effluents**, rather than attempt to generate demand once a reuse site has been identified.
2. **Develop sustainable financing models**. If a project is deemed economically feasible, careful consideration of the financial deal structure becomes necessary. Even under the most promising conditions, full cost recovery in reuse is unlikely, so some combination of subsidies and consumer payments may be necessary.
3. **Consider reuse within an over-arching policy model designed to address water scarcity**, not as an adjunct to wastewater treatment. The benefits of reuse alone rarely will justify the costs of wastewater treatment.
4. **Target reducing freshwater withdrawals**. Demand management and water conservation strategies clearly are the most cost-effective approaches to reduce withdrawals. Investment in national water reuse strategies is difficult to justify if water allocations and demands are not effectively regulated.
5. **Address institutional problems**. Reuse must be considered via concerted discussion between water supply and sanitation agencies,

implying that governance at a higher, coordinating level will be necessary.

Conclusions

This chapter sets out to answer three questions related to wastewater reuse in the Middle East and North Africa region:

1. Given the scarcity of water, why have many governments been slow in promoting wastewater reuse?
2. What insights for the future of wastewater reuse can be gleaned from regional and international experiences?
3. How should policymakers adapt the wastewater management agenda to their country's economic context?

Although the answers to these questions have not been fully resolved, important insights emerge from this study:

1. Many constraints to more widespread reuse
2. Insufficient economic analysis of reuse and treatment options
3. Generally high costs and negative or low rates of return associated with wastewater treatment
4. Preference for freshwater
5. Lack of effective price signals
6. Difficulties in structuring financial deals, and inherent limitations in the amount of water that can be used.

For reuse to make sense, it must be part of a larger water strategy that includes demand management and conservation strategies, and that *treats water as a scarce and valuable economic resource*. In most MNA countries, irrigation schemes are inefficient; groundwater is over-pumped; and surface water resources are poorly managed. Such conditions eliminate the potential economic benefits of reuse.

Meanwhile, population growth and urbanization are increasing the demand for domestic water and the production of wastewater. Climate change will reduce the amount of renewable freshwater resources in MNA. Trade networks, increasing tourism, and the preferences of a more educated urban populace and neighboring countries will affect plans for wastewater treatment, increase the demand for safe and high-value agricultural products grown in the region, and encourage ecological and recreational uses of water.

As countries face these evolving challenges, they will become more and more focused on reforming their water management systems and institutions, and will likely devote more attention to evaluating the option of reuse. For the time being, the constraints in the sector make it unlikely that a reuse revolution in MNA is imminent. However, the importance of this policy option surely will increase over time.

Appendix 25.1 Sewerage and Wastewater Treatment in MNA and Other Selected Countries

Country	Sewerage rate (%) Urban	Sewerage rate (%) Over-all	Treatment rate (% collected)	Volume treated (mcm/yr)	Type of treatment	Notes
Algeria	78–85	65	73	600 1	Secondary	Mostly lagoons
Bahrain	70–77		100	44.9	Secondary	Activated sludge, some tertiary (ozone)
Djibouti	5	4	0	0	None	None
Egypt	68	42	79	2971	19% primary; secondary	Activated sludge, ponds, trickling filters
Iran	17–20	11	4	130		
Jordan	70	50	88	72	Secondary	Lagoons and activated sludge; overloading frequent
Kuwait		85	87	103	Tertiary	
Lebanon		40	2	4	Secondary	Planning treatment and reuse around Beirut and Ba'albeck treatment plant (tertiary)
Libya	54	54	7	40		
Morocco	70	40	6–8	40	Secondary	Effluents/raw sewage mostly discharged to sea and surface waters
Oman	90	81	13	9.8	Secondary	Activated sludge, aerated ponds
Qatar		80		43		
Saudi Arabia	45	37	75	548	Secondary	Activated sludge, aerated ponds
Syria	96	71	57–67	550	Secondary	Activated sludge, lagoons Significant dumping of untreated waste; Damascus upgrade for reuse of tertiary-treated effluents
Tunisia	68	50	79	148	Secondary	Mostly activated sludge, ponds; moving to tertiary
UAE	91	87	22	193	Secondary; tertiary	
West Bank and Gaza	25	23	34–54	14–24	Primary; secondary	Sludge drying beds, ponds, frequent overloading, O&M problems
Yemen	40	12	62	46	Secondary	Ponds, frequent overloading
Israel		92–95	79	296	Secondary; some tertiary	Ponds, activated sludge, natural filtration + recharge
Cyprus	73	60	100	6	Mostly tertiary	
Malta		95	13	2.5	Secondary; some tertiary	Piloting RO to promote industrial reuse

References

Ahmad, S. 1991. "Public Attitude towards Water and Water Reuse." *Water Science and Technology* 23 (10–12): 2165–70.

Al–Dadah, J.Y. 2003. "Socioeconomic Aspects of Wastewater Reuse in the Gaza Strip." In *First Mediterranean Network on Wastewater Reclamation and Reuse*. Izmir, Turkey: Ege University.

Alhumoud, J., H. Behbehani, and T. Abdullah. 2003. "Wastewater Reuse Practices in Kuwait." *The Environmentalist* 23 (2): 117–26.

Ali, S. 2004. Project Information Document: North Gaza Emergency Sewage Treatment Project. Palestinian Water Authority and World Bank, Gaza.

Al–Jayyousi, O.R. 1995. "An Analysis of Future Water Policies in Jordan: Using Decision Support Systems." *International Journal of Water Resources Development* 11(3): 315–30.

Almadani, A. 2006. "Wastewater Reuse in Agriculture in the Kingdom of Bahrain." In Regional Workshop on Health Aspects of Wastewater Reuse in Agriculture, WHO, Amman.

Al-Wahaibi, S., and N. Al-Hasni. Country Presentation: Oman. In Regional Workshop on Health Aspects of Wastewater Reuse in Agriculture, WHO, Amman.

Amami, H.E., D. Natsoulis, and D. Xanthoulis. 2005. *Evaluation économique du traitement des eaux usées traitées par épuvalisation*. In *Réutilisation des eaux usées traitées et des sous-produits de l'épuration : Optimisation, Valorisation et Durabilité*. Tunis: l'Institut National de Recherche en Génie Rural, Eaux et Forêts.

Angelakis, A., M. Marecos Do Monte, L. Bontoux, and T. Asano. 1999. "The Status of Wastewater Reuse Practice in the Mediterranean Basin: Need for Guidelines. *Water Research* 33 (10): 2201–17.

Asano, T., F. Burton, H. Leverenz, R. Tsuchihashi, and G. Tchobanoglous. 2007. *Water Reuse: Issues, Technologies, and Applications*, ed. M. Eddy. New York: McGraw Hill.

Ashley, R.M., N. Souter, and S. Hendry. 2001. "The Importance of Public Attitudes and Behaviour for the Management of Urban Water Systems." In *Frontiers in Urban Water Management: Deadlock or Hope?* Marseille: IWA Publishing.

Atallah, S., M. Khan, and M. Malkawi. 1999. "Water Conservation through Islamic Public Awareness in the Eastern Mediterranean Region." *Eastern Mediterranean Health Journal* 5 (4): 785–97.

Atiri, R.A., N. Gharbi, and S. Dkhil. 2005. *"Evaluation de l'exploitation des périmètres irrigués à partir des eaux usées traitées."* In *Réutilisation des eaux usées traitées et des sous-produits de l'épuration : Optimisation, Valorisation et Durabilité*. Tunis: Institut National de Recherche en Génie Rural, Eaux et Forêts.

Bahri, A., and F. Brissaud. 1996. "Wastewater Reuse in Tunisia: Assessing a National Policy." *Water Science and Technology* 33 (10–11): 87–94.

Bahri, A. 2002. "Water Reuse in Tunisia: Stakes and Prospects." In *Vers une maîtrise des impacts environnementaux de l'irrigation: Atelier du PCSI*. Montpellier, France: CEMAGREF, CIRAD, IRD, Cédérom du CIRAD.

Bahri, A., C. Basset, F. Oueslati, and F. Brissaud. 2001. "Reuse of Reclaimed Wastewater for Golf Course Irrigation in Tunisia." *Water Science and Technology* 43 (10): 117–24.

Bahri, A. 2007. Conference call, ed. M.J.a.C. Kfouri. Washington, DC.

____. 1998. "Wastewater Reclamation and Reuse in Tunisia." In *Wastewater Reclamation and Reuse*, ed. T. Asano. Lancaster, PA: Technomic Publishing.

Bank, W. 2000. "Comprehensive Development Review, Yemen: Building Block on Urbanization." World Bank.

Baquhaizel, S., and A.S. Mlkat. 2006. "Wastewater Management and Reuse in the Republic of Yemen." In Regional Workshop on Health Aspects of Wastewater Reuse in Agriculture, WHO, Amman.

Bazza, M., and M. Ahmad. 2002. "A Comparative Assessment of Links between Irrigation Water Pricing and Irrigation Performance in the Near East." In *Irrigation Water Policies: Micro and Macro Considerations*. Agadir, Morocco: FAO.

____. 2003. "Wastewater Recycling and Reuse in the Near East Region: Experience and Issues." *Water Science and Technology: Water Supply* 3 (4): 33–50.

Becker, N.I.R. 2002. "The Effect and Reform of Water Pricing: The Israeli Experience." *International Journal of Water Resources Development* 18 (2): 353–66.

Benabdallah, S. 2003. *"La réutilisation des eaux usées traitées en Tunisie." Etudes et rapports d'expertise* II.

Boubaker, A. 2007. *"Evaluation participative du PISEAU: Synthese des resultats."* Projet d'Investissement dans le Secteur de l'Eau (PISEAU).

Brenner, A., S. Shandalov, R. Messalem, A. Yakirevich, G. Oron, and M. Rebhun. 2000. "Wastewater Reclamation for Agricultural Reuse in Israel: Trends and Experimental Results." *Water, Air, and Soil Pollution* 123 (1): 167–82.

Bucknall, J., A. Kremer, T. Allan, J. Berkoff, N. Abu-Ata, M. Jarosewich-Holder, U. Deichmann, S. Dasgupta, R. Bouhamidi, and V. Ipe, *Making the Most of Scarcity: Accountability for Better Water Management in the Middle East*. World Bank.

Chenini, F., D. Xanthoulis, and B. Soudi. 2005. *Réutilisation des eaux usées traitées et des sous-produits de l'épuration : Optimisation, Valorisation et Durabilité*. Tunis: Institut National de Recherche en Génie Rural, Eaux et Forêts

Chesrown, S. 2004. Jordan Valley Preliminary Land Use Master Plan Project Final Land Use Report. Jordan Valley Authority (JVA), The Hashemite Kingdom of Jordan, Chemonics International, and USAID, Amman. Vol. 1 of 5.

Choukr-Allah, R. 2004. "Wastewater Treatment and Reuse in Morocco: Situation and Perspectives." In Third Water Saving in Mediterranean Agriculture (WASAMED) Workshop, Cairo.

Darwish, M., F. El-Awar, M. Sharara, and B. Hamdar. 1999. "Economic-Environmental Approach for Optimum Wastewater Utilization in Irrigation: A Case Study in Lebanon." *Applied Engineering in Agriculture* 15 (1): 41–48.

Darwish, M. 2001. "On Electric Power and Desalted Water Production in Kuwait." *Desalination* 138 (1): 183–90.

DATEX. 1997. *Feasibility Study for Wastewater Reuse Scheme for Nuweiba*. USAID: Cairo.

DeSena, M. 1998. "Public Opposition Sidelines Indirect Potable Reuse Projects." *Water Environment and Techology* 11 (5): 16–18.

Dinar, A., and J. Mody 2004. "Irrigation Water Management Policies: Allocation and Pricing Principles and Implementation Experience." *Natural Resources Forum* 28 (2): 112–22.

Dolnicar, S., and C. Saunders. 2006. "Recycled Water for Consumer Markets: A Marketing Research Review and Agenda." *Desalination* 187 (1–3): 203–14.

El-Gohary, F, F. Nasr, and S. El-Hawaary. 1998. "Performance Assessment of a Wastewater Treatment Plant Producing Effluent for Irrigation in Egypt." *The Environmentalist* 18 (2): 87–93.

FAO (UN Food and Agriculture Organization). 2006. AQUASTAT database. www.fao.org/ag/agl/aglw/aquastat/dbase/index.stm. Rome.

____. 2006. "Compendium of Food and Agriculture Indicators." Rome. www.fao.org/statistics/compendium_2006/default.as2006

____. 2003. *"L'irrigation avec des eaux usees traitees : Manuel d'utilisation."* ed. B.R.l.–o.e.B.s.–r.l.A.d. Nord. Rome.

Fatta, D., M. Al-Rusan, K. Hameed, C. Gokcay, S. Anayiotou, and M. Loizidou. 2004. "The Operation of Urban Wastewater Treatment Plants and the Reuse Practices in the Mediterranean Countries: The Medaware Project." In INCO–MED Water Conference, MEDAQUA II, Amman.

Fatta, D., Z. Salem, M. Mountadar, O. Assobhei, and M. Loizidou. 2004. "Urban Wastewater Treatment and Reclamation for Agricultural Irrigation: The Situation in Morocco and Palestine." *The Environmentalist* 24 (4): 227–36.

Fattal, B. and others. 1981. *Developments in Arid Zone Ecology and Environmental Quality*. Philadelphia: Balaban.

Fedler, J. 2002. "Israel's Agriculture in the 21st Century." Ministry of Foreign Affairs, Jerusalem.

Feitelson, E. 2005. "Political Economy of Groundwater Exploitation: The Israeli Case." *International Journal of Water Resources Development* 21 (3): 413–23.

Friedler, E., and O. Lahav. 2006. "Centralised Urban Wastewater Reuse: What Is the Public Attitude?" *Water Science and Technology* 54 (6–7): 423–30.

Friedler, E., O. Lahav, H. Jizhaki, and T. Lahav. 2006. "Study of Urban Population Attitudes towards Various Wastewater Reuse Options: Israel as a Case Study." *Journal of Environmental Management* 81(4): 360–70.

Friedler, E. 1999. "The Jeezrael Valley Project for Wastewater Reclamation and Reuse, Israel." *Water Science and Technology* 40 (4): 347–54.

Gibson, H.E., and N. Apostolidis. 2001. "Demonstration: The Solution to Successful Community Acceptance of Water Recycling." *Water Science and Technology* 43 (10): 259–66.

Hafez, A., and S. El–Manharawy. 2003. "Economics of Seawater RO Desalination in the Red Sea Region, Egypt. Part 1. A Case Study." *Desalination* 153 (1): 335ff.

Hartling, E.C. 2001. "Laymanization: An Engineer's Guide to Public Relations." *Water Environment and Technology* (April): 45–48.

Haruvy, N. 1997. "Agricultural Reuse of Wastewater: Nation-Wide Cost-Benefit Analysis." *Agriculture, Ecosystems and Environment* 66 (2): 113–19.

Haruvy, N., S. Shalhevet, and I. Ravina. 2003. "Financial and Managerial Analysis of Irrigation with Treated Wastewater in Israel." *Journal of Financial Management and Analysis* 16 (2): 65–73.

Hendy, S.M.H. 2006. "Wastewater Management and Reuse in Egypt." In "Regional Workshop on Health Aspects of Wastewater Reuse in Agriculture," WHO, Amman.

Henry, B. 2005. "*Gestion de la demande en eau en Méditerranée: Identification et caractérisation des actions d'information/sensibilisation/formation/participation*." Jordan.

Hidalgo, D., and R. Irusta. 2004. "The Cost of Wastewater Reclamation and Reuse in Agricultural Production in the Mediterranean Countries."

Hoehn, J., and D. Krieger. 2000. "An Economic Analysis of Water and Wastewater Investments in Cairo, Egypt." *Evaluation Review* 24 (6): 579.

Hussain, I., L. Raschid, M. Hanjra, F. Marikar, and W. van der Hoek. 2001. "A Framework for Analyzing Socioeconomic, Health and Environmental Impacts of Wastewater Use in Agriculture in Developing Countries." Working Paper Series. Colombo: International Water Management Institute.

Hussain, I., L. Raschid, M.A. Hanjra, F. Marikar, and W.v.d. Hoek. 2002. "Wastewater Use in Agriculture: Review of Impacts and Methodological Issues in Valuing Impacts." Working Paper Series. Colombo: International Water Management Institute.

Icekson-Tal, N., O. Avraham, J. Sack, and H. Cikurel. 2003. "Water Reuse in Israel—the Dan Region Project: Evaluation of Water Quality and Reliability of Plant's Operation." *Water Science and Technology: Water Supply* 3 (4): 231–37.

IPCC (International Panel on Climate Change). 2007. *The Physical Basis of Climate Change: Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK and New York, NY: Cambridge University Press.

Juanico, M., 1996. "The Performance of Batch Stabilization Reservoirs for Wastewater Treatment, Storage and Reuse in Israel." *Water Science and Technology* 33 (10–11): 149–59.

Juanico, M., and A. Milstein. 2004. "Semi-intensive Treatment Plants for Wastewater Reuse in Irrigation." *Water Science and Technology* 50 (2): 55–60.

Kaisi, A., Y. Mohamed, and Y. Mahrouseh. 2004. "Nonconventional Water Use in the Syrian Arab Republic." In Third Water Saving in Mediterranean Agriculture (WASAMED) Workshop, Cairo.

Kamizoulis, G., A. Bahri, F. Brissaud, and A. Angelakis. 2003. "Wastewater Recycling and Reuse Practices in Mediterranean Region: Recommended Guidelines."

Karaa, K., F. Karam, and N. Tarabey. 2004. "Wastewater Treatment and Reuse in Lebanon: Key Policies and Future Scenarios." In Third Third Water Saving in Mediterranean Agriculture (WASAMED) Workshop, Cairo.

Khateeb, N. 2001. "Sociocultural Acceptability of Wastewater Reuse in Palestine." In *Water Management in Islam,* ed. N. Faruqui, A. Biswas, and M. Bino. New York: United Nations University Press, 79–84.

Khouzam, R. 2003. "Economic Aspects of Wastewater Reuse Study Case: The Arab Nation." ERF Working Paper Series, Cairo.

____. 2003. "Economic Aspects of Wastewater Reuse: The Egyptian Case." ERF Working Paper Series, Cairo.

Kouraa, A., F. Fethi, A. Fahde, A. Lahlou, and N. Ouazzani. 2002. "Reuse of Urban Wastewater Treated by a Combined Stabilisation Pond System in Benslimane (Morocco)." *Urban Water* 4 (4): 373–78.

Kurukulasuriya, P., and R. Mendelsohn. 2006. "A Ricardian Analysis of the Economic Impact of Climate Change on African Cropland." In *Climate Change and Agriculture in Africa*. Pretoria: Centre for Environmental Economics and Policy in Africa.

____. 2006. "Endogenous Irrigation: The Impact of Climate Change on Farmers in Africa." In *Climate Change and Agriculture in Africa*. Pretoria: Centre for Environmental Economics and Policy in Africa.

Lahlou, A.A. 2005. 'Wastewater Reuse." In *Managing Water Demand: Policies, Practices and Lessons from the Middle East and North Africa*, ed. E. Baroudy, A. Lahlou, and B. Attia. London: IWA Publishing, 11–24.

Lawrence, P., S. Adham, and L. Barrott. 2002. "Ensuring Water Re–Use Projects Succeed: Institutional and Technical Issues for Treated Wastewater Re-Use." *Desalination* 152 (1): 291–98.

Lazarova, V., B. Levine, J. Sack, G. Cirelli, Jeffrey, H. Muntau, M. Salgot, and F. Brissaud. 2001. "Role of Water Reuse for Enhancing Integrated Water Management in Europe and Mediterranean Countries." *Water Science and Technology* 43(10): 25–33.

Lee, T., J.L. Oliver, F. Teneere, L. Traners, and W.F. Valiron. 2001. "Economics and Financial Aspects of Water Resources." In *Frontiers in Urban Water Management: Deadlock or Hope*. London: IWA Publishing.

Libhaber, M., and M. Michail. 1987. "Innovative Methods in Wastewater Treatment for Agricultural Reuse in Israel." In Water Reuse Symposium IV, Denver, CO.

Libhaber, M. 2007. Face-to-face meeting, M. Jeuland, ed. Washington, DC.

Lokiec, F. 2005. "South Israel 100 Mm^3/Year BOT Seawater Desalination Project." In International Forum on Water Industry. Qingdao: IDE Technologies Ltd.

Madi, M., and O. Braadbaart. 2002. "Willingness of Farmers to Pay for Reclaimed Wastewater in Jordan and Tunisia." *Water Recycling in the Mediterranean Region* 3 (4): 115–22.

Malkawi, H., and M. Mohammad. 2003. "Survival and Accumulation of Microorganisms in Soils Irrigated with Secondary Treated Wastewater." *Journal of Basic Microbiology* 43 (1): 47–55.

Mancy, K., B. Fattal, and S. Kelada. 2000. "Cultural Implications of Wastewater Reuse in Fish Farming in the Middle East." *Water Science and Technology* 42 (1): 235–39.

Mantovani, P., T. Asano, A. Chang, and D. Okun. 2001. "Management Practices for Nonpotable Water Reuse." Water Environment Research Foundation, Alexandria, VA.

Mantovani, P., A. Bakalian, X.C. de Beauchêne, M.L. Khrouf, A.L. Abid, F.W. Bolle, R. Soldansky, and M.A. Locussol. 2007. *"Revue Stratégique du Programme National d'Assainissement*." Draft for internal review. World Bank.

Massoud, M., and M. El–Fadel. 2002. "Economic Feasibility of Wastewater Reuse in Agriculture: A Case Study." In International Symposium on Environmental Pollution Control and Waste Management, Tunis.

McCornick, P.G., A. Hijazi, and B. Sheikh. 2004. "From Wastewater Reuse to Water Reclamation: Progression of Water Reuse Standards in Jordan." In *Wastewater Use in Irrigated Agriculture: Confronting the Livelihood and Environmental Realities*, ed. C. Scott, N. Faruqui, and L. Raschid. Colombo: CABI Publishing.

McCornick, P.G. 2007. E.t.M. Jeuland, ed. Chapel Hill, NC.

McCornick, P.G., N. Haddadin, H. Rashid, and R. Sabella. 2001a. "Options for Water Reuse in Wadi Zarqa and from Other

Amman–Zarqa Sources: Water Reuse Component." Ministry of Water and Irrigation, Jordan; USAID, Jordan and Vermont.

McCornick, P.G., N. Haddadin, and R. Sabella. 2001b. "Water Reuse Options in the Jordan Valley: Water Reuse Component." Ministry of Water and Irrigation, Jordan; USAID, Jordan and Vermont.

MEDAWARE. 2001. "Development of Tools and Guidelines for the Promotion of the Sustainable Urban Wastewater Treatment and Reuse in the Agricultural Production in the Mediterranean Countries." www.uest.gr/medaware/contact.htm

Menahem, G. 1998. "Policy Paradigms, Policy Networks and Water Policy in Israel." *Journal of Public Policy* 18 (03): 283–310.

Menegaki, A., N. Hanley, and K. Tsagarakis. 2007. "The Social Acceptability and Valuation of Recycled Water in Crete: A Study of Consumers' and Farmers' Attitudes." *Ecological Economics* 62 (1): 7–18.

Mizrahi, S. 2004. "The Political Economy of Water Policy in Israel: Theory and Practice." *Journal of Comparative Policy Analysis: Research and Practice* 6 (3): 275–90.

Mrayyan, B. 2005. "Optimal Utilization of Reclaimed Wastewater for Irrigation Purposes: Case of As-Samra Wastewater Treatment Plant." *Journal of Environmental Assessment Policy and Management* 7 (4): 735.

Najjar, M. 2006. "Wastewater Services, Effluent Reuse and Health Aspects (Jordan)." In Regional Workshop on Health Aspects of Wastewater Reuse in Agriculture, WHO, Amman.

Nazzal, Y., M. Mansour, M. Al Najjar, and P.G. McCornick. 2000. "Wastewater Reuse Law and Standards in the Kingdom of Jordan." Ministry of Water and Irrigation, Amman.

Oron, G. 1998. "Water Resources Management and Wastewater Reuse for Agriculture in Israel." In *Wastewater Reclamation and Reuse*, ed. T. Asano. Lancaster, PA: Technomic Publishing Company, 757–78.

Papaiacovou, I. 2001. "Case Study: Wastewater Reuse in Limassol as an Alternative Water Source." *Desalination* 138 (1): 55–59.

Pasch, J., and P. Macy. 2005. "Building Sustainable Wastewater Reuse in Jordan." *Water Supply* 5 (3–4): 17–25.

Pescod, M. 1992. "Wastewater Treatment and Use in Agriculture." FAO Irrigation and Drainage Paper.

Quna, S., L. Magiera, S. Nolte, S. Taha, and D. Bohnet. 2006. "Planning Jordan's Water Future Lessons Learnt from the Water Sector Planning

Support Project." Ministry of Water and Irrigation; Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), Amman.

Rashed, M., S. Awad, M. Salam, and E. Smidt. 1995. "Monitoring of Groundwater in Gabal el Asfar Wastewater Irrigated Area (Greater Cairo)." *Water Science and Technology* 32 (11): 163–69.

Sbeih, M. 1996. "Recycling of Treated Water in Palestine: Urgency, Obstacles and Experience to Date." *Desalination* 106 (1): 165–78.

Sbeih, M.Y. 2003. "Pricing the Irrigation Water in the Jordan Valley as a Means of Water Saving in Palestine. Consensus to Resolve Irrigation and Water Use Conflicts in the Euromediterranean Region. Proceedings ICID 20th European Regional Conference, Montpellier, France, 14–19 September 2003." ICID, New Delhi. www.icid.org

Scott, C., N. Faruqui, and L. Raschid-Sally. 2004. "Wastewater Use in Irrigated Agriculture: Confronting the Livelihood and Environmental Realities."CAB International (CABI), Colombo.

Schneider, S.H., H. Gleick, and L.O. Mearns. 1990. "Prospects for Climate Change." In *Climate Change and U.S. Water Resources*, ed. P.E. Waggoner. New York: John Wiley and Sons, 41–73.

SEMDE/EMWIS. 2005. "Water Supply, Sanitation and Sewage: Lebanon Country Report."

Shahalam, A., B. Abu Zahra, and A. Jaradat. 1998. "Wastewater Irrigation Effect on Soil, Crop and Environment: A Pilot Scale Study at Irbid, Jordan." *Water, Air, and Soil Pollution* 106 (3): 425–45.

Shatanawi, M., and M. Fayyad. 1996. "Effect of Khirbet As-Samra Treated Effluent on the Quality of Irrigation Water in the Central Jordan Valley." *Water Research* 30 (12): 2915–20.

Shatanawi, M., A. Al-Nabi, M. Daqqa, and S. Mazahreh. 2004. "Reclaimed Wastewater Treatment and Reuse in Jordan: Policy and Practices." In Third Water Saving in Mediterranean Agriculture (WASAMED) Workshop, Cairo.

Shelef, G. 1991. "Wastewater Reclamation and Water Resources Management." *Water Science and Technology* WSTED 4 24 (9).

Shelef, G., and Y. Azov. 1996. "The Coming Era of Intensive Wastewater Reuse in the Mediterranean Region." *Water Science and Technology* 33 (10–11): 115–25.

Shelef, G., Y. Azov, A. Kanarek, G. Zac, and A. Shaw. 1994. "The Dan Region Sewerage Wastewater Treatment and Reclamation Scheme." *Water Science and Technology* 30 (9): 229–38.

Shetty, S. 2004. "Treated Wastewater Use in Tunisia: Lessons Learned and the Road Ahead. In *Wastewater Use in Irrigated Agriculture:*

Confronting the Livelihood and Environmental Realities, ed. C. Scott, N. Faruqui, and L. Raschid-Sally. CAB International.

Sorour, M. 2005. "Treated Wastewater: Water Quality Standards and Regulations, International Experience." World Bank, Saudi Arabia.

Sturm, C., L. Ribbe, and C. Schwabe. 1996. "Water Resources Management in the West Bank." Berlin.

Tal, A. 2006. "Seeking Sustainability: Israel's Evolving Water Management Strategy." *Science* 313 (5790): 1081.

Tchobanoglous, G., and A. Angelakis. 1996. "Technologies for Wastewater Treatment Appropriate for Reuse: Potential for Applications in Greece." *Water Science and Technology* 33 (10): 15–24.

Trenberth, K.E., and others. 2003. "The Changing Character of Precipitation." "Bulletin of the American Meteorological Society" 84: 1205–17.

Tsagarakis, K., and N. Georgantzis. 2003. "The Role of Information on Farmers' Willingness to Use Recycled Water for Irrigation." *Water Science and Technology: Water Supply* 3 (4): 105–13.

UN (United Nations). 2001. "The Role of Desalinated Water in Augmentation of the Water Supply in Selected ESCWA Member Countries." Economic and Social Commission for Western Asia, New York.

____. 2006. *World Population Prospects: The 2006 Revision*. www.un.org/esa/population/publications/wpp2006/wpp2006.htm

USAID (US Agency for International Development). 2005. "Morocco Watershed Protection and Management: Final Report." USAID and Chemonics International, Inc., Washington, DC.

Wade, N. 2001. "Distillation Plant Development and Cost Update." *Desalination* 136 (1): 3–12.

Wang, B., L. Wang, G. Li, P. Qi, and Y. Liu. 2003. "Case Studies on Municipal Wastewater Reclamation and Reuse in China." *Water Science and Technology: Water Supply* 3 (3): 117–24. www.cababstractsplus.org/abstracts/Abstract.aspx?AcNo=20053021064

WASAMED. 2004. "Treated Sewage Effluent: An Alternative Water Supply for the Maltese Islands." In Third Water Saving in Mediterranean Agriculture (WASAMED) Workshop, Cairo.

WHO (World Health Organization). 2006. "A Compendium of Standards for Wastewater Reuse in the Eastern Mediterranean Region." Geneva.

____. 2005. "A Regional Overview of Wastewater Management and Reuse in the Eastern Mediterranean Region, R.O.f.t.E.M.R.C.f.E.H. Activities." Geneva.

WHO/UNICEF. 2006. "Coverage Estimates: Improved Sanitation. www.wssinfo.org.

Xu, P., F. Brissaud, and M. Salgot. 2003. "Facing Water Shortage in a Mediterranean Tourist Area: Seawater Desalination or Water Reuse?" *Water Science and Technology: Water Supply* 3(3): 63–70.

Zheng, X. 2002. "Research and Pilots Program on Municipal Wastewater Reclamation and Reuse in China." World Bank Water Forum, Washington, DC.

Zhou, Y., and R.S.J. Tol. "Implications of Desalination for Water Resources in China: An Economic Perspective." *Desalination* 164 (3): 225–40.

____. 2005. "Evaluating the Costs of Desalination and Water Transport." *Water Resources Research* 41: W03003.

Zimmo, O., G. Petta, N. Mahmoud, R. Al-Saed, Z. Mimi, and M.A. Madi. 2005. "Prospects of Efficient Wastewater Management and Water Reuse in Palestine." Water Studies Institute, Birzeit University, West Bank, Palestine.

26

Desalination Opportunities and Challenges in the Middle East and North Africa Region

Khairy Al-Jamal and Manuel Schiffler

Seawater desalination has the potential to help alleviate global water scarcity.[1] In the past century, global water consumption levels increased almost 10-fold, reaching or exceeding the limits of renewable water resources in some areas, including the Middle East and North Africa (MNA). Meanwhile, over the past decades, the cost of desalination and its energy intensity have decreased drastically, and its environmental footprint has been reduced These trends are likely to continue.

As experience and technology have developed, production costs for desalination have fallen. Technologies such as reverse osmosis, electrodialysis, and hybrids can deal with different types of input water and/or are more energy efficient. Unit sizes have increased, bringing economies of scale. These advances drove down prices from an average of US$1.0/$m^3$ in 1999 to US$0.50/$m^3$–0.80/$m^3$ in 2004 (World Bank and BNWP 2004).

The MNA Region is relatively water poor. With approximately 1000 m^3/capita per year, the region falls far below the world annual average of 8000 m^3/capita. By 2025 MNA's annual average water per person is expected to fall to less than 550 m^3 (Belloumi 2007). By the same year, climate change is expected to have led to more drought and

[1] This chapter does not discuss brackish water desalination, which is usually of smaller scale than seawater desalination. Nevertheless, the former can make important contributions to alleviate local water scarcity in inland locations by desalinating brackish groundwater, spring water, or drainage water for both irrigation and domestic water supplies.

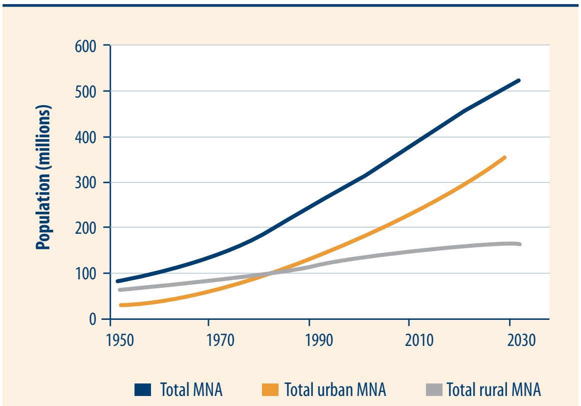
a 20 percent reduction in renewable fresh water resources (Doumani 2008; IPCC 4 2007).

Seawater desalination is no panacea for the water woes of the MNA region. It is just one instrument among many within a framework of integrated water resource management (IWRM). Other instruments include appropriate agricultural and trade policies, efficient water utilities with low levels of nonrevenue water, appropriate cost recovery, limited use of targeted subsidies, and increased reuse of treated wastewater.

This chapter summarizes the water demand and supply status in MNA and analyzes the projected demand growth and the water resources enhancement needed to bridge the gap. The chapter also gives a quick overview of the desalination technologies and their trend as well as a general cost analysis of reverse osmosis (RO) desalination based on recent figures. Furthermore, sensitivity analyses of the cost in relation to energy price, energy efficiency, and financing interest rate have been conducted.

Desalination in the Geographic and Economic Context of MNA

Figure 26.1 MNA Region Rural and Urban Population Trends, 1950–2030 *(millions)*



Source: World Bank 2007.

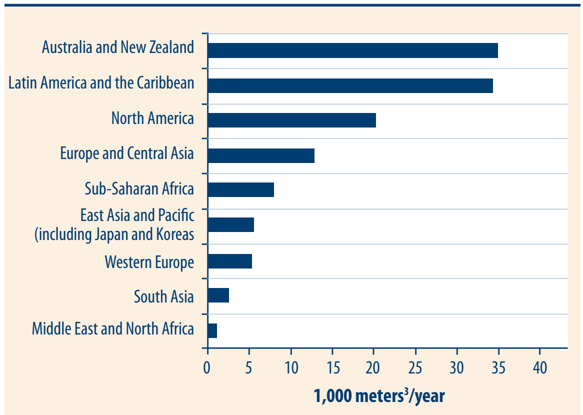
In 2007 the total population of the Middle East and North Africa (MNA) Region reached 300 million inhabitants (figure 26.1), with a rate of annual increase of 1.7 percent (World Bank 2007). The population is expected to reach more than 500 million by 2030.

This population increase is taking place in a region that is largely arid and semi-arid. The annual per capita renewable water resource is limited to 1,100m^3 (figure 26.2). This low annual average puts MNA among the relatively water-poor countries. Sixty percent of the water originates outside the region, and the region is already exploiting more than 75 percent of its total available resources (Doumani 2008; FAO AquaStat, 1998–2002). These two realities make it even more difficult to achieve water security. Moreover, these limited resources are not equally distributed. They can vary from 0.0m^3 in Kuwait to 3000 m^3/capita per year in Iraq (figure 26.3). In 14 countries in the region, per capita water resources are less than 500 m^3 per year.

The scarcity of water resources has many negative consequences:

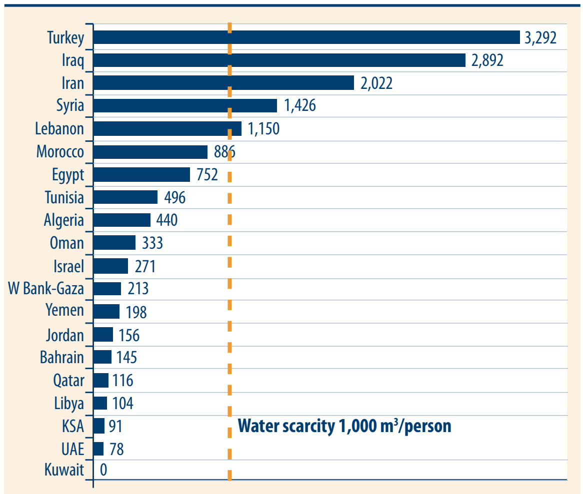
- Challenges the social stability of a growing population
- Further disturbs and degrades "natural" systems by encouraging the use of low-quality irrigation water
- Leads to groundwater contamination
- Reduces crop yields and limits cultivation
- Raises the risk of long-term damage to soils and aquifers that may not be easily recoverable
- Could lead to water conflicts.

Figure 26.2 Actual Renewable Water Resources per Capita, by Region



Source: FAO AquaStat, 1998–2002.

Figure 26.3 Total Renewable Water Resources per Capita, by Country



Source: Hamilton 2006.

In terms of its water resources, the MNA region is expected to be negatively affected by climate change. By 2050 the surface temperature is expected to increase by 2.5°C. Precipitation is expected to decrease by 10.5 percent, and runoff may decrease by 20 percent–30 percent (Doumani 2008). Thus, the available renewable resource would decrease by approximately 20 percent: from 400x10^9 m^3/yr to approximately 320x10^9 m^3/yr. However, most of this impact is expected to be felt after 2025. By 2025, renewable water resources are expected to decline by 30x10^9 m^3/yr (7.5 percent)—equivalent to approximately half the flow of the Nile—to approximately 370x10^9 m^3/yr.

Water Demands and Future Trend

Even though the region is severely stressed in meeting today's water demands, the situation is expected to worsen. At 75 percent, the MNA region is rapidly approaching full use of its total available water resources. Water going to agriculture remains the most important requirement (85 percent) followed by the domestic, industry, and tourism sectors (10 percent–15 percent). Municipal, industrial, and tourism water requirements may double or triple by 2025.

The forecast for water requirements depends on future economic and demographic trends as well as on agricultural policies and incentives for water conservation. Climate change also will increase water demand, as higher temperatures will increase both domestic and agriculture demands through higher evapotranspiration (ET) by crops on the land under irrigation. However, *the single largest factor influencing water demand will be the rate of increase of irrigated land,* which in turn is determined largely by agricultural policies and public investment in irrigation infrastructure.

Bridging the Gap and the Role of Desalination

Desalination accounts for 1.8 percent of the region's water supply. By 2025 it could reach 8.5 percent. However, the expected decline in renewable water resources (30x10^9 m^3/yr) is such that even the massive expected expansion of seawater desalination (24.2 x10^9 m^3/yr) would only partially compensate the impact of climate change. Furthermore, these two major trends would impact sectors and countries differently. The increase in desalination capacity would be used for municipalities and industries, whereas the decline in renewable water resources is expected to affect primarily agriculture. In addition, the increase in desalination capacity will be concentrated almost exclusively in the high-income, energy-exporting wealthier countries of the region, primarily in the Gulf countries. The latter have no significant renewable water resources and thus will not be significantly affected by a decline in precipitation. The MNA countries that will be affected primarily by a decline in precipitation are the same ones that will find it more difficult to afford desalination.

The speed at which desalination will be adopted in the region will be affected by how climate change will affect rainfall patterns. Droughts in Israel during 1998–2002 and in Algeria in 2004 triggered the choice to invest in large-scale seawater desalination. If droughts become more frequent and severe as a result of climate change, governments will not want to their major cities to depend on drought-prone surface water resources. Thus, the extent and severity of droughts will be key factors driving desalination investments.

The prospects for desalination vary greatly among MNA countries depending on their incomes and water scarcity and whether their major cities are located close to the coast. *Coastal cities in wealthy, water-scarce countries have been and are likely to be the main drivers for future seawater desalination in MNA*. The Gulf countries—Algeria, Israel, and Libya—with a combined total of less than 20 percent of the MNA population—belong to this first group of countries. The heavy energy subsidies in all of the countries in this group (except Israel) increase the financial viability of desalination.

A second group of countries is water scarce but cannot take advantage of the benefits of desalination because of their settlement patterns, lack of financial resources, or ongoing conflicts. For example, most of the populations of Jordan, Syria, and Yemen live at high altitudes or far from the sea. The supply of desalinated water to highland cities is prohibitive, especially during times of high energy prices. Other parts of the region, such as Gaza, which had advanced plans for seawater desalination in the 1990s, cannot fulfill their potential due their current political circumstances. This diverse group of countries within MNA accounts for less than 10 percent of the region's population.

Finally, *the third group of countries has sufficient water resources to satisfy most municipal needs for the time being*. These countries, including Egypt, Iran, Iraq, and Morocco, are home to close to 70 percent of the region's population. Seawater desalination in these countries is likely to remain confined to their water-scarce coastal areas such as the Egyptian Red Sea coast and Southern Morocco. The bulk of these countries' water supply will continue to be supplied by conventional water resources independent of climate change and future possible advances in desalination technology.

Thus, to sum up, *desalination is no panacea to solve water scarcity in MNA*. It is only one of many instruments to bridge the gap between water supply and demand within an integrated water resource management framework. In many countries, desalination will play a subordinate role to other instruments. On the demand side, these alternatives include agricultural policies; water conservation; increasing water use efficiency, particularly in agriculture; increased metering; more appropriate pricing;

Table 26.1 Expected Savings in Water Supply due to Application of Demand and Supply Management Techniques in MNA Region by 2025

Demand sector	Total demand *(109 m³/year)*	Fresh *(109 m³/year)*	Reuse *(109 m³/year)*	Leak reduction/ efficiency *(109 m³/year)*	Saving *(109m³/yr)*
Domestic	75	60.0	0	15.0	15.0
Agriculture	425	325.5	30	42.5	72.5
Total	500	385.5	30	57.5	87.5

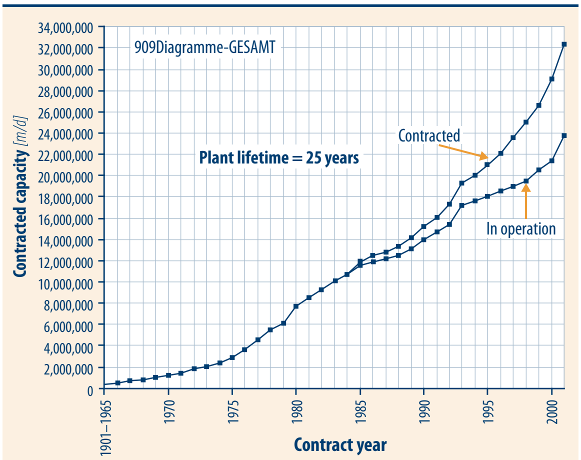
and on-site recycling and reuse. On the supply side, other options include leak and loss minimization and enhancing the use of reclaimed water (reuse of treated wastewater). For instance, application of wastewater reuse (50 percent of domestic demand), reducing leaks from 40 percent to 20 percent, and increasing irrigation efficiency by 10 percent will save approximately $104x10^9$ m^3/yr (table 26.1). This amount is approximately three times the expected increased desalination capacity.

MNA has approximately 60 percent of the world's desalination capacity ($7.2x10^9$ m^3/yr). According to the countries' plans and the historic desalination capacity increase, the total capacity is expected to reach $19.1x10^9$ m^3/yr by 2016 and possibly $31.4x10^9$ m^3/yr by 2025 (Balaban 2008).

Water Desalination Trend: MNA and the World

During the last 50 years, there has been a steady growth worldwide of desalination plants and their capacity (figures 26.4 and 26.5) (IDA 2002). Most of this growth has been in the oil-rich Middle East and has been based on distillation technology. However, alternative processes, most notably reverse osmosis (RO), also have been developed during this time. RO has grown spectacularly over this period and now dominates some sectors of the market.

Figure 26.4 Cumulative Global Capacity of Contracted and Operated Desalination Plants, 1901–2000



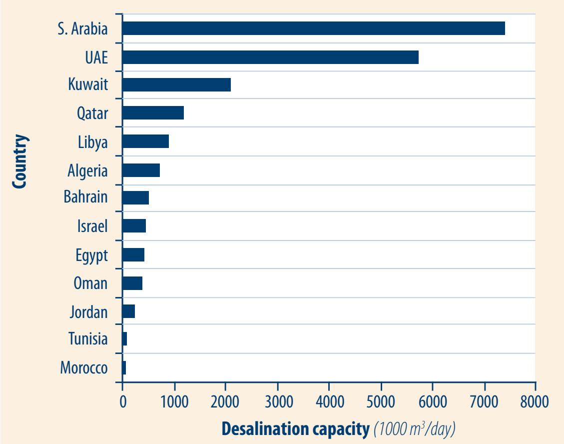
Source: IDA 2002.

The desalination market is strong, with significantly increased orders over 2001–02 of approximately 3.0 m^3 and 1.5 m^3/day globally and in MNA, respectively (figure 26.4). In 2002, 15 million m^3/day of the 24 million m^3/day seawater desalination plants' global capacity exists in MNA (figure 26.4).

Saudi Arabia is home to 30 percent of the MNA desalination capacity. Production of desalinated water there reached 7.4 million m^3/day in 2006 (Balaban 2007) (figure 26.5).

Additional desalination investment is planned in the MNA Gulf countries and elsewhere. The required investment up to 2025 is estimated at US$25 billion–30 billion.

Figure 26.5 Potential Operational Desalination Capacity in MNA Countries, 2006



Source: Balaban 2008.

Table 26.2 Desalination Capacity in MNA *(1000 m^3/day)*

Country	Desalination capacity end 2006	Capacity forecast 2011	Capacity forecast 2016	Capacity forecast 2025
Algeria	727	3191	4985	8,214 [a]
Egypt	432	528	888	1,536
Libya	899	1,869	3,775	7,206
Israel	440	1000[b]	1,790	3,212
Morocco	59	285	491	862
Tunisia	89	195	297	481
Jordan	240	541	898	1,541
S. Arabia	7,410	12,564	17,654	26,816
Kuwait	2,081	3,446	4,617	6,725
Bahrain	519	1,183	1,977	3,406
Qatar	1,197	1,676	2,481	3,930
Oman	377	1,140	2,059	3,713
UAE	5,730	9,030	12,330	18,270
Total *(103 m^3/day)*	**20,200**	**36,648**	**54,242**	**85,911**
Total *(103 m^3/yr)*	**7,373,000**	**13,376,520**	**19,798,330**	**31,357,588**

Sources: Balaban 2008; GWI 2004; and DLR 2007.
Notes:
a Extrapolated.
b Estimated.

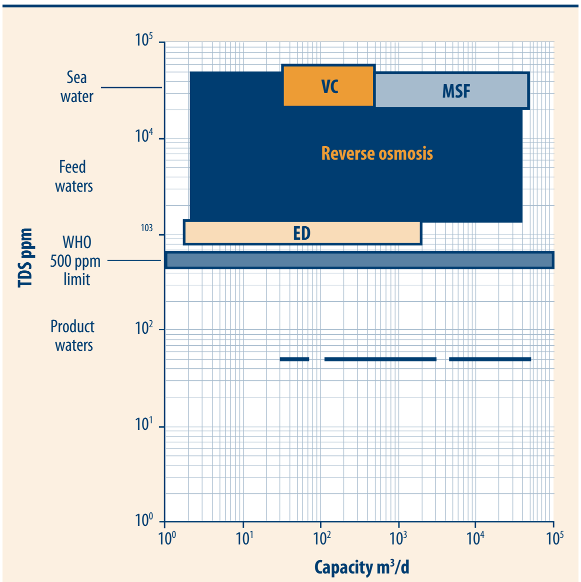
As experience and technology have developed, production costs for desalination have fallen. Technologies such as reverse osmosis, electrodialysis, and hybrids can deal with different types of input water and/or are more energy efficient. Unit sizes have increased, bringing with them economies of scale. These advances have driven down prices from an average of US\$1.0/m^3 in 1999 to between US\$0.50/m^3 and US\$0.80/m^3 in 2004 (World Bank and BNWP 2004). However, the future trajectory of desalination costs will depend on energy price trends.

Desalination Technologies: Aspects and Limitations

One convenient and useful way to classify desalination processes is to separate those that use a change of phase to separate the pure water from the feed water from those that accomplish this separation without a change of phase.[2] The *phase-change processes* are multi-stage flash (MSF), multi-effect boiling (MEB) or multi-effect distillation (MED), vapor compression (VC), thermal and mechanical and solar distillation (distillation processes); and freezing. The *single-phase* category comprises reverse osmosis (RO) and electrodialysis (ED) (membrane process).

The ranges of the applicability of the various desalination processes vis-à-vis the quality of the feed water appear in figure 26.6. In general, the phase change processes tend to be used to treat high-salinity waters, particularly seawater. Membrane processes are used over a wide range of salinity from brackish to seawater. The application of electrodialysis is limited to brackish water applications. In membrane processes, energy consumption is directly related to the salinity of the feed water. In distillation processes, the salinity of the feed water has little impact on the overall energy consumption.

Figure 26.6 Ranges of Applicability for Desalination Processes



[2] That is, from liquid to water vapor, or from liquid to ice.

Other basic parameters that should be examined to select the most appropriate desalination process are:

- *Co-generation*. In some instances, both power and water are required. To optimize cost, a careful analysis of the combinations of processes must be carried out.
- *Availability of energy resources*. All desalination processes use energy. Theoretically, assuming a 100 percent efficiency rate, approximately 1.6 kWh/m^3 is the minimum energy requirement. However, the actual energy requirements are sometimes much higher (table 26.3).Consequently, desalination has been seen as a very energy-intensive process. The development of reverse osmosis and, more recently, the improvements in energy recovery devices (energy exchanger and pressure exchangers) have changed this situation. Bringing down energy consumption in Mediterranean seawater RO plants to 2.5 kWh/m^3 has put seawater desalination within reach of many communities. To determine the most cost-effective process for each community, planners should survey all the available energy resources—conventional or renewable energy sources as well as waste or low grade heat availability. Table 26.3 illustrates the specific energy consumption of the various processes. The figures for the thermal processes have remained almost the same for the last decade.
- *Plant size*. The size of the desalination plant normally is dictated by the water demand. Before any process is selected, the size

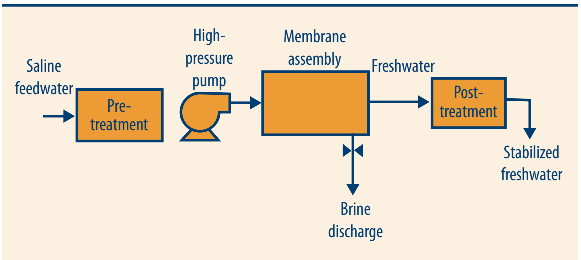
Table 26.3 Estimated Energy Consumption for Desalination Processes

Process	Steam energy (kWh/m^3)	Elect. energy (kWh/m^3)	Elect. energy equivalent (kWh/m^3)
Seawater			
MSF	7.5–11.0	2.5–3.5	10.0–14.5
MED	4.0–7.0	2.0	6.0–9.0
VC	—	7.0–15.0	7.0–15.0
SWRO	—	2.5–8.0	2.5–8.0
Brackish			
BWRO	—	0.5–2.5	0.5–2.5
ED	—	0.7–2.5	0.7–2.5

Source: World Bank and BNWP 2004.
Notes: MSF = multi-stage flash, MED = multiple effect boiling, VC = vapor compression, SWRO = seawater reverse osmosis, BWRO = brackish water reverse osmosis, ED = electrodialysis.

parameters of each process should be considered. The MSF process has been developed and adapted to very large applications (10,000–60,000 m^3/day). In recent years, the size of MED and VC processes has been increased and may have some advantages over MSF. The largest MED plant built to date is 20,000m^3/day. Due to the modularity of membrane processes, they can be used for a wide range of applications, from very small to large scale.

Figure 26.7 Schematic Diagram of Single-Pass RO Desalination Plant



The RO industry has grown very quickly, and the global capacity has risen from 10 percent during the 1990s to approximately 45 percent. RO is favorable due to its modularity, low capital investment, technological advancement in the membrane industry, compact plant size, ease of automation, fewer environmental impacts, and low operation cost. The typical configuration of an RO plant is illustrated in figure 26.7.

Desalination consists of placing a semipermeable membrane in contact with a saline solution under a pressure higher than the solution osmotic pressure, typically 50–80 bar for seawater. The feed is pressurized by a high-pressure pump and made to flow across the membrane surface. Part of this feed passes through the membrane, which removes the majority of the dissolved solids. The remaining water and rejected salt emerge from the membrane modules as a concentrated reject stream under high pressure. In large plants, the reject brine pressure energy is recovered in a turbine, energy exchanger, or pressure exchanger. The pretreatment required is a function of the scaling tendency of the water and the level of undissolved solids. The key to the successful operation of this process takes place during pretreatment. The product water from RO usually has 100–500 ppm of total dissolved solid (TDS), which complies with WHO guidelines regarding drinking water quality

Environmental Aspects of Desalination and Renewable Energy

Desalination of seawater consumes a significant amount of energy, which is required for the process itself (approximately 90 percent) in the form of thermal energy (distillation processes) or mechanical energy, usually obtained from electricity (RO process). Electrical energy also is needed in all plants to operate auxiliary equipment such as pumps and dosing systems. If fossil fuels are used as the primary energy source, the greenhouse (mainly CO_2) and acid rain gases (NO_x, SO_x) emitted into the atmosphere have a major environmental impact. Desalination plants also emit gases that do not originate from fossil fuel combustion but were dissolved in the seawater. In thermal plants, the feed water is usually deaerated, and gases evolve from the evaporating brine in flashing chambers. Both processes increase carbon dioxide (CO_2) emissions, which are stored in the oceans in the form of bicarbonate and cause the release of other atmospheric gases (mainly O_2 and N_2) from seawater. Table 26.4 summarizes qualitative environmental impacts of RO, MSF, and ED desalination plants.

Gaseous emissions. Distillation plants use both heat and electrical power. If the plant is large, such as those installed in the Gulf, the generation of power using fossil fuel is usually coupled to the production of water using MSF or MED distillation plants. Such plants use more total energy than RO plants, which use only electrical power. RO emits less CO_2 than does distillation. In some areas, high-sulphur fossil fuels are used to generate electrical power; in these plants, SO_2 as well as CO_2 emissions may occur.

Brine discharge. There is concern about brine discharge and its environmental impacts. In seawater plants, brine is discharged in the sea. Any chemicals added to the desalination process for scale and fouling prevention and corrosion reduction as well as corrosion products flow back into the sea. Coastal currents should be examined to ensure that discharges are not swept back around into the intake system. If discharge occurs in a small, enclosed bay or there is no coastal current, concentrations of the substances can build up, a situation that is clearly to be avoided. There is increasing concern in the Gulf about the amount of desalination taking place and the fact that the Gulf is a small, enclosed sea. This build-up can damage the fragile marine ecosystem and threatens marine life.

Land-based brackish water plants can experience severe problems in disposing the brine discharge. The aquifer and the surrounding habitats can be endangered. There are three options: the discharge can be spread over the land and allowed to drain back into the ground; it can be pumped into solar ponds for evaporation; or it can be re-injected back into the ground. None of these solutions is completely sustainable.

Visual intrusion. Desalination plants can be visually intrusive. Seawater plants usually are built on the coast. In areas in which tourism is important, a plant can be an eyesore. In Cyprus, the Dhekalia and the Larnaca plants were located some 500 meters from the shore to keep the shoreline clear.

Noise emissions. Desalination plants also can be noisy. RO plants have high-speed pumps, which normally are housed in buildings to reduce the noise. Problems have arisen when, during the summer, doors have been left open to reduce building temperatures and have enabled the noise to escape.

Table 26.4 Qualitative Overview of Environmental Impacts of Three Desalination Technologies

Effect/type of plant	RO	MSF	E.D.
Noise	H	M	L
Water effluent	M	H	M
Microelements	L	H	L
Toxic material	M	H	M
Air pollution	L	H	M
Industrial risk	L	H	M

Note: H = high, M = medium, L = low.

Greenhouse gas emissions from power plants associated with desalination plants pose a peculiar dilemma. Although desalination plants are a tool to adapt to climate change by making water supplies less vulnerable to droughts, they themselves contribute to accelerate climate change. This dilemma could be resolved by either accelerating the development of renewable energy in the MNA region or by purchasing carbon credits to compensate for the GHG emissions of desalination plants. So far, neither of these options has been used in the region.

Renewable Energy Alternatives for Desalination

Large desalination plants in the MNA region typically are powered by fossil energy. The energy requirements for desalination plants can be met through renewable energy sources (RES), which produce no CO_2

directly. Wind and photovoltaic (PV) energy are the most commonly used; wave power is possible in the future.

Until recently, renewable energy was used as a power source for desalination only for small plants in remote areas that had no access to electricity from the grid. In recent years, research and development (R&D) in this field has intensified. Worldwide, several RES pilot desalination plants have been installed, and the majority has been operated successfully. Virtually all of these were custom designed for specific locations and utilize solar, wind, or geothermal energy to produce fresh water.

For distillation technologies, power is supplied by using waste energy from adjacent power plants (co-generation). For membrane technologies, dedicated gas-fired power plants often are built next to the desalination plants. Medium-sized desalination plants receive electricity from the grid, which in the MNA region typically is generated by fossil energy or large-scale hydropower.

Outside MNA, the first large desalination plant powered almost entirely by renewable energy was commissioned in Perth, Australia, in 2008. The plant is powered primarily by an 80MW wind park developed concurrently with the desalination plant and located more than 200 km from the plant. The wind park feeds into the grid, from which the desalination plant receives its power supply, which is independent of wind conditions. Despite the recent spike in world energy prices, similar joint developments of large-scale renewable energy and large desalination plants have not yet materialized in the MNA region.

Desalination Cost Analysis

For discussion, the desalination cost for SWRO plant is considered in this section. In general, the desalination cost is divided into capital and operating costs. Over the last decade, the capital and operating costs of seawater desalination plants have decreased significantly in real terms. The reasons are:

Capital Costs

- Process design improvements
- Membrane performance development and lower cost per m^2 (RO)
- Manufacturing methods and increased volume
- Increased competition

Operating Costs

- Process performance
- Membrane life (RO)
- Energy efficiency improvements
- Interstage boost pumping (RO)
- Improved chemicals
- Reduced corrosion
- Privatization.

As a consequence of this, costs to desalinate water have fallen consistently for many years. The price reached US$0.52/m^3 in the Ashkelon SWRO plant in Israel in 2005. The cost breakdown is illustrated in table 26.5.

Table 26.5 Typical Cost Breakdown for RO Desalination Plant

Parameter	Early 1990s	Current
Capital cost	\$1000 to \$1200/m^3/day capacity	\$800/m^3/day capacity
Capital cost/m^3 at 5% interest rate	\$0.26	\$0.18
Energy consumption kW.h/m^3	6	3.5
Energy cost \$/m^3 at \$0.06/kW.hr	\$0.36	\$0.21
Membrane replacement cost \$/m^3	\$0.16	\$0.035
Labor and chemicals \$/m^3	\$0.14	\$0.10
Total cost \$/m^3	\$0.92	\$0.525

The cost can vary as the interest rate and/or the energy prices change. At 10 percent interest rate, the cost will rise to US$0.62/m^3. Figures 26.8 and 26.9 illustrate the sensitivity analysis results for the change in the interest rate and the energy cost of the proposed SWRO in the Palestinian Gaza Strip.

Private Sector Participation in Desalination

As discussed above, desalination is a relatively capital intensive technology and requires high operation and management skills. The Gulf countries initially financed desalination plants with their own resources and operated them through public agencies, such as the Saline Water Conversion Corporation (SWCC) in Saudi Arabia. However, in the 1990s, the Gulf countries switched to Build-Operate-Transfer (BOT) contracts. Under these, private companies financed, built, and operate desalination plants for a period of typically 30 years, during which they are being paid fees directly by the government or a public utility off-taker for their services. BOT contracts also have become the norm for the development of large desalination plants in the MNA region outside the Gulf.

However, some countries have been exceptions to this trend. For example, Malta operates all of its desalination plants publicly. To compare the performance of the public and private operators, Israel has authorized its bulk water supply company, Mekorot, to develop one large desalination plant in parallel to a series of similar desalination plants under BOT contracts.

Figure 26.8 Interest Rate Sensitivity Analysis of Water Production Cost for SWRO Desalination Plant in Gaza Strip

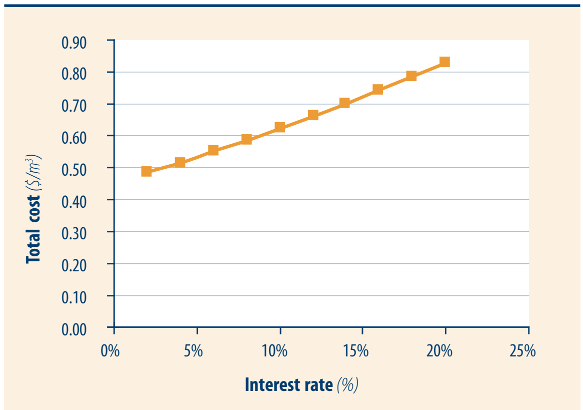
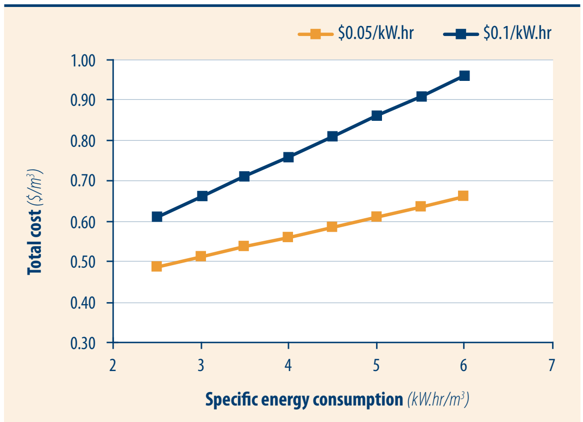


Figure 26.9 Energy Cost Sensitivity Analysis of Water Production Cost for SWRO Desalination Plant in Gaza Strip



Conclusions

Based on the above discussion, 10 conclusions can be drawn:

1. Desalination is playing and will continue to play a significant role to respond to the MNA region's growing water demands. The technology became well proven and has become cheaper.
2. Climate change, which is expected to cause more frequent droughts in the region, is likely to accelerate investments in desalination.
3. Desalination is no panacea. To maximize net benefits, it needs to be combined with other supply-side and demand-side approaches within the framework of integrated water resource management.
4. Advances in desalination technologies have reduced the cost of desalination to approximately US$0.52/m³. These advances have increased the affordability of desalinated water.

5. MNA's desalination capacity is increasing by 1.5×10^6 m^3/day every year. The capacity is expected to reach 31.4×10^6 m^3/day. This figure will entail an increase of approximately 20.0×10^6 m^3/day from the current capacity. The required investment is approximately US$20.0 billion.
6. Outside the Gulf countries, almost all new desalination plants are using reverse osmosis. This preference is due to RO plants being flexible and modular and having low operation and capital costs, and to advances in the energy recovery devices.
7. The cost of desalinated water is sensitive to the costs of both energy and financing. Thus, low-interest-rate financing reduces the cost of desalination and increases the affordability of desalinized water.
8. In most MNA countries, the private sector has been and will remain a key player in promoting desalination. The private sector can provide capital and increase efficiency in management and operation.
9. Desalination has both positive and negative environmental impacts. On the positive side, desalination will conserve conventional water resources, which can preserve aquatic ecosystems in rivers, and will prevent groundwater depletion and saline intrusion due to over-abstraction. However, desalination also is associated with negative impacts including greenhouse gas emissions, brine discharge including chemicals from pre-treatment processes, and noise and visual pollution. The industry is well established, and mitigation measures are being implemented and refined continuously, particularly concerning brine discharge.
10. Greenhouse gas emissions from power plants associated with desalination plants can be significant. These GHG pose a peculiar dilemma. While desalination plants are a tool to adapt to climate change by making water supplies less vulnerable to droughts, they simultaneously contribute to accelerated climate change. This dilemma could be resolved by either accelerating the development of renewable energy in the MNA region or purchasing carbon credits to compensate for the GHG emissions of desalination plants. Neither option yet has been used in MNA.

References

Balaban, M. 2008. "Desalination in Maghreb." Euromed Conference on Desalination Strategies in South Mediterranean Countries.

Belloumi, M. 2007. "Desalination as an Option to Resolve Problems of Water Scarcity in MNA Region." Second French Serbian Summer School Vrnja_ka Banja, October 7–13.

Booz and others. 2006. "Public Private Partnership in the MNA Water Sector, Challenges and Opportunities." OECD Conference on Public Private Partnership for Infrastructure Financing, Istanbul. November.

Doumani, F.M. 2008. "Climate Change Adaptation in the Water Sector in the Middle East and North Africa Region: A Review of Main Issues." PAP/RAC Workshop, Sardinia, May 19–21.

FAO (UN Food and Agriculture Organization). 1998–2002. "AquaStat."

German Aerospace Center (DLR). 2007. "Concentrating Solar Power for Seawater Desalination." www.dlr.de.en.

Global Water Intelligence (GWI). 2004. Desalination data. www.globalwaterintel.com.

Remawi, E. 2006. "Entrepreneurship as Public Policy: Completing the Ecosystem with Technology Venture Capital." HCT-MIT Entrepreneurship Conference. September.

United Nations Population Division. 2003. "World Urbanization Prospect 2003." www.un.org/esa/population/unpop.htm.

____. 2005. "Rural Water Supply and Sanitation in the Middle East and North Africa Region."

Wangnick, K. 2002. 2002 IDA Worldwide Desalting Plants Inventory. Produced by Wangnick Consulting for the International Desalination Association, Gnarrenburg, Germany.

World Bank. 2007. *The World Bank Annual Report*.

World Bank and Bank-Netherlands Water Partnership (BNWP). 2004. "Seawater and Brackish Water Desalination in the Middle East, North Africa and Central Asia."

27

Enhancing the Socioeconomic Viability of Spate Irrigation through Conjunctive Use in Coastal Areas in Yemen: Case Study of Wadi Ahwar

Arjen de Vries and Tarun Ghawana
Supervised by Ahmed Shawky Mohamed

Introduction

Need to Integrate the Management of Spate Irrigation, Groundwater Irrigation, and Groundwater Recharge

The recent increase of cultivated areas and yields in Yemen is due largely to the increased use of groundwater. The number of wells used in conjunction with spate flow has increased significantly, making irrigation possible between spate floods. Moreover, water productivity from groundwater-fed irrigation typically can be six times higher than from spate irrigation. Management systems no longer can be focused on the spate flow but also should take into account the impact of spate on recharging the groundwater. This chapter examines the interconnections among spate irrigation, groundwater irrigation, and groundwater recharge from spate flows. The chapter explains how all three processes form part of an integrated water system. With specific reference to Wadi Ahwar, the chapter shows how an integrated water resource management approach can improve the overall system's productivity and sustainability.

Irrigation is a major source of livelihoods in rural Yemen. For centuries, inhabitants of the coastal areas have been harvesting spate rain, mostly for irrigation but sometimes for domestic use. However, unlike conventional irrigation schemes in Egypt or Iraq, spate irrigation in Yemen is regulated only in space—but not in time. Flash floods are too fast or too erratic to be stored in conventional (multipurpose) surface dams. The Yemenis regulate spate runoff by building surface-water "diversion" structures, thus maximizing the spatial utilization of runoff rather than storing the water for interseasonal use. The diversion structures often are small scale and low cost because the unpredictability of spate flows makes large-scale investments uneconomic.

This chapter discusses developing the "conjunctive use" potential of spate water in Yemen's coastal areas. It presents *unconventional low-cost/economic solutions for storing excess spate water in the groundwater (or in subsurface top soils)*. In these ways, the stored water can be used later to supplement irrigation in the low flood periods, or at least for domestic purposes. Harnessing the conjunctive use of surface and groundwater also can help reduce the mining of groundwater near the coast, thus reducing saline intrusion into (drinking) water wells.

Table 27.1 Characteristics of Groundwater Storage, Small Dam Storage, and Large Dam Reservoirs

	Groundwater storage	Small dams and surface reservoirs	Large dam reservoirs
Advantages	■ Little evaporation ■ Widely distributed ■ Operational efficiency ■ Available on demand ■ Water quality	■ Ease of operation ■ Response to rainfall ■ Multiple use ■ Groundwater recharge	■ Large, reliable yield ■ Carryover capacity ■ Low cost per m^3 water stored ■ Multipurpose (power and flood control) ■ Groundwater recharge
Limitations	■ Slow recharge rate ■ Groundwater contamination ■ Cost of extraction ■ Recoverable fraction	■ High evaporation losses ■ Relatively high unit cost ■ Absence of over-year storage	■ Complexity of operation ■ Siting ■ High initial investment cost ■ Time needed to plan & construct
Key issues	■ Declining water levels ■ Rising water levels ■ Management of access/use ■ Groundwater salinization ■ Groundwater pollution	■ Sedimentation ■ Adequate design ■ Dam safety ■ Environmental impacts	■ Social impacts ■ Environmental impacts ■ Sedimentation ■ Dam safety

Source: IWMI 2000.

Artificial recharge is defined as any engineered system designed to introduce and store water in an aquifer (Topper and others 2004). However, an adverse connotation of "artificial," in a society in which community participation in water resource management is becoming more prevalent has led to a new name: Managed Aquifer Recharge (MAR) (Gale 2005).

MAR can be useful for many of today's water issues and concerns. As an increasingly important tool for water managers, it may be useful for repressurizing aquifers subject to declining yields, saline intrusion, or land subsidence. MAR also can play an important role as part of a package of measures to control over-abstraction and restore the groundwater balance (Gale 2005), or be applied to maintain or improve local ecology and environment. MAR may help to improve water quality in aquifers and infiltrate storm runoff for both damage control and subsequent reuse in drinking or irrigation supplies.

MAR applications generally are not stand-alone interventions because they are a component of the broader hydrological system and usually part of a larger water supply or water management system. Application of MAR should be considered in this broader framework to arrive at the most cost-effective solution.

The great variety of available MAR techniques and the varying site specifics have led to a large variety in scheme design and construction (figure 27.1).

MAR applications are subdivided into 5 principal techniques and 14 subtypes. The main techniques are chosen in relation to the type of technique used either to intercept the water or to get the water infiltrated. The subtypes are specific engineering techniques that are applied, many of which are known to stakeholders or often cited in references. Induced bank infiltration is a distinctive technique that cannot be listed under any other main MAR technique. Therefore, it is assigned to a separate class in which it is both technology and subtype.

One thus can think of groundwater recharge from spate flows in Yemen as the missing piece of the three-way relationship among

Figure 27.1 MAR Classification: Overview of MAR Techniques and Subtechniques

<table>
<tr><th colspan="2">Technology</th><th colspan="2">Subtype</th></tr>
<tr><td rowspan="8">Techniques referring primarily to getting water infiltrated</td><td rowspan="4">Spreading methods</td><td colspan="2">Infiltration ponds & basins</td></tr>
<tr><td colspan="2">Flooding</td></tr>
<tr><td colspan="2">Ditch, furrow, drains</td></tr>
<tr><td colspan="2">Irrigation</td></tr>
<tr><td colspan="3">Induced bank infiltration</td></tr>
<tr><td rowspan="3">Well shaft and borehole recharge</td><td rowspan="2">Deep well injection</td><td>AS(TR)</td></tr>
<tr><td>ASR</td></tr>
<tr><td colspan="2">Shallow well shaft/pit infiltration</td></tr>
<tr><td rowspan="6">Techniques referring primarily to intercepting the water</td><td rowspan="4">In-channel modifications</td><td colspan="2">Recharge dams</td></tr>
<tr><td colspan="2">Subsurface dams</td></tr>
<tr><td colspan="2">Sand dams</td></tr>
<tr><td colspan="2">Channel spreading</td></tr>
<tr><td rowspan="2">Runoff harvesting</td><td colspan="2">Barriers and bunds</td></tr>
<tr><td colspan="2">Trenches</td></tr>
</table>

Source: Gale 2005.

spate water use, groundwater use, and groundwater recharge from spate flows. *For sustainable resource management, project interventions should balance the output from spate water in the high flood periods with the recharge to groundwater.*

When water storage solutions are developed, groundwater storage structures (as opposed to surface dams) often are ignored. In Yemen, storing water in the soil profile through subsurface or sand dams in semi-arid areas, including spate-irrigated areas, is more cost effective than constructing conventional dams. Very limited research has been carried out on the relationship between recharge and spate. However, most recharge is expected to take place in the wadi beds rather than in the channels and irrigation fields. Through spate, recharge can be enhanced through flatting the river slopes and through ponding. In general, the flow velocity should be reduced, thereby enhancing the recharge. From a geological point of view, it would be better to enhance infiltration upstream rather than downstream, because the sediment downstream is often loamy to clayey. Another important aspect to consider is the subsurface flow. This flow is the main source of downstream wells. By cutting this flow through building impervious structures (such as concrete dams), this downstream recharge may be reduced significantly.

Applying the categorization of MAR techniques to Yemen, myriad options could enhance groundwater recharge and interseasonal conjunctive use:

a. *Artificial recharge*. It penetrates fine soils or the impermeable underlying layers (for rainfall, runoff, or return flows such as from treated wastewater).
b. *Small recharge dams for inter/intraseasonal storage*. These enhance the water infiltration upstream of the dam. However, sometimes (as in Oman) they are used to store the dam's upstream runoff, then release it to recharge the groundwater downstream. For a given budget, having a cascade of small recharge dams is preferred to having one big recharge dam, as the latter may cause big evaporation losses.
c. *Small, low-cost sand-storage/subsurface dams for inter/intraseasonal storage* (at least to provide rural water supply, if not irrigation). As sand accumulates upstream, these structures enhance the natural storage capacity of the river bed/banks. Even if the underlying layer is relatively impermeable, a significant amount of water can be stored in the river bed (above the impermeable layer) and in the river banks. In contrast to typical surface recharge dams, this method results in

no evaporation and no sedimentation (bed load) issues. In addition, the weir can be designed so that the wash load overtops the weir's sill, and subsequent flash floods will further wash out that load.

d. *Surface-water diversion system*. This system can be designed to divert part of the runoff toward a location in which recharge/subsurface dams can perform better, that is, in which the soil porosity and/or permeability/storativity/transmitivity of the underlying layers is good enough.

This chapter shows how such techniques to enhance groundwater recharge could be applied in Wadi Ahwar.

Water Management in Coastal Areas Needs Not Only Infrastructural Interventions but Also Institutional and Information Measures

This chapter focuses on the groundwater issues of a typical coastal wadi, for which spate irrigation is one of the key elements of the water resources system.

Spate irrigation is closely associated with groundwater use and recharge. Due to the increase of groundwater use in Wadi Ahwar, mainly through an increase in the number of shallow wells, agricultural production in the spate irrigation command area has increased. However, for conjunctive groundwater use to be efficient and effective, careful demand and resource management are essential. The over-abstraction of groundwater not only impacts the quality of the resource but also can lead to saltwater intrusion and hence water quality deterioration.

Current observations on groundwater levels and saltwater intrusion in Wadi Ahwar indicate the need for a sustainable approach toward groundwater and its development. Stakeholders in the wadi agreed that intervention is urgently needed to reverse the unsustainable depletion of the resource, water quality deterioration, and saltwater intrusion. Although no conflict has yet arisen among water users such as farmers and rural water supply users, conflict may be imminent. Thus, the necessity for certain measures, including public awareness and community involvement, is urgent.

For sustainable water management, there are certain essential nonphysical requirements:

1. *Extensive information is key.* In most coastal wadis including Ahwar, the understanding of hydrogeological processes is still limited. This lack of understanding is due mainly to limited historical data. Floods

are the main contributor to groundwater recharge. Hence, the high temporal variance in floods translates into high temporal variance in recharge. Careful monitoring is essential to predict the recharge and thus the groundwater that can be utilized sustainably without jeopardizing the resource.

Wadi Ahwar is characterized by a high spatial and temporal variability of rainfall. The temporal variability is relatively well known and can be measured from any adjacent meteorological station. However, information on the spatial variability is usually much more limited. Studies in the region illustrate that rainfall distribution is very spotty. In Saudi Arabian basins, there have been examples of wadi flows generated from zero observed rainfall. This phenomenon also illustrates the complexity of quantifying runoff based on conventional densities of rain-gauge networks.

2. *Socioeconomic and institutional measures must support physical interventions.* For example, similar projects in Ethiopia and Kenya have shown that insufficient involvement of local communities in water harvesting schemes is a major constraint to success. Even when good physical investments are made, groundwater use needs to be regulated. In Yemen, it is difficult to enforce this regulation through central control. In contrast, by capitalizing on the tribal culture dominant in Yemen, the needed regulation can be ensured by local communities, namely Irrigation Councils (ICs) and Water User Associations (WUAs). These have been successfully piloted in the World-Bank-financed Irrigation Improvement Project (IIP) in Wadi Zabid, Tuban, and Ahwar.

Wadi Ahwar: Typical Spate-Reliant Coastal Basin in Yemen

The use of spate water for irrigation is as ancient as humankind's cultivation of land. According to several archeological and historical evidences, Yemen was the first country in the world to practice spate irrigation. This unique system reached its zenith during the Shebean period in the first millennium BCE. The intense development of trade after the Islamic period may have promoted the spread of spate irrigation from Yemen to other arid and semi-arid regions. Yemen's water resources have become unsustainable due to the neglect of the traditional spate irrigation system on the one hand, and over-exploitation of groundwater for its multiple uses on the other. In most spate irrigation systems in

Yemen, the major floods occur between June and September, which is the time of heavy rainfall in upper catchments. Crop growth takes place exclusively between October and February. It depends on the water stored in the soil and adjacent low-lying fields. Deep soils are able to store ample moisture for the crops during periods with no precipitation.

Wadi Ahwar is located in the southern Arabian Peninsula, in the eastern Abyan Governorate. Delta Ahwar is located approximately 200km east of Aden. Ahwar, Al Hanad, and Al Mabrak along the coast of the Arabian Sea are the major villages in the delta. Wadi Ahwar is formed by joining the two tributaries, Wadi Saba and Wadi Jahir.

The total catchment area is estimated at 6352 km^2. The active catchment of Wadi Ahwar to Faud Weir is 4052 km^2, and up to Hanad Weir is 4062 km^2, because approximately 36.2 percent of the total catchment of this wadi does not produce runoff during small or average flood. Wadi Ahwar is 160 km long and originates from the high mountains (altitude approximately 2350m), from which it receives high rainfall. After flowing down from the mountainous region, Wadi Ahwar has formed an alluvial plain that is the main agricultural area of Ahwar delta. Two modern structures are constructed on Wadi Ahwar to irrigate 7000 ha of land by utilizing the available spate. The catchment has a tropical hot and arid climate with very poor rainfall and high evaporation. However, there is no credible meteorological station within the catchment to register the annual variations of meteorological parameters.

The 2004 population of Wadi Ahwar was estimated at 34,646. The average family size was 10.2. Per the official statistics, the rural population was as high as 73.5 percent of the country. Rural population exceeds urban because agriculture and livestock production provide the country's main livelihoods. The wide variation in topography and climate enables producing various crops, livestock, and honey.

What Is the Safe Yield?

Scientific Rationale

Safe yield traditionally has been defined as the maintenance of a long-term balance between the amount of groundwater abstracted and the amount of groundwater recharged. Hence, pumping is restricted to the natural replenishment of groundwater. However, this definition ignores the discharge from the system. If abstraction equals recharge, abstraction plus discharge is greater than recharge. Therefore, *the safe yield does not equal the sustainable yield*.

Under natural conditions and over a long period, the discharge of an aquifer will equal the recharge. Additional discharge from wells destroys this equilibrium. The equilibrium can be restored only if recharge is augmented and/or the natural discharge is decreased.

It therefore is important not to consider sustainable groundwater yield as a fixed volume of water that can be utilized but to address the system in a more integrated manner, that is, to take into account the whole water system including surface water.

To establish a sustainable yield, three aspects should be considered:

1. *Conceptual water budget*. In estimating the water budget, all stakeholders should be represented so that the balance reflects both the natural system and all users. The natural system should include both ground- and surface water. Initially, this budget can be an estimate. Eventually, modeling will be necessary to establish the budget more exactly and to predict how the system will respond to future changes such as increased demand or climate change. These models also can help to estimate terms such as changes in storage, discharge, and hydrogeological properties.
2. *Spatial scale*. If the spatial scale is not understood and defined, any approximation of sustainable yield is meaningless. Local abstractions might seem sustainable when compared to the regional sustainable yield. However, even limited local abstractions still may have a large negative impact, such as localized saltwater intrusion. Therefore, the scale at which the sustainable yield is determined should take into account possible local effects.
3. *Temporal scale*. Pumping and recharge are time dependent, varying over different time scales. To estimate the sustainable yield, the timing of future water needs and recharge should be understood. In other words, the sustainable yield is not a constant but could change continuously and must be related to a certain time period. In other words, should the sustainable yield be based on figures of the last 10 years, or on only the last year? The time factor is critical for defining the sustainable yield.

The abovementioned uncertainties in the definition of the different terms of the water budget led to the idea that *water resource sustainability must be considered within the framework of probability* (Howard 2002). According to Howard, sustainability must be defined as "a system that maintains acceptable risk over an indefinite time horizon." Our inexact understanding of the water budget means that we should *focus on adaptive management: adapting to a changing physical and socioeconomic environment*. Adaptive management does not mean that specifying fixed levels of water use through instruments such as permits is not required. It does mean that we must recognize that the specified quantities can change.

Estimating Sustainable Yield in Wadi Ahwar

The main intent of sustainable groundwater use is to optimize abstraction while maintaining a minimum outflow to the ocean to prevent saltwater intrusion. To estimate the sustainable yield of Wadi Ahwar, it is not necessary to include aspects such as wetlands and stream base flow because perennial streams and wetlands are minimal or do not exist. Therefore, for Wadi Ahwar, the sustainable yield can be defined as almost equal to the natural recharge of the aquifer on an average annual basis, that is, because man-made abstraction almost equals total discharge.

Recharge in the wadi is not well understood, so it is difficult to estimate aquifer sustainability. The aquifers receive recharge via underflow from the mountains or infiltration from surface wadis; or gap flow during periods of more intense rainfall, direct surface recharge from rainfall (likely to be insignificant), and agricultural return. Understanding the relationship among the rainfall amount and intensity, surface hydrologic response, and aquifer recharge is of fundamental importance.

Although rainfall is the primary hydrological input, in arid and semi-arid areas such as Wadi Ahwar, rainfall is characterized by extremely high spatial and temporal variability. The main input to estimate the sustainable yield is the surface runoff and hence the groundwater balance. Runoff flow is composed of two main elements: base flow, which has its origin in groundwater; and surface runoff, which is the accumulation of rainfall that drains to the stream. The basin characteristics that affect the base flow and the surface runoff include geology, soil type, vegetation cover, precipitation, drainage area, and moisture condition. The variable rainfall conditions in Wadi Ahwar make it difficult to estimate average runoff and hence the sustainable yield.

It therefore can be reasoned that, to estimate the safe yield, the variability of the hydrological and climate system can best be taken into account by taking average figures for a 10-year period. The current water balance suggests that the current safe yield (estimated in 2008) in Wadi Ahwar is 18 Mm^3. The lack of data, both spatial and temporal, makes this figure highly approximate.

Data Collection, Information, and Monitoring

Monitoring is the main source for data and information. Examples of monitoring in Wadi environments include the assessment of water resources for future development and for rainwater and floodwater harvesting.

Current Monitoring Activities and Well Inventory

No groundwater monitoring takes place in Wadi Ahwar. The only information on available resources is based on old studies, such as the 1990 donor-funded study. Since the 1990s, many changes have taken place in both Yemen's physical and socioeconomic systems. To provide more recent data and to develop a management plan with different scenarios, a monitoring network will have to be designed and developed.

Based on the consultancy study, a proposal was drawn up for monitoring wells. For a monitoring network design, additional analyses of the hydrological system need to be carried out. However, based on a preliminary assessment, it seems logical to install a number of monitoring wells parallel to the wadi up to the coast, and a few wells across the wadi.

Recommendations

NWRA has limited experience with groundwater resource monitoring. Moreover, it has no clear vision of information management. The water authority should consider delegating different information systems tasks to the appropriate administrative level (national, regional, and local). In this way, NWRA should be capable of designing and managing the overall monitoring system.

Given the above observations, the following short-term activities can be identified to develop a monitoring plan for Wadi Ahwar:

1. Develop monitoring objectives and strategy.
2. Develop a monitoring plan that defines the required hardware, software, and human resources.
3. Design monitoring network based on hydrogeology.
4. Provide protocols, guidelines, tools, and standards for different monitoring activities. These aspects should correspond to NWRA guidelines.
5. Carry out an inventory of necessary capacity and equipment at all levels.
6. Set up communication with regional NWRA offices, and define mandates for each NWRA office.

Possible Measures in Wadi Ahwar

Despite the lack of accurate hydrological data on Wadi Ahwar, it is clear that over-abstraction takes place and leads to saltwater intrusion. It also is believed that a great amount of water is being lost to sea (and through nonbeneficial evapotranspiration). These assessments suggest that there is opportunity for both conventional interventions such as rainwater harvesting, and nonconventional measures such as artificial recharge and demand management. Integrating these conventional and nonconventional measures can lead to sustainable conjunctive use. The desired outcome is to balance (1) reducing water losses and storing excess water to optimize rural livelihood throughout the year; and (2) maintaining the minimum spillage to sea as needed to counteract seawater intrusion.

Two main categories of proposed measures can be distinguished:

1. Supply-oriented measures to make more water available for different users
2. Demand-oriented measures to reduce water demand and consequently reduce the groundwater abstraction and control the drawdown of the groundwater table.

Such measures could be part of an overall sustainable water management plan, as described below.

However, to decide on the appropriate measures, a better understanding of the hydrogeological system is important. For example, it would be useful to know to what extent the excess wadi runoff can be recharged. If the amount of excess water is limited, proposed recharge structures will only redistribute the groundwater resources but not augment them. Furthermore, it is not yet completely clear whether the recharged water will be temporarily or permanently intercepted by the shallow aquifers. The available information does give some insights. However, given the sharp increase in groundwater development of the last 20 years, a 1990 donor-funded study will have to be updated before any recharge structures can be constructed.

Nevertheless, the recent well and abstraction inventory indicates that the total volume of surface water used for irrigation has not increased. This fact suggests that a surplus outflow of water to sea still exists and can be intercepted and recharged. In addition, more efficient irrigation practices would lower evaporation and increase the volume of water available for recharge.

For these measures to be effective, the abstraction of groundwater will need to be regulated. Although NWRA will play a key role in monitoring abstractions and regulating the drilling of boreholes, enforcement obviously will be a very difficult issue. It is suggested that *community-based groundwater management* would be the most effective approach.

All stakeholders in the water resources in the wadi agree that measures need to be taken to reverse the negative impacts of unsustainable abstraction. They result in depletion of the resources, quality deterioration, and saltwater intrusion. Although no conflicts have yet arisen, there is a clear need for awareness and stakeholder involvement in the use of the resource.

Supply-Oriented Measures

Storage and recovery of excess water

To store excess water for later use, subsurface dams are probably the most feasible option.

The use of injection boreholes requires little surface area and enables recharging an aquifer isolated from the surface by a semi-pervious or impervious layer. However, the technique is more vulnerable to disruption and requires more high-tech maintenance than surface infiltration. To avoid frequent clogging of the well screen of an infiltration borehole, degassed water and high standard water quality are needed. Before large-scale implementation of injection boreholes, pilot schemes are required to test for the proper design and water quality characteristics to be used.

Subsurface dams may operate at low hydraulic loading rates and also improve water quality. Subsurface dams are a relatively inexpensive intervention, require low-level technology, are easy to construct, and offer opportunity for community involvement. The infiltration rate is strongly dependent on the groundwater table, which must be relatively deep. Recovery is usually by abstraction wells located in the vicinity of the infiltration site.

Suitable locations for subsurface dams are probably upstream, where the wadi basement is not yet at great depth and a dam would be relatively easy to realize. The storage capacity of a typical subsurface dam and reservoir of 4 m depth, 50 m width, and 500 m length would be some 10,000 m^3, assuming a drainable storage coefficient of 0.10. Already the government of Yemen has made great effort to construct small or subsurface dams to recharge groundwater. Most of these dams have not been very effective in recharging the groundwater. Nonetheless, the intervention is very promising in a wadi environment, subject to certain considerations:

- *Siting of the dams is an important aspect of implementation*. The unconfined layer should be within a shallow-to-moderate depth (preferably not more than 10 m) and in a well-defined impermeable layer.
- *Sites with saline soils should be avoided for dam construction*. While reduction in the salt levels through continuous water use is feasible, reduction requires operational procedures beyond those generally expected of small rural farmers.
- The economic conditions of the sites are such that participatory or bottom-up approaches are essential in constructing the dam (and obtaining maximal socioeconomic benefits). Using locally available materials and community labor reduces costs and enhances efficiency, acceptance, and dam life span. The human factor is essential for the success of underground dams. If there is no cooperative effort, and subsequent ownership, by the community, effective operation and adequate maintenance are unlikely. Successful examples of community involvement in dam construction can be found in Ethiopia and Kenya (box 27.1).
- The successful application of subsurface dams would require an analysis of the hydrogeological system of Wadi Ahwar. Additional

Box 27.1. Kitui Sand Dams, Kenya

The Kitui Sand Dam project in Kenya is an example of how communities use their knowledge about water to cope with droughts. Since 1990, a local NGO in Kitui (Sahelian Solutions Foundation, or SASOL) has been assisting local communities to build small-scale *sand dams*, which store water in artificially created sandy aquifers. Water is stored within the sand and gravel particles, which accumulate against the dam wall. "Sand' refers to the sand behind the dam wall that holds the water. The dam wall itself is made of concrete. Sand dams can store water in up to 35 percent of the total volume of sand stored upstream of the dam. The stored water is protected against high evaporation losses and contamination. The water is captured for use through a hand-dug well or tube well using a bucket or hand-pump. Downstream areas are not significantly influenced by the presence of a sand dam. The efficiency of the design is improved by constructing dams in cascade.

Note: A total of 500 sand dams have been constructed in Kenya, creating a reliable source of water, even during droughts (as was proved in 2006).

Box table 27.1. Socioeconomic Performance of Sand Storage Dams, Kitui, Kenya

Vulnerability categories	Vulnerability indicators	Before dam construction	After dam construction
Agriculture	# of cash crops	1.5	2.8
	Irrigated crops *(%)*	37.0	68.0
Special aspects	Water collection—domestic *(mins.)*	140.0	90.0
	Water collection—livestock *(mins.)*	110.0	50.0
Gender	Average walking distance to water—women *(km)*	3.0	1.0
Economic	Income *(US$/year)*	230.0	350.0
Health	Households suffering from malnutrition *(%)*	31.6	0.0

boreholes would be necessary to collect extra information on the geology and lithology of the subsoil, infiltration capacity, and potential storage. After construction of the subsurface dams, these boreholes should be used to continuously monitor the water levels and water quality sampling (see appendix A27.1, comments on monitoring).

Saltwater intrusion barrier

Many boreholes and dug wells in a 10 km-corridor along the coastal zone close to Ahwar have become saline. To stop saltwater intrusion, an intrusion barrier should be built. The principle of injecting fresh water into an aquifer to form a barrier against saltwater intrusion from the sea is to push back the saltwater–freshwater interface. Salinization and a scheme to stop the process are shown schematically in figure 27.2.

The groundwater salinity in the Ahwar area probably is caused not only by a lateral shift in the saltwater–freshwater interface but also by upward coning of saltwater. Rising saline water can be counteracted by using 2 filters in 1 abstraction well. The lower well screen will intercept upcoming saline water; the upper one will continually produce fresh water (figure 27.3). Before considering implementation of a freshwater antisalinity barrier, further investigation is necessary to study the mechanisms of increased salinity.

The time required to reduce water salinity would be considerable and could reach the order of tens of years. Hence, to decrease the rate of saline intrusion in underlying aquifers, the most effective practice may be to reduce the extraction of coastal zone groundwater for irrigation.

Figure 27.2 Process of Saltwater Intrusion

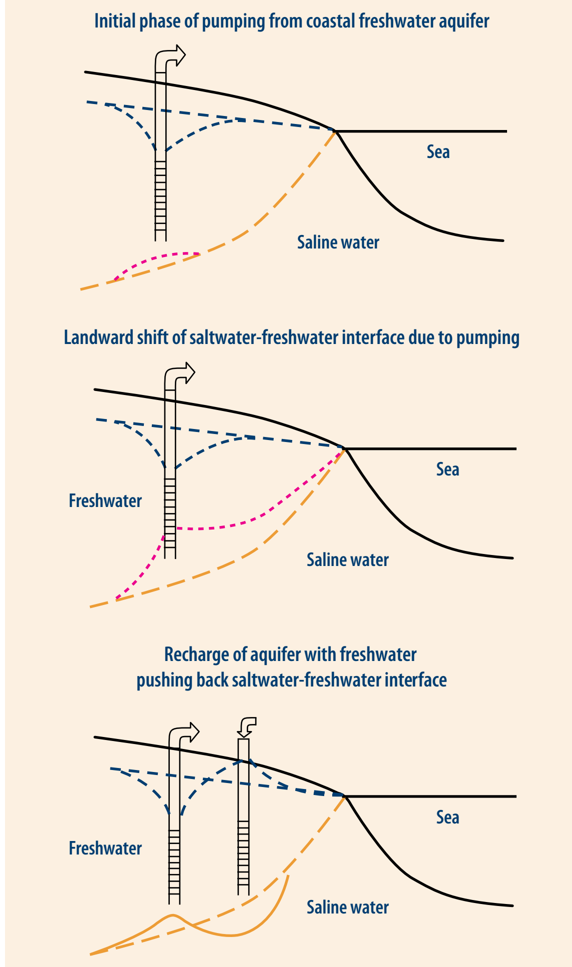
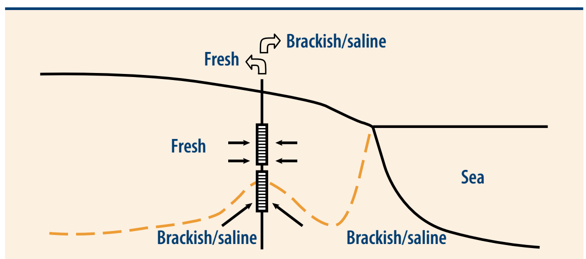


Figure 27.3 Use of 2 Abstraction Wells at 1 Location to Counteract Salinization



Demand-Oriented Measures

As just noted, measures to *strengthen groundwater recharge* should be complemented by equally important actions to *limit groundwater abstraction*. The design and implementation of such demand-management measures are extremely complex and political. They require consultation and bargaining among numerous stakeholder groups. Consequently, this chapter does not propose specific packages for the Wadi Anwar area, However, given that demand management is an essential component of an integrated approach to groundwater sustainability, the four options below merit further investigation.

1. *Downstream/upstream tradable water rights*. The aim would be to create a financial incentive for upstream water users to allow more water to flow downstream as surface or groundwater. The increased flows would improve downstream groundwater balances. Clearly, the design of such a system would be extremely high risk and complex, and would require a long period of consultation and bargaining among stakeholders. Strict monitoring would be required to prevent farmers from both selling and using their water simultaneously.
2. *Command and control measures,* Regulatory measures could include requiring well-drilling permits and restrictions on abstractions. Water-saving measures, such as drip irrigation and the cultivation of more water-efficient crops, could be enforced. As for enhanced recharge, such measures would require better monitoring of the hydrogeological system. However, so long as groundwater is considered a free-access commodity, enforcement will be very difficult.
3. *Community-based groundwater management*. Given the difficulty of enforcing "command and control" measures, self-regulation seems to be the only approach to sustainable use of groundwater at the local level in rural areas. Self-regulation focuses on the development of local norms to control groundwater abstraction and use. As shown by projects in India (APWELL and APFAMGS),[1] raising awareness of the resource among users increases the farmers' commitment to proper groundwater use. In these projects, the farmers themselves measure the water levels and water yields. However, the main challenge is to translate this data into information that helps the farmer or community understand the groundwater

dynamics, increases their awareness of the need for regulation, and informs good decisions regarding water shortages.

4. *Incentives.* Extension and training should be integral parts of the implementation of the new measures and regulations. Alternatively, negative incentives, such as groundwater pricing or higher diesel prices, could help to limit abstraction.

Conclusions

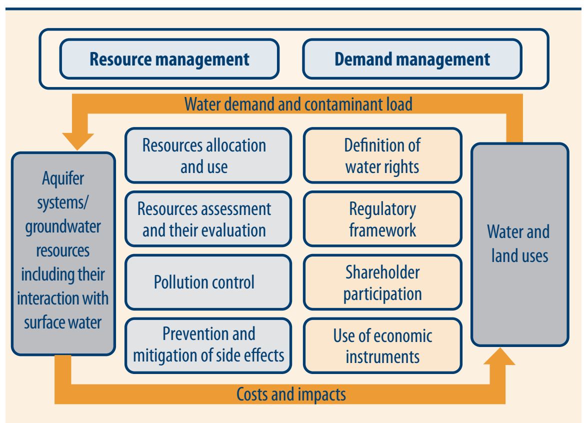
The welfare of the Wadi Ahwar population depends on re-establishing the area's hydrogeological balance.

The usual solution to encourage sustainable use of groundwater is to impose regulations. Examples are registering abstraction points and defining water rights. However, given the difficulty in enforcing regulation, *self-regulation* seems to be the only path toward sustainable use. In addition, there is an opportunity to *enhance groundwater recharge*.

It therefore is suggested to develop a groundwater management plan. The plan would cover all aspects of integrated groundwater management, on both the demand and the supply sides: water harvesting, regulating use, alternative crops, and more efficient irrigation and monitoring.

Establishing the groundwater management plan should involve local stakeholders in three processes: assessing the resource, assessing the demand, and negotiating the adoption of resource management decisions. The groundwater management plan should include simple "rules of thumb" that focus on water use at the village level and help to control the abstraction and use of

Figure 27.4 Integrated Groundwater Management Plan



[1] FAO-India projects, Andhra Pradesh Ground Water Irrigation Schemes (AP-WELL) and Andhra Pradesh Farmer-Managed Groundwater Systems Project (AP-FAMGS). The latter's online masthead reads, "Demystifying Science for Sustainable Development."

scarce groundwater resources. These management rules should be sustainable and environmentally sound. Options for resource enhancement also will be studied. The linkages among the water resource, resource management, and demand management are illustrated in figure 27.4.

Appendix A27.1 Hydrogeological and Groundwater Analysis in Wadi Ahwar

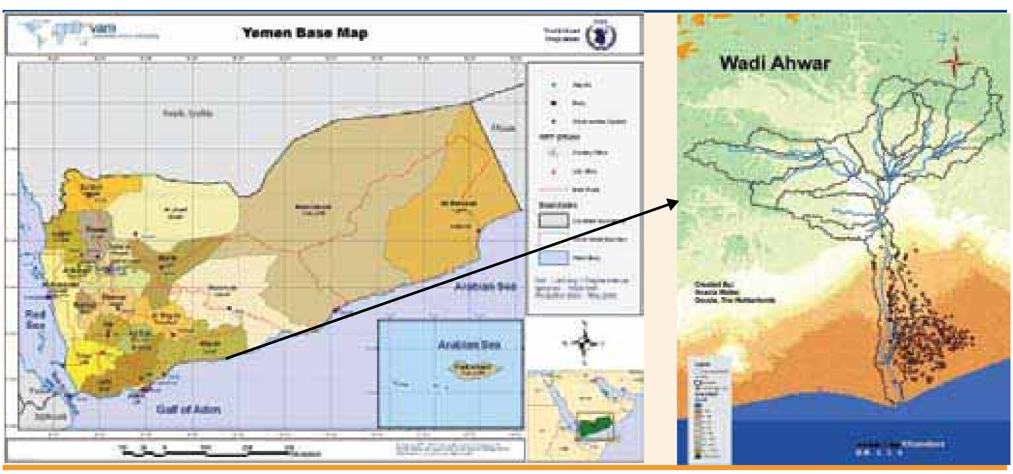
General Hydrogeological Setting

Location

The Ahwar Delta extends along the coastline and is approximately bordered by coordinates 130 26'-130 36' N and 460 39'-460 48' E. The total area of the delta is estimated to be approximately 150 km^2, with the greatest width of approximately 17 km at the coast. The delta is part of a large catchment of approximately 6,400 km^2 to the south of a range of mountains running east from Mudiah and rising to over 2,000m some 70 km north of the coast. The steep escarpment of the mountains represents the narrow watershed, with catchments draining in a northeast direction toward the Ramlat as Sabatayn. Because the high ground approaches nearer to the coast, the delta of Wadi Ahwar is less extensive than the deltas of Wadis Tuban and Bana. The gradient of the Wadi Ahwar bed is 1.5 percent–2.9 percent. Starting as a narrow canyon-shaped valley, the wadi eventually turns into piedmont plain, gradually widening to 2 km. The upper reaches of the wadi bed consist of pebbles, downstream sand, then semi-gravel, and eventually compact sand close to the sea. The shape of the bed is lost in the delta area. Figure A27.1 shows the location of Wadi Ahwar, outline of the catchment, and observed wells.

The wadi drains a large area of highly dislocated basement rocks and the inland margins of the quaternary volcanic outcrop. The upper

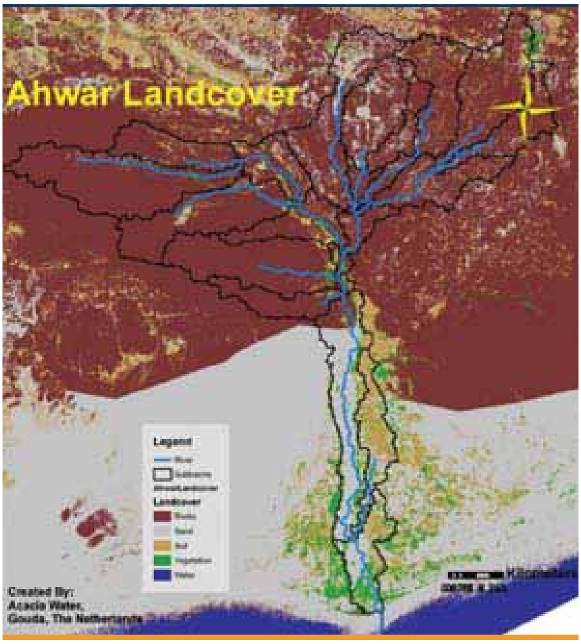
Figure A27.1 Location of Wadi Ahwar, Yemen



Source: Hydrosult, Inc. 2008a.

catchment contains extensive areas of flat plain (Lawdar, Mudiah, Deman, and Guishan areas) that are underlain by alluvium and are reported to be extensively developed for agriculture.

Figure A27.2 Interpreted Landcover, of Wadi Ahwar Region, Yemen



Landcover

The Ahwar region landcover is dominated by rock outcrops and sandy areas. The wadi has scanty vegetation, mostly small shrubs. The small area of soil-covered land is used predominantly for agriculture. Based on satellite imagery, figure A27.2 gives an impression of the landcover of the whole catchment.

Climate and rainfall

The climate in the delta is arid and characterized by high sunshine radiation with an average annual temperature of over 34.2°C. Potential evapotranspiration (ET) is very high, averaging 3,033 mm/year. Average annual rainfall of the whole catchment is 150 mm. Likewise, the estimated average precipitation for the delta is 49 mm. As long-term data are not available, it is difficult to indicate trends in annual rainfall. Also, as mentioned earlier, the spatial variation of rainfall in wadis can be significant. The accuracy of the estimations is therefore unknown.

Groundwater resources system

The water resources in the Ahwar area comprise the wadi flow and the interconnected groundwater system, which is recharged by the wadi flow and by infiltration of the irrigation water. The major part of the rainfall in the catchment generates the surface runoff to the wadi flow. Only a small portion of total precipitation directly infiltrates in the catchment and reaches the wadi flow as lateral groundwater inflow. Beyond the water resources themselves, the water resources system comprises irrigated land and infrastructure such as wells, canals, and weirs. The character of the delta is largely the product of the natural flow of the runoff of the wadi through the delta, constructed surface water diversions, irrigation canal network, and irrigated fields. The wadi itself is shaped by the regular floods that have an average estimated duration of 68 hours. The maximum flood event was reported in March 1982 with a discharge rate of 5,340 m^3/s.

The surface runoff of the wadi is partially diverted and used for spate irrigation. The surface water balance in the wadi has the following components:

- Infiltration and evaporation during irrigation
- Infiltration and evaporation during wadi flow
- Discharge to the sea.

The groundwater balance in the wadi comprises:

Replenishment

- Lateral groundwater inflow
- Recharge during irrigation (transmission losses)
- Recharge during wadi runoff

Discharge

- Consumptive groundwater use
- Groundwater outflow to the sea.

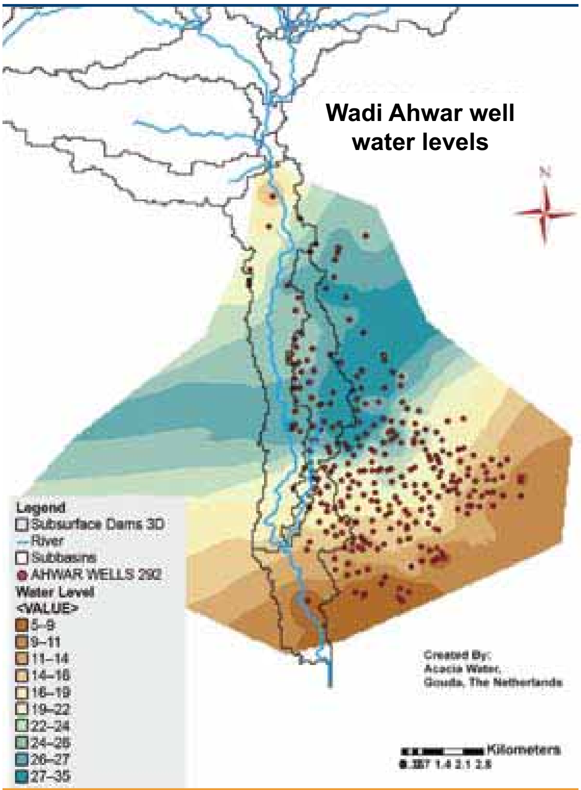
The groundwater system of the delta consists of three major aquifers that are interconnected and most likely form a single aquifer system. The shallow aquifer 10 m–50 m thick occurs in sand and gravel. It is unconfined and hydraulically connected with the deeper aquifers. The middle aquifer consists of gritstone and conglomerate with calcareous matrix. It occurs throughout the delta except for the apex. The thickness of the aquifer ranges between 20 m–40 m. The depth to the top of the aquifer increases to the south from 20 m to 40 m. The deeper aquifer lies at a depth ranging from 70 m to 200 m and consists of sandstone, limestone, and conglomerate.

Groundwater Analysis

Groundwater levels

From June–September 2008, Hydrosult carried out a well inventory in the Ahwar area to ascertain well depths and water levels. The data

Figure A27.3 Well Inventory and Extrapolated Groundwater Levels, Wadi Ahwar, Yemen



were converted into a spatial layer using the advanced GIS software, ARCGIS. By overlaying this data with the drainage layer, the spatial bias of the data is revealed in terms of location of all the observed wells only on the left hand side of the drainage flow direction. There are hardly any observed well data on the other side of the drainage network. These points are scattered well enough inside and outside the catchment area of the drainage to permit interpolation. To have an impression of the groundwater flow and occurrence on the right hand side of the flow, groundwater wells data points were used for interpolation, using the Inverse Weighted Distance method. Moran's I Spatial Autocorrelation Index was used to measure clustering patterns and spatial autocorrelation.

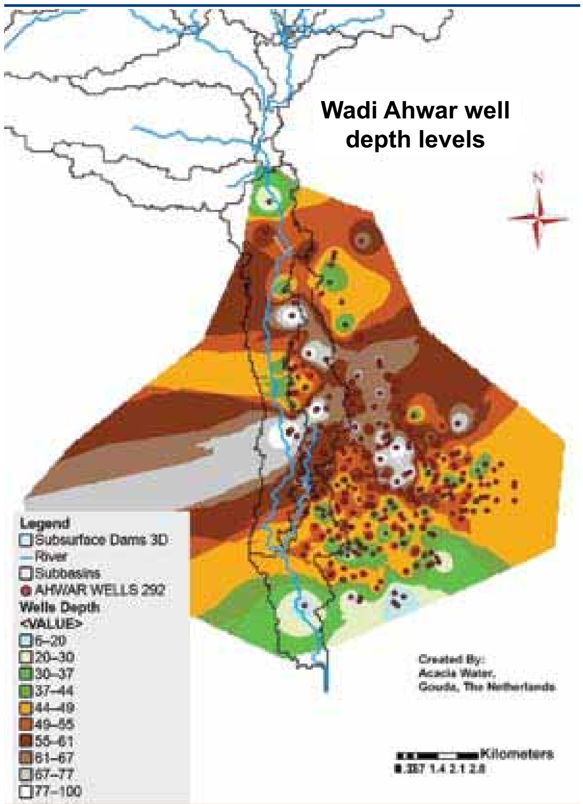
Figure A27.3 indicates shallow water levels in the area closer to the sea. The reason could be the intrusion of seawater in the groundwater aquifer zones. The spatial autocorrelation index is 3.1, which indicates clustering of the well water levels.

Figure A27.4 illustrates the well-depth variance. It indicates a slight tendency for shallower well depths in the area closer to the sea, where water levels are shallow, and in the upper region. The deeper well depths occur in the central delta. The reason for the presence of the relatively low well depths in the upper region could be the availability of surface spate irrigation for longer periods. The middle area shows most of the deeper wells, whose presence could be due to the short duration of availability of surface irrigation as well as the distance from the sea.

Groundwater balance

A 1990 donor-funded study estimated total groundwater resources based on both analytical and mathematical simulations. The total natural storage, defined as the volume of gravitational water accumulated in pores and fissures of water-bearing rock beneath the zone of multiyear fluctuations of groundwater level, was estimated at 1099 Mm^3. Most of this storage is found in the central and southern delta. Storage in the upper two aquifers amounts to 845 Mm^3, including 84 Mm^3 with salt content >5 g/l. The total estimate is based on a storage capacity of 0.19 for gravel/pebbles, 0.1 for muddy sands, and 0.03 for conglomerates. Table A27.1 presents estimates of groundwater balance.

Figure A27.4 Average Well Depth, Wadi Ahwar, Yemen



The different studies provide very different estimates. According to the 1990 study, the total influx from outside the delta is 4.3 Mm^3–4.9 Mm^3. However, the Hydrosult study suggests a total inflow from outside of only 0.7 Mm^3. This difference cannot be explained. However, the difference of the

Table A27.1 Groundwater Balance, Wadi Ahwar, Yemen

Budget items *(total in Mm^3)*	**1988–89**	**1972–88**	**Hydrosult's 2008 estimate**
Groundwater influx from north	0.2	0.2	0.7
Lateral influx	4.7	4.1	
Recharge from spate irrigation	19.5	18.0	10.5
Recharge from wadi runoff			7.4
Total credit	***24.4***	***22.3***	***18.7***
Groundwater outflow	8.9	9.4	
Groundwater abstraction *(netto)*	5.8	3.3	19.0
Evaporation	9.4	9.7	9.7
Total debit	***24.1***	***22.4***	
Balance	**0.3**	**–0.1**	**–9.0**

Source: Hydrosult, Inc. 2008b.

direct recharge from spate or runoff probably results from a reduction of the command area.

Based on the Hydrosult estimate, it could be concluded that mining takes place at a rate of at least 9 Mm^3 per year on average. This rate is supported by field observations of such reported increase of salinization of certain wells. However, given the uncertainty of the figures, particularly the evaporation estimate, it is difficult to draw any hard conclusions regarding over-abstraction and safe yield.

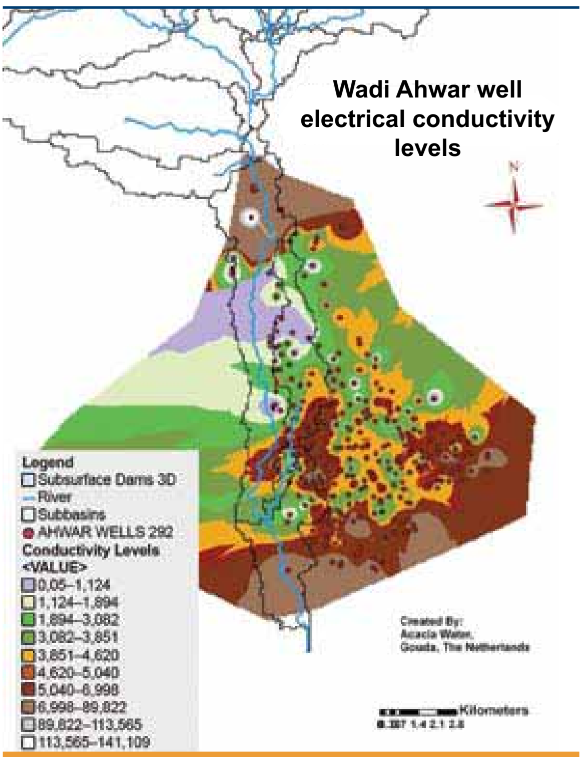
Given an average annual wadi flow of 66 Mm^3, the outflow to sea amounts to almost 50 percent of the total flow. Based on the previous studies, it was estimated that, to prevent saltwater intrusion, groundwater outflow to sea should not be less than 9 Mm^3. However, we would need to consider seasonal variation in wadi flow before concluding whether there is scope for additional safe abstraction.

Groundwater quality and saltwater intrusion

Groundwater salinity in the upper aquifer ranges from 2.5 grams/liter (g/l) to 4.5 g/l, possibly reaching values of 5-9.5 g/l. Total dissolved solids (TDS) concentration increases considerably toward the coastline, reaching a value of 15 g/l. For the middle aquifer, TDS concentration ranges from 1.3 to 1.7 g/l at a reported 1km from the wadi channel to 2.3 g/l measured at other locations. TDS concentration in the lower aquifer is reported to be no more than 2 g/l. The local population reportedly has to use brackish water for domestic purposes: with TDS of up to 1.5 g/l (3600 persons); 1.5–3 g/l (8400 persons, including the population of the city of Ahwar); and even more than 3 g/l (approximately 1,000 persons).

No data is available from previous studies about the position of the saltwater front in the delta. It was concluded, however, that a

Figure A27.5 Average Electrical Conductivity Levels, Wadi Ahwar, Yemen

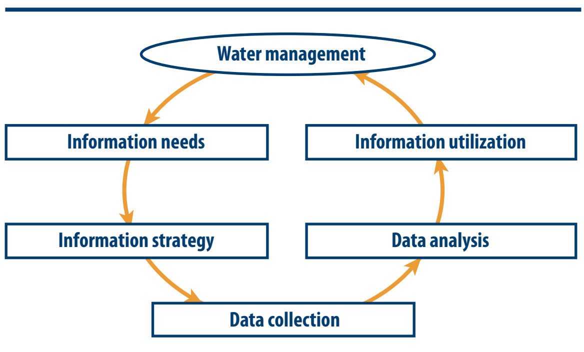


saltwater intrusion at some coastal producing wells is likely as a result of a continuous groundwater abstraction. A GIS analysis was performed on water quality data as observed by Hydrosult (2008) showing higher conductivity levels (that is, higher electrical conductivity, or EC) near the coast. Observations and discussions in the field also have shown strong evidence of saltwater intrusion, with a direct consequence on the viability of agriculture in these areas. However, lack of historic data prevents an analysis of trends over time.

Figure A27.5 indicates the spatial occurrence of EC in the groundwater observations. The pattern suggests that conductivity not only is influenced by seawater intrusion but also may be affected by other factors such as soil types, leaching effects, and pre-existing saline groundwater.

Future Water Demands

No information is available about future water requirements in the delta. No strong population growth is expected. However, due to the increasing use of diesel pumps, abstraction of groundwater is expected to continue to grow. The growing abstraction will strongly determine future demand.



References

Haile, A.M. 2007. *A Tradition in Transition: Water Management Reforms and Indigenous Spate Irrigation Systems in Eritrea*. Taylor & Francis Group. The Netherlands: A.A. Balkema.

Hydrosult, Inc. 2008a. Hydrosult Feasibility Study for Irrigation Improvement in Wadi Ahwar, supported by the World Bank-financed Irrigation Improvement Project (2000–08). Montreal. www.hydrosult.com/

____. 2008b. "Groundwater Assessment: Irrigation Improvement Project." Draft report. Montreal. www.hydrosult.com/

IWMI. *Water Scarcity and the Role of Storage in Development*. IWMI. 2000. Research Report 39. Colombo. www.lk.iwmi.org/Pubs/Pub039

Maimore, M. 2004. "Defining and Managing Sustainable Yield." *Groundwater* 42 (6).

Wheater, H., and A.A. Radwan. 2002. "Hydrology of Wadi Systems." IHP Regional Network on Wadi Hydrology in the Arab Region. UNESCO, Paris.

World Bank. 2008. "Republic of Yemen, Groundwater and Soil Conservation Project and Community-Based Water Management Project." Technical Mission Report April 7–17.

World Bank/GW-MATE (Groundwater Management Advisory Team). 2003. "Yemen: Rationalizing Groundwater Resource Utilization in the Sana'a Basin." Case Profile 2.

Appendix A1. List of Authors

Safwat Abdel-Dayem
Consultant
Safwat_eid@hotmail.com

Rachid Abdellaoui
Consultant

Nathalie Abu-Ata
Operations Officer
WBIRC
World Bank
nabuata@worldbank.org

Naji Abu-Hatim
Senior Rural Development Specialist
MNSSD
World Bank
Nhatim@worldbank.org

Maher Abu-Taleb
Senior Water Resources Management Specialist
MNSSD
World Bank
mabutaleb@worldbank.org

Abdulhamid Azad
Senor Irrigation Engineer
MNSSD
World Bank
aazad@worldbank.org

Aldo Baietti
Lead Technical Specialist
WBISD
World Bank
Abaietti@worldbank.org

Alexander Bakalian
Lead Water Resources Specialist
MNSSD
World Bank
abakalian@worldbank.org

Mohammed Benouahi
Lead Water and Sanitation Specialist
MNSSD
World Bank
Mbenouahi@worldbank.org

Julia Bucknall
Lead Natural Resources Management Specialist
MNSSD
World Bank
Jbucknall@worldbank.org

Richard Calkins
Consultant
MNSSD
World Bank
rcalkins@worldbank.org

Xavier Chauvot de Beauchêne
Water and Sanitation Specialist
MNSSD
World Bank
xchauvot@worldbank.org

Susmita Dasgupta
Lead Environmental Economist
DECRG
World Bank
SDasgupta@worldbank.org

Arjen de Vries
Consultant
Acacia Water (Solutions in Groundwater)
Arjen.devries@acaciawater.com

Hani El Sadani
Senior Water Resources Engineer
MNSSD
World Bank
helsadanisalem@worldbank.org

Tarun Ghawana
Consultant
Acacia Water (Solutions in Groundwater)
Tarun.Ghana@acaciawater.com

Maged Hamed
Senior Environmental Specialist
MNSSD
World Bank
mhamed1@worldbank.org

Sarah Houssein
Consultant

N. Vijay Jagannathan
Sector Manager Water
MNSSD
World Bank
Njagannathan@worldbank.org

Khairy Al-Jamal
Senior Infrastructure Specialist
MNSSD
World Bank
kaljamal@worldbank.org

Marc Jeuland
Consultant

Claire Kfouri
Water and Sanitation Specialist
MNSSD
World Bank
ckfouri@worldbank.org

Alexander Kremer
Senior Sector Economist
MNSSD
World Bank
Akremer@worldbank.org

Manish Kumar
Consultant
manishkr67@gmail.com

Mohamed El Hedi Louati
Ministry of Agriculture and Water Resources, Tunisia
louati@iresa.agrinet.tn

Andrew Makokha
Senior Water and Sanitation Specialist
AFTU2
World Bank
Amakokha@worldbank.org

Pier Mantovani
Lead Water and Sanitation Specialist
MNSSD
World Bank
pmantovani@worldbank.org

Mohammed Mehany
Operations Analyst
MNSSD
World Bank
mmehany@worldbank.org

Craig Meisner
Environmental Economist
ECSSD
World Bank
Cmeisner@worldbank.org

Juan Morelli
Consultant
Jbmorelli@hotmail.com

Jackson Morill
Consultant and Associate
Beveridge & Diamond P.C.
Washington DC
jmorrill@bdlaw.com

Sana Agha Al Nimer
Senior Water and Sanitation Specialist
MNSSD
World Bank
saghaalnimer@worldbank.org

Bekele Debele Negewo
Water Supply Specialist
MNSSD
World Bank
bdebelenegewo@worldbank.org

Christopher J. Perry
Consultant
chrisjperry@mac.com

Richard Pollard
Senior Water and Sanitation Specialist
MNSSD
World Bank
Rpollard@worldbank.org

Manuel Schiffler
Senior Economist
LCSUW
World Bank
Mschiffler@worldbank.org

Ahmed Shawky Mohamed
Senior Water Resources Specialist
MNSSD
World Bank
Ashawky@worldbank.org

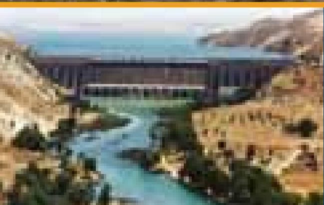
Jose Simas
Consultant
Jsimas@worldbank.org

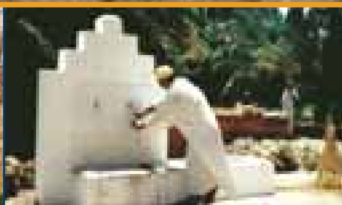
Ayat Soliman
Senior Natural Resources Management Specialist
MNSSD
Asoliman@worldbank.org

Satoru Ueda
Senior Water Resources Specialist
AFTWR
World Bank
sueda@worldbank.org

Wendy Wakeman
Lead Social Development Specialist
MNSSD
World Bank
Wwakeman@worldbank.org

Christopher Ward
Consultant and Researcher
Institute of Arab and Islamic Studies
University of Exeter
wardcsward@aol.com





THE WORLD BANK
Middle East and North Africa Region (MNA)
1818 H Street, N.W.
Washington, DC 20433