in_**focus** from research to policy

# Water

## LOCAL-LEVEL MANAGEMENT

by David B. Brooks

International Development Research Centre

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# Foreword

When the International Development Research Centre (IDRC) was created in 1970 "to initiate, encourage, support and conduct research into the problems of the developing regions of the world," it immediately turned its attention, and some of its financial support, to water-related research. Its early focus on supply technologies — such as inexpensive, simple-to-use handpumps — evolved to encompass water treatment and quality control, and has more recently broadened to questions of conservation and management. In doing so, IDRC has recognized that the water crisis is, as reflected in the summary report of the World Water Vision, "a crisis of managing water so badly that billions of people — and the environment — suffer badly." It has also recognized that local organizations and communities who have the most at stake are key to effective management of scarce water supplies.

This book synthesizes IDRC's experience in local water management and presents a number of pointed, well-constructed recommendations for decision-makers, policy analysts, and researchers. From a review of the issue of freshwater supply and local water management, it explores examples of IDRC-supported field research in three broad, interconnected categories: small-scale water supply; wastewater treatment and reuse; and watershed management and irrigation. Based on this research, a series of policy-relevant results are addressed in propositions aimed at decision-makers and researchers in government and beyond.
To summarize:

**For decision-makers:**

- ➛ Water management research can generate powerful consequences for politics and policy.
- ➛ Decision-makers make a big mistake when they dismiss small groups and small solutions, as they often do.
- ➛ Distributing the costs and benefits of managing scarce water imposes hard choices. Making those choices, and giving them effect, requires institutional capacity.
- ➛ There is one iron rule for managing groundwater and aquifer supplies: assume the worst.
- ➛ Successful local water management requires, and deserves, close collaboration between communities and governments.

**For researchers:**

- ➛ Hard data can pay rich dividends, even when outcomes disappoint.
- ➛ Local participation and local education increase the chances for successful and effective research.
- ➛ Scaling up can generate welcome economies but intensify inequalities. Both effects need to be understood.

- ➛ Scaling up can succeed where institutions are capable of distributing the gains and the costs.
- ➛ Social and economic factors are always important in local water management. Sometimes they are paramount.

**Armed with these propositions, the book goes on to advance the following recommendations for policy and for research:**

- ➛ Up, down, and sideways: local water management should always be informed by a three-part economic analysis.
- ➛ Policy and research should shift their focus from enlarging supplies of water to managing demand.
- ➛ Policymaking should always start by accepting social custom and cultural norms as given, but not sacrosanct.
- ➛ Beware of generalizations, but share knowledge promptly.
- ➛ To achieve good government, and good science, evaluate in a transparent, participatory, and continuous manner.

Finally, the book plots some future directions in which faster progress can be made in both the science and the conduct of local water management.

About a decade before the 1997 formation of the World Water Council and its vision exercise, IDRC had begun to place greater emphasis on participatory research and on community-based approaches to development. Thus, it is entirely appropriate that this effort to bring its research on water directly to the attention of policy analysts and decision-makers should deal with local water management.

Devolution of the power to **manage** water (not just read metres and fix leaks) will not come easily. The forces to maintain a top-down approach to water are well entrenched and serve many power elites. However, it will not come at all without a vision that indicates that, in the right circumstances, management by villages, communities, nongovernmental organizations, and water-users' associations may be the most appropriate way, not just to deliver water, but also to conserve its quality and its quantity. If this publication expands recognition of that vision, it will have achieved its purpose.

***Margaret Catley-Carlson***
January 2002

Margaret Catley-Carlson is Chair of the Global Water Partnership, a member of the World Water Commission, and a governor of Canada's International Development Research Centre. She is former President of the Population Council, a nonprofit, nongovernmental research organization established in 1952. Prior to joining the Council, she was Deputy Minister of Health and Welfare Canada, President of the Canadian International Development Agency, and Deputy Executive Director (Operations) of UNICEF.

# Preface

Local and community-based water management seems to be an old idea whose time has come again. For too many years, the role of local people has been, if not totally ignored, at least downplayed. Not that the developing world suffered from any failure to see water as a problem, or from the absence of water projects intended to alleviate scarcity. Just the reverse.

Scarcity of fresh and potable water was all too evident, and development projects abounded. National governments together with donor agencies and international financial institutions built new supply systems at all scales, from water pumps to massive dams. And to some degree these technical fixes worked. Fresh water was brought to many households and many farms, and capacity was built in formal and informal institutions to respond to water scarcity. These are no small accomplishments, and, in the renewed enthusiasm for decentralization and local management, they should not be ignored.

Despite the gains, however, the water projects of the first several development decades, by and large, fell short of their original promise. Many reasons could be cited: principal among them is that technical solutions to water scarcity were designed to mould social and cultural factors rather than the other way around. Only in the last decade or so have we come to recognize that, if efforts to improve the quantity or quality of water supply are to be successful, not only must they be technically sound and economically feasible, they must also deal directly with poverty alleviation, local empowerment, and ecological protection.

As a pioneer in supporting research for development, IDRC rightfully joined the rest of the development community in devoting a part of its program budget to work on water supply. For the first 20 years, the bulk of this work was technical: improved water pumps and rooftop water harvesting, for example. Gradually, studies began to include farmers or villagers in the research team and to consider options for "community-based" water security. Until, by the mid-1990s, the emphasis was clearly on socioeconomic and behavioural aspects of water supply. Today, the focus of IDRC's work has shifted to demand management and the devolution of water management to lower levels of government and communities.

Recognizing that IDRC is not alone in this shift to a more institutionally focused approach, one purpose of this book is to share IDRC's research results with other donors and other research institutions. Further, it recognizes that lessons learned from earlier work must inform and guide such projects. This publication does just that, encapsulating what has been learned from 30 years of IDRC-supported research on the potential and limitations of local water management. Donors and research institutions, nongovernmental and community-based organizations, national government agencies and municipal governments — it is for decision-makers in these organizations that this publication is primarily intended.

Many people contributed to the preparation of this book. Thirty years of IDRC project staff and associated researchers in Canada and throughout the developing world are the ultimate source. Interns Sarah Wolfe and Tilly Shames assisted in the search and review of the IDRC water portfolio and helped me to glean indications of greater or lesser success with community involvement. Finally, John Hay, an Ottawa-based writer, took on much of the task of drafting the original text. He and I interacted almost daily over a 3-month period of intense writing and review. I am very grateful for his contribution.

There have been too many assumptions and too few scientifically documented studies of local water management, and indeed other forms of local natural resource management. I hope that this synthesis for decision-makers will contribute to the learning process, and that it will stimulate the research and experimentation necessary to determine when community-based water management can be efficient, equitable, and sustainable.

***David B. Brooks***
January 2002

David B. Brooks is a specialist in natural resources who works with the International Development Research Centre in Ottawa, Canada. Dr Brooks has a background in geology and economics and was the founding director of Canada's Office of Energy Conservation, Dr Brooks worked for 6 years with Friends of the Earth and then for 5 years as a principal with the firm of Marbek Resource Consultants Ltd. His main research interests lie in ways to move toward more sustainable development in the production and use of minerals, energy, and water. His most recent books are *Watershed: The Role of Fresh Water in the Israeli–Palestinian Conflict* (IDRC 1994), which he coauthored, *Management of Water Demand in Africa and the Middle East* (IDRC 1997), which he coedited, and *Water Balances in the Eastern Mediterranean* (IDRC 2000), which he also coedited.

**Part 1**

# The Issue

Water scarcity threatens us all — menacing our well-being, jeopardizing our livelihoods, and sometimes endangering our lives. In more prosperous countries, water shortages curtail economic growth and diminish the quality of life. In poorer countries — especially among poor people — the scarcity of good water in adequate quantities already counts as a deadly affliction. It breeds sickness, blocks development, deepens inequalities of income and opportunity, and undermines the survival of entire societies. The natural environment is everywhere imperiled by these scarcities, and by misguided attempts to overcome them. When water scarcity occurs at the boundaries of ethnicity or privilege, or at international borders, or between urban and rural communities, it can intensify the risk of conflict.

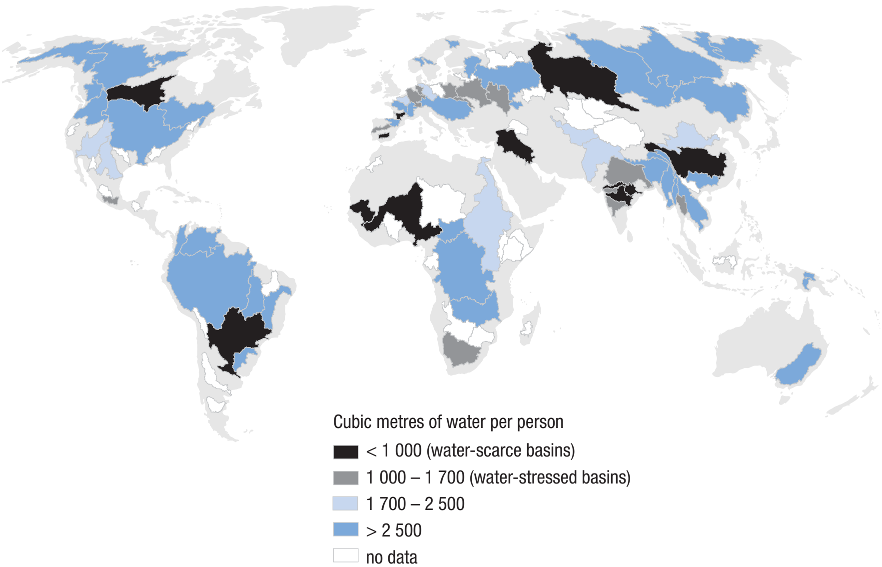
It is fair to answer that water scarcities are hardly new to the human condition. True. The Bible, the Koran, and other scriptures are rich with references to water — and to water-based conflict. But present and future scarcities matter more than ever before, and to more of us. Population growth, industrialization, and urbanization are depleting and polluting lakes, rivers, and aquifers irreversibly. New technologies empower us to extract water supplies faster than the rate of replenishment. Catastrophic human-made environmental damage is done on a global scale never before possible. And with the integrating forces of globalization, we are all now implicated in the troubles of others, no matter how distant. (The Algonquin needn't have concerned themselves with the droughts of ancient Assyria; ignorance and indifference toward foreign tribulations are no longer options in the present age.)

These are the hard facts. As reported in 2001 by the United Nations Population Fund (UNFPA), the global population has tripled in 70 years while water use has grown six-fold. Within the next 25 years, fully one-third of the world's population will experience severe water scarcity. Right now, more than 1 billion people lack access to safe drinking water; 3 billion people (half of everyone on Earth) lack access to basic sewage systems. More than 90 percent of all the sewage produced in the developing countries returns to the land and water untreated. For many millions of people, freshwater scarcity is defined as much by poor quality as by insufficient quantity.

Such statistics, alarming enough, actually understate the scarcity problem. All but a small fraction of available fresh water is needed to grow food; much of the rest must be left in place for transportation, fishing, hydro-generation, and many other uses (not to speak of sustaining the environment itself). Moreover, disparities of availability create dramatic inequalities. China, for example, accounts for 7 percent of the world's renewable freshwater supplies — but 22 percent of the world's population. Canada, with about half a percent of the world's population, accounts for 9 percent of the world's renewable fresh water. More than half the planet's fresh water is contained within just 10 countries.

And scarcities are spreading (see Figure 1).Water-scarce countries are customarily defined as those with less than 1 000 cubic metres of fresh water available per person per year — not enough to provide adequate food or support economic development, and a potential cause of severe environmental difficulty. Countries with 1 000 to 1 700 cubic metres per person per year are said to be water-stressed. UNFPA calculates that 508 million people lived in 31 water-stressed or water-scarce countries in 2000; by 2025 those numbers will likely rise to 3 billion people in 48 countries. The number of people suffering water scarcity will double in 25 years, and the total living with water stress will be six times higher by then. All of this will happen even though global water consumption has recently begun to level off, growing now only at about the same rate as global population.

**Figure 1.** **Worldwide availability of fresh water.**
(adapted from *Watersheds of the World*, World Resources Institute 1998)



Managing these disparities effectively and fairly constitutes one of the great imperatives of governance that now confront us. But it is an imperative complicated by still other hard facts. Water is a renewable resource, in the sense that the global hydrological cycle turns endlessly through the dynamics of evaporation, condensation, and runoff. In every practical way, however, the global supply of fresh water available for human use is fixed while human demand is ever-growing. In some places the supply is severely insufficient, and declining by the day.

More to the point, water has no substitute. The entire biosphere survives on water, not least for a constant resupply of oxygen. Unlike other scarce and diminishing resources, water cannot be replaced by the invention or discovery of some liberating alternative. We need water; nothing else will do.

Facts like these generate their own consequences — and raise urgent issues of water management. The scarcity of water, like any resource scarcity, imposes the inevitable questions: Who gets how much? At what cost? And at what price, if any? But there are deeper questions that also need to be addressed: Who decides? By what procedures? What features of governance will most likely produce management decisions that are fair, effective, and environmentally sustainable?

These and other issues, taken together, shape the political economy of scarce water. They test our collective capacity — as communities, countries, and participants in the international system — to accommodate competing interests and to reconcile rival claims. The best answers include, as often as not, the application of good technology, some of it embedded in traditional knowledge and some of it inspired by fresh science and new insight. Inevitably, only in the processes of good governance will issues of fair and effective and environmentally sensitive management be resolved. In the end, managing scarce fresh water requires the development of institutions that are open, informed, participatory, and responsible.

## Why local water management?

It is now conventional wisdom (and true as well) that water scarcities typically reach beyond community boundaries and political borders; they are generally the shared problems of countries and continents. Indeed, for many countries, the water body is the border. About 40 percent of the world's population lives now in river basins shared by more than one country. Scores of communities (think of Israel and Palestine) rely for drinking water on the same over-stressed aquifers. This is why water scarcity, ill-governed, so frequently raises the risk of conflict. It is also why, importantly, people find ways to manage shared water much more often by cooperation than by warfare. In short, sound water management both requires and impels national, regional, and international action.

But national and supranational strategies alone are not enough. Experience around the world proves that local management is essential to the sustainable exploitation of scarce water supplies. In the first place, large-scale, centralized water management has proceeded about as far as it can in many regions. In those places, there are no more big rivers to dam; aquifers are being mined to exhaustion; vast irrigation schemes have reached their limits; decision-making itself grows remote and cumbrous. Big engineering projects — productive or not — are also growing increasingly expensive. They cause great and in some cases intolerable harm to the environment. And they frequently incite a justifiable fear and resistance (as when megaprojects are imposed on the territories of indigenous peoples). Even if international conflict over water is rare, domestic and intercommunal conflict is not. Countries may not go to war for water, but governments do fall because of failures to deliver enough good water to their own citizens.

Community-based natural resource management — and specifically water management — must play a critical part with those larger approaches in solving scarcity problems. Local water management permits a democratizing decentralization of decision and accountability. Well done, it empowers people (particularly the poor and otherwise disadvantaged) to take part in the decisions that define their own futures. And it encourages the integration of traditional knowledge with innovative science to promote fair and efficient supply management. In these ways, water degradation and shortage can be transformed into sustainable sufficiency.

## That's the theory. Does it work in practice?

The following pages describe the confirming lessons learned in 30 years of applied research supported by Canada's International Development Research Centre (IDRC) in partnerships throughout the developing world. This is neither a treatise in hydrology nor an essay in resource economics. Instead, it is intended as a compact summary of relevant findings, immediately useful to the design, execution, and evaluation of local water policy. It might also serve, in some modest degree, as a call to practical action.

The discussion moves first to an examination of field research approaches in three broad and interconnected categories: small-scale water supply technologies; wastewater treatment and reuse; and watershed management and irrigation. Next, policy-relevant results are addressed in a series of propositions aimed at decision-makers and at researchers in government and beyond. Armed with these results, specific recommendations are then advanced for policy and for research. Finally, future directions are plotted where progress can be accelerated in the science and the conduct of local water management.

Readers will detect the recurrence of two themes running through this publication. The first concerns the enduring worth of traditional knowledge, as inherited and practiced by women and men in their own communities over the generations. The second theme concerns the central importance of good governance in carrying out water research, and in the timely application of research to policy and management. Successful governance and research each demand an alert sense of a community's social, cultural, and political structures — including most particularly its power structures. In truth, these two themes converge on one basic principle: people need to be engaged in the decisions affecting their lives.

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Part 2

# The Approaches

To repeat: Water scarcities occur on local, regional, and even global scales. Their damaging effects are most persistent and dramatic in arid and semi-arid areas, where the capture and conservation of water are age-old and compelling preoccupations of life. (Arid and semi-arid watersheds are home to about one-sixth of the world's people, but nearly three-quarters of the world's poorest people.) Nowadays, however, scarcities intrude just as harmfully on communities less accustomed to coping with freshwater shortages — from the high, cool valleys of the Himalayas to the muddy hillside favelas of tropical cities. These are the scarcities of inadequate rainfall, the depletion and pollution of freshwater sources, and the pressures of urban population densities — compounded ordinarily by government neglect and mismanagement.

Decades of research have demonstrated that some of the most powerful responses to these scarcities have been mounted at the level of households, farmers' fields, villages, and city neighbourhoods. It often turns out that traditional practice points the way to more effective local management of water supplies, particularly when reinforced by science-based innovation. And almost always, successful applications of research and management are determined as much by social, economic, and political factors as by any choice of technology. Armed with good information and sufficient autonomy, people usually prove to be reliable conservators of their own local resources.

What follows, therefore, is a short survey of three approaches to local water management — with a focus on the findings (and the failures) most relevant to improving policy and practice.

## 1. Small-scale water supply

### Fog catchers

They flutter delicately on the tops of coastal cliffs — long and wispy polypropylene nets, glistening with moisture, transforming windborne mists into precious water for thirsty villages on the slopes below.

Fog catchers represented an ingeniously simple idea. A fine mesh netting was braced against the damp wind, so that water would condense on the filaments, then collect in troughs and flow by pipe to where it was needed (see Figure 2). At a stroke, arid stretches of coastal Chile, Peru, Ecuador, and several other countries around the world were seizing much-wanted water out of thin air.

First developed (with funding from IDRC and UNESCO) in the mid-1980s, fog collection actually imitates the work of nature. Trees serve as natural fog catchers; a forest growing in an arid area can drip as much water into the dry soil as might ever arrive

**Figure 2.** **Fog-catching technology is sound. Yet, for a number of reasons, fog catchers have not succeeded in practice.**

through rainfall. And the technology has proven sound. By the early 1990s, a local array of fog catchers in Chile was producing some 11 000 litres of water daily — enough to supply everyone in the nearby village with about 33 litres a day. (That was more than double the amount they were paying to have delivered by truck.) Similar results have since been achieved in places as diverse as Mexico, Nepal, South Africa, and Oman.

Yet, for all their technical elegance, fog catchers have not succeeded as well in practice. The reasons are instructive.

First, follow-up research has shown that producing water from fog — even in arid reaches — can be costlier than available alternatives. Costs are acutely sensitive to the distance between the nets (usually on remote clifftops and hillsides) and the nearest village of consumers. In the case of the main Chilean test site, the system required 6 kilometres of PVC piping.

Second, fog catchers are fragile and demanding, both physically and socially. Nets tear, pipes leak, and wind can blow the whole structure over. Continuous maintenance calls for a new kind of governance that has to be organized and sustained by the local community.

Third (and maybe partly as a consequence), fog catchers come to be regarded by local communities as second-class water sources — attractive only until villages are connected to pipelines or some other "modern" supply system. In Chile, moreover, much of the fog water was consumed not as drinking water but for horticulture and forestry. In part, this was ascribed to public concerns about airborne contamination by heavy metals from area mines.

Results of these and other experiences will be assessed with more detail in the next part of the publication. It is enough here to draw four brief conclusions about fog catchers. The first is that fog catchers can supply small volumes of potable water where alternatives are inaccessible or unaffordable. The second conclusion is that they are no substitute for conventional water systems where such systems are available and adequate. Third, technical innovation was not matched in these cases by an equally close attention to issues of cost, pricing, and institutional maintenance. And fourth — this key, because it is typical — research on fog collection has already taken new and unexpected directions with potential payoffs greater than imagined for the original projects. In settings as different as Sweden, Israel, and Tanzania, researchers are experimenting with harvesting dew — taking the moisture from the night winds that blow across even the driest deserts.

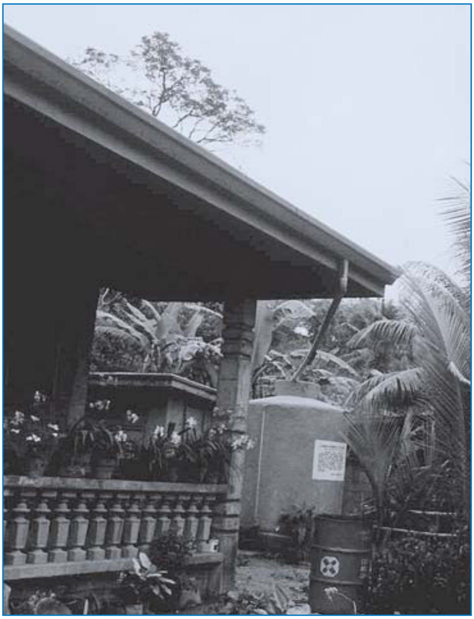
## Rooftop water harvesting

In dusty villages of the Jordan Valley, on the high plains of East Africa, among the paddies of Southeast Asia (and on pioneer homesteads of North America), rooftop water harvesting has been practiced for centuries. It is commonest in arid and semi-arid zones, but familiar too in monsoon climates of seasonal downpours and on islands where fresh water is never plentiful.

Depending on local custom and materials, roofs may be sloped or flat, solid or thatched. But the real variations — and the research challenges — emerge when it comes to moving the collected water and storing it. This is where the tough technical problems with roof water arise: in keeping the water clean and in engineering cost-effective storage (see Figure 3).

Research in the Middle East, Africa, and Asia has consistently shown that designing and maintaining safe and healthy water-storage systems can prove taxing even where rooftop water harvesting is an established tradition. At a minimum, the water must be allowed first to wash off the roof. And for obvious reasons, birds need to be kept away. Then the saved water must be stored in closed containers or impermeable cisterns if it is to be used for drinking or washing; in addition, methods of taking water from storage must be sanitary. Finally, the cistern or reservoir must be located away from pollutants.

**Figure 3.** **Rooftop water harvesting is a proven and mature technology. Application requires little more than community energy and organizational will.**



Still, all these projects confirmed the great potential of rooftop water collection. In Gaza City — with a scant 400 millimetres of rain per year — appropriately designed systems could provide enough clean water to satisfy the drinking, cooking, and hand-washing needs of a family of six indefinitely.

The impediments to deploying rooftop systems more extensively and productively are partly organizational, partly economic. Dissemination of methods (and enthusiasm) will not occur in communities without practical demonstrations of effectiveness and durability. Textbook designs must be adapted to local circumstances and local expectations. In most cases, community-level training in construction and maintenance (often with the engagement of local schoolteachers) was necessary. All of which takes continuing organization to accomplish.

That leaves issues of cost, especially for storage tanks. In Palestine, as elsewhere, ferrocement has been found to perform best for durability and clean maintenance. But at an installed cost of roughly US$200 per household, this is more than many families can afford. Two policy responses present themselves:

1. Alternative pricing and payment schemes can be devised — including a modest subsidy element justifiable as a worthwhile social benefit.

2. Storage cisterns can be designed and built to serve several families or a city block together — cutting unit costs through economies of scale, but requiring some system of ensuring fair distribution.

All of these innovations — in demonstrations, training, financing, local maintenance, and sharing stored water — demand institutional capacity-building. Fortunately, research finds that construction and maintenance generally fall easily within the capabilities of local people; frequently women lead in learning the skills of protecting healthy water quality. In nearly every project, nongovernmental organizations (NGOs) were active in design, knowledge dissemination, and construction.

By and large this is a proven and mature technology. Application requires little more than community energy and organizational will. This necessary community engagement is another point to be taken up again in the next part.

### Field water harvesting

Diverting and gathering scarce rainwater — for household gardens, watering stock, and even drinking water — have busied communities for thousands of years. Field water harvesting is seen most obviously in semi-arid areas, where losses to evapotranspiration can be four or five times greater than rainfall in a year. It works best as a rule where there is not enough rain to support agriculture without intervention, but enough rain to produce crops at least in occasional years.

Rich varieties of local technologies have developed over the millennia, from simple dikes, ditches, and embankments to the sophisticated tunnel systems of Syria — the "qanats" built to carry water over many kilometres from mountain sources to farm fields and cities. Palmyra, a Syrian metropolis in Roman times, existed like other cities in the region only on the strength of its capacity to gather, move, and store fresh water.

Too often, and for diverse reasons, traditional methods of harvesting field water have fallen into disuse or failed to match new and growing demands. IDRC-funded research has therefore focused on two objectives. The aim in some projects has been to discover whether more or less conventional water-harvesting techniques can be applied in unconventional places, or with unfamiliar communities. In other projects, the objective has been to scale up old methods to cover much wider areas, with new technologies like satellite-aided mapping and complex mathematical models for slope and soil analysis, crop selection, and rainfall tracking.

Most of these projects (in Kenya, Jordan, Yemen, and Syria) can be counted as successes (see Box 1). Some have demonstrated that old water-harvesting strategies, with new methods, can be made to work at scales measured in the hundreds of hectares. A few have revealed how integrated approaches to land and water management can optimize the uses of water and save soils.

### 1. Restoring Traditions, Conserving Resources

In the stony highlands of Yemen, rainfed farming developed centuries ago on an intricate system of handmade terraces. These terraces conserved fertile soils and controlled erosion — albeit at the cost of brutally hard labour. But for the last 30 years many of the terraces have collapsed into disrepair and disuse; fertility has been lost while erosion has accelerated.

Collaborating with the International Center for Agricultural Research in Dry Areas, IDRC-supported researchers set out to discover the causes of this degradation, with the aim of designing policy that would restore agriculture, improve food security, and increase rural incomes. As usual in such investigations, the causes turn out to be varied and complex.

Work on the water-saving terraces had fallen off in part because the men of these communities were drawn away to higher-paying city labour. But researchers uncovered other reasons as well: a lack of clearly distributed obligations between tenants and landowners for field maintenance and cost-sharing, and the inaccessibility of credit for farmers to invest in their own water management.

Experimentation found new ways to rebuild and buttress ancient terraces, with less labour and at acceptable costs. But in the course of the project, there was this added and unexpected discovery: as job prospects declined in the cities, farmers who returned were eager to test new crops and methods even as they revived old ones. Conserving field water made food production suddenly more profitable.

In short, reviving traditional water management approaches can require both technical and policy ingenuity. But the rewards can be significant — and surprising.

What these projects also show, however, is that promising research results seldom translate effortlessly into acceptance by local farmers and householders. Outcomes indicate that smaller and less complicated approaches are more likely to be adopted and put to lasting use than grand designs of integrated resource management.

On the Syrian steppe, multiyear research on integrated resource development has generated valuable data on erosion control and dike design for significant improvements in cropping and revegetation, for example. But it also demonstrates that altering the land for better water harvesting requires significant investment, which will only be forthcoming if credit is made available to either public or private enterprises. Even then, the price received for crops grown with this water must be high enough to cover costs. This implies either specialization in high-value market crops and larger flocks, or subsidies for some part of the cost to reflect the value both of rural employment creation and of protecting the steppe environment.

This is the sort of socioeconomic analysis that almost invariably emerges as central to productive new initiatives in water management. In the Syrian case, promoting high-value market crops and large flocks would benefit mainly those who are already better off; subsidizing the social and environmental gains, on the other hand, would shift more of the benefits to poorer families.

## Aquifer protection and recharge

Strictly speaking, "aquifers" are geological layers holding water, whether in sand or gravel or flowing through the pores, seams, and fractures of bedrock. ("Aquifer" in its Latin roots means "water-bearing.") In common parlance, aquifer also refers to the prized water itself — subterranean and still not fully understood bodies of water slowly flowing through bedrock and the deepest subsoils. Extending in some cases under thousands of square kilometres, with hundreds of kilometres from their rainfall sources to the springs and seeps where they emerge, aquifers are vastly important sources of water. And they are compromised almost everywhere by overuse and contamination.

From the Sahel to Latin America to Indonesia, aquifers are suffering the desperate effects of bad management (or no management at all). In many regions, freshwater supplies from aquifers have declined catastrophically; some have completely stopped, at least in the dry seasons. The quality of aquifers has also been degraded, either by the salinization that frequently follows the reduction of water pressure from over-pumping, or by infiltration of fertilizers, chemical wastes, and other contaminants.

Aquifer stress qualifies as a genuine crisis in many parts of the world, and specifically in urban Latin America where many cities are inescapably dependent on these sources. (The water table in the Mexico City area dropped 20 metres in only 50 years.) As a result, IDRC has encouraged new research on the protection of known aquifers and the development of new ones. At the University of Costa Rica, for example, an IDRC-supported Master's Program in Water Resources and Hydrogeology has fostered new studies of local and urban aquifer protection and recharge (see Box 2).

In the Middle East, meanwhile, IDRC-funded researchers from Israel and Palestine have been working together to design joint management of their shared Mountain Aquifer. Although the Mountain Aquifer derives almost all its intake from the West Bank, most of its storage area and springs are concentrated in Israel. And because it flows so fast, great efforts have to be expended to prevent the rapid spread of pollution. So researchers were first obliged to conduct some basic hydrologic fact-finding. Since then they have developed a model for joint and sustainable management — promoting it to policymakers in both communities for implementation. (In these small countries, so reliant on limited water, the relationship between researcher and policymaker tends to be close; in a few cases they are the same person.)

## 2. Building Capacity for Aquifer Management

It was a bold presentation — and potentially worth millions of dollars to the hard-pressed people of Nicaragua. More than that, it gave proof that developing countries can build their own capacity for better local water management.

In 1997, officials in Managua were concluding that the city's aquifer, lying right below the capital, would soon be exhausted. (Managua is not alone in this plight. Most Central American cities are faced with declining water tables.) The only apparent alternative, specified in Managua's water plan, was to seek out and develop a new water source far from the city's boundaries.

But Managuans were saved from the cost of abandoning their aquifer by the meticulous and convincing analysis presented by a member of Nicaragua's own Environment and Natural Resources Ministry. He explained how the Managua aquifer, after more than 70 years of pumping, still had plenty of water left — if managed well and protected from pollution.

The author of this analysis had been among the first graduates of the University of Costa Rica's Master's Program in Water Resource Management and Hydrogeology. Launched in 1993 with IDRC support, and in collaboration with Canadian researchers, the program admits students from the seven Central American republics with the aim of helping them achieve greater water management capacity. Most of the early theses addressed problems of aquifer depletion or degradation.

Population growth, urbanization, and industrialization have put at serious risk the freshwater supplies needed by Latin American cities. Solutions will come only with sound research and timely local management of these endangered resources.

All of the simulations here have shown the overwhelming advantage of joint and cooperative management over separate and competitive exploitation.

Chosen technologies differ across cases, but overall aquifer approaches follow two courses: protection and recharge. Protection means controlling pumping rates at levels that do not outpace rates of inflow, and defending the aquifers themselves against pollution. Recharge can mean something as simple as digging pits or trenches to gather rainy-season water, so as to speed aquifer replenishment. More complicated recharge tactics might involve injecting large volumes of water under pressure into deep wells, refilling permeable rock for later extraction. Needless to add, it is crucial in either course first to collect the hard and basic facts of local and regional hydrogeology before investing in the remedial engineering.

Outcomes of this research have been revealing — as much in the failures as in the successes. On the whole, each case has yielded careful scientific analyses of aquifer conditions, along with models for better management. In Latin America, as a typical example, research showed clearly that over-pumping and pollution were already threatening urban water supplies. Research has also shown that vigorous programs of aquifer protection and recharge could rescue those growing populations from imminent and dangerous shortages; fracture zones in some hard igneous rocks near cities can carry enough water for all urban uses, so long as pumping is carefully managed.

Much less successful, on the other hand, have been attempts to put that knowledge to practical use. Once again, technical issues once solved seem to have been trumped by socioeconomic issues that have scarcely been addressed. Instead of recommending ways to mitigate the harms of over-pumping, for instance, it might have been better in some projects to investigate the underlying reasons for over-pumping. Those reasons would include, not least, the political economy of distributing water at prices far below the cost of extraction and delivery. It was rarely obvious, moreover, how particular strategies of aquifer protection and recharge would specifically help poor people — the designated beneficiaries at the design stage of most of these projects. Lastly, it has to be said of some cases that any emphasis on socioeconomic and equity questions (such as it was) usually originated not in the developing countries themselves but at IDRC and among Canadian researchers. That is why the recently intensified concentration on economic, political, and social factors — evidenced in the University of Costa Rica program — represents a welcome corrective. What is still worrying (and another subject for the next part) is why decision-makers seem reluctant to respond to a problem like aquifer exhaustion until the problem degenerates beyond rescue.

## 2. Wastewater treatment and reuse

An old and rather obvious response to water shortage is to recycle dirty water after it is used. That can mean reusing treated "gray water" after bathing, laundering, and cooking; it can also extend, with much more care, to reuse of "black water" from toilets. In some places, recycling wastewater carries the approval of local tradition. Elsewhere, it has become a new and pressing (if sometimes resisted) necessity.

Conventional approaches to wastewater disposal in developing countries have taken two forms: capital-intensive replicas of systems favoured in the industrial countries, and primitive variants of open sewers and cesspits. Neither approach satisfies. Capital-intensive systems import technologies that are typically inappropriate. They cost too much. And they seldom benefit anyone outside the cores and well-off suburbs of principal cities. Pits and open drains, though cheap, disintegrate without careful maintenance into smelly sources of disease and breeding grounds for rats and insects.

Worse still, neither of these approaches begins where they must: with the need to put valuable recycled water to second and third uses. "Once-through" systems are no longer supportable — as people in the Middle East, for instance, now recognize. Already, with freshwater sources drying up, some countries are now getting much of their agricultural water from recycled and treated wastewater. But it is not cheap to restore water to a standard suitable for agriculture, and especially not if the water goes to irrigate food crops.

So it is understandable that intensive searches are under way for wastewater recycling systems purpose-built for low-income countries, villages, and neighbourhoods. The objective in every case is to meet the requirements of public health and human nutrition without imposing even more stress on overdrawn freshwater supplies. The techniques tested have been both inventive and varied.

IDRC-supported research in Senegal, for example, has pursued the technical and socioeconomic feasibility of exploiting aquatic plants, like water lettuce, to convert household wastewater into water fit for irrigating small market gardens; similar research in Palestine has looked at the purifying effects of duckweed. A project in Egypt has tested the production of drinking water by subjecting wastewater to slow sand filtration and settling ponds, along with low-cost systems of septic tanks and small-bore pressurized pipes. In Cambodia, by contrast, a heavily engineered wetland was installed for Battambang (the country's second-largest city) and monitored for effectiveness and productivity. It models a system sizable enough to recycle all the wastewater of a small city.

And the results?

Success in these projects proved to be decisively influenced by local circumstance and experience. In Senegal, water lettuce thrived in one community, where new vegetable crops were profitably marketed, but not in another. (As frequently happens, technical outcomes are far better documented and more readily explained than social and economic factors. If this sounds like an admonition to researchers, it also presents them with opportunities to tune their field research more responsively to the needs of local groups on the one hand and to policymakers on the other.)

As a generality, recycling water into irrigation through sewage lagoons and ponds has been found safe when done well. Projects in Senegal and Peru, to name two, found no significant health risks. So far as can be determined, environmental damage is also absent — although longer term effects remain to be measured. Risks in consuming crops raised in recycled wastewater, where measured, appeared negligible. Because of the hazards in black water, however, it has been judged prudent to treat only gray water in systems designed for isolated villages, individual households, or small neighbourhoods where sophisticated maintenance cannot be guaranteed. Black water has been fed only into systems built at larger scales. (It is worth mentioning here that scholarly study has concluded there is no blanket prohibition in Islamic law against the use of recycled water, as long as the waste is properly treated first. Recycled wastewater is successfully used in Saudi Arabia.)

Operational maintenance of these systems can determine success as much as the original design. Cambodia's engineered wetland, and Palestine's duckweed systems, were found to be "fussy" and maintenance-intensive. Smaller gray-water systems, on the other hand, functioned relatively trouble-free and were easily managed with minimal training.

As for the economics of these schemes, the general conclusion is that while highly engineered systems may justify themselves in a social cost–benefit calculus (where human health, productivity, and other factors are taken into account), they are probably not going to pay for themselves out of revenues on an income statement. Selling the treated water they produce can probably cover operational costs, but not capital costs. These systems also take up considerable urban land, which is expensive. For smaller household and village systems, on the other hand, revenues from additional gardening output commonly suffice to encourage local participation; gray-water systems generate enough income to pay both capital and operating costs. These recycling systems also generate new savings by cutting the frequency and cost of pumping out septic tanks — enough sometimes to repay all the recycling costs, even before accounting for added incomes from market gardens.

Local response to the introduction of wastewater treatment and reuse has been largely positive. As a result, capacity-building occurs beneficially in two respects. First, these usually small-scale projects inherently elicited local participation in construction, usage, training, and management. Second, because local authorities and NGOs were ordinarily the executing agencies, they gained experience not just in facility management but also in research methods, operations, public health, and financial analysis.

At the centre of these activities in many countries has been a strong and welcome gender component. In West Africa and the Middle East especially, local women have taken leadership roles in finance, operations, and management of both treatment plants and associated market gardens. This fact reflects the disproportionate burden of fetching and carrying water that is borne by women in many communities.

In the end, however, local engagement is a necessary but not a sufficient condition of lasting success in wastewater recycling programs. Follow-up research shows that if projects larger than household-sized are to perform effectively for the long run, they need continuing government support. (Regrettably but tellingly, the city-scale Cambodian plant stopped functioning after IDRC funding ended.) The necessity of government participation here is economic and institutional, not technical; the larger and costlier the facility, the more important government collaboration will be. For one thing, larger systems require organized arrangements for allocating costs and revenues. For another, inducements (and maybe enforcement) might be needed to win the cooperation of those who are used to disposing of their wastewater for free — whether onto their own fields or into unhealthy drains. Finally, governments may be called upon to reform building codes or land-use regulations (especially in and around cities) to permit and encourage wastewater recycling. But when all these attributes are in place, wastewater treatment and reuse can contribute valuably to overcoming local water scarcities.

## 3. Watershed management and irrigation

Remarkably, we need nearly 100 times as much water to grow our food as to provide drinking water. Around the world, irrigation accounts for two-thirds of all the fresh water used by humans. Around the world, irrigated land produces some 40 percent of all the food we eat. So irrigation is vital to our very survival.

These facts alone would argue for careful management of irrigation water, whether gathered from the surface or pumped from the subsurface. But there are still other and demanding reasons why irrigation — and watershed management more generally — will require new and more knowledgeable local management. First of all, the per-capita sum of land under irrigation has been contracting. Not only is population growth outracing expansion of irrigation, but considerable areas of farmland are being removed from irrigation because of salinity and contamination, or because of urban encroachment. Second, appalling volumes of costly irrigation water are wasted. In the developing countries, as much as 75 percent of water diverted or pumped for irrigation is lost to evaporation, leakage, seepage, or simply bad management. And third, most of the water that flows through irrigation systems serves multiple purposes. An irrigation canal, for example, might also be used to raise fish, to water animals, to wash clothes, to flush away wastes, and sometimes (if inadvisably) for drinking water. Conserving irrigation water for these other uses contributes to productivity and to public health.

Improving the management of watersheds and irrigation raises difficult issues of equity and efficiency, along with the technical problems of hydrology and agronomy. Large irrigation schemes, and expensive pumping from aquifers and groundwater, usually call for large investments of money — which tends to favour those with money to invest. Poor farmers, remote communities, and indigenous minorities may face special obstacles securing a say in such management decisions — and in sharing the benefits. Some of these issues arise in the research reported here, exploring local management of surface, subsurface, and the so-called "conjunctive" use of surface and subsurface water together.

Other issues of course require research at broader levels. Notably, substantial gains can be made in crop water-use efficiency in rain-fed agriculture, and far higher water-use efficiency can be achieved in irrigated agriculture. Actions in these areas would not merely reduce the need for additional water to grow food, but would also increase the scope for local management.

## Surface water management

IDRC-supported research in surface water has concentrated, understandably, on the arid and semi-arid regions — where water is the limiting factor on development, and where gains in income and quality of life depend critically on achieving irrigation efficiencies. In many of these areas, water gets multiple uses, meeting a variety of agricultural and household needs. Projects therefore typically address water and soil management together, and several have applied a microlevel examination of how individual families cope with persisting water scarcity.

Some of the most noteworthy research in this field has been hosted by Egypt. In one project, researchers evaluated the potential for improving irrigation efficiency by taking advantage of local knowledge (see Box 3). Another project, conducted in the unforgiving desert of Egypt's northwest coast, focused on improving the lives of local Bedouin by increasing farm production without damaging the fragile ecosystem. This project was an exploration of the biophysical and human dynamics of life in

North Africa's wadis — the rocky streambeds that briefly fill and revive in the rare passing rainstorms. The results added up to an exotic interaction of high technology and long-tested local knowledge: computer-based information systems integrating Bedouin custom with life-sciences data, resource inventories, biomass production statistics, and environmental consequences, all to identify preferred management options.

Findings have been both illuminating and troubling. New insights have emerged into surface water supplies, rainfall

### 3. Enhancing Desert Irrigation

In Egypt, where yearly rainfall can total 3 millimetres and populations are booming, there is a life-and-death urgency to improving irrigation for food production. Loss of irrigation water is not just wasteful. It can ruin the land through salinization, waterlogging, and pollution. And it means precious foreign exchange must be spent to import food.

With IDRC funding, university researchers in Cairo sought to increase irrigation efficiency by studying actual operations of farmers in their fields. Investigators confirmed that agriculture in the study area, west of the Nile, had exceeded the sustainable potential of local groundwater. The happier discovery was that the right kinds of irrigation could slow the pace of well-drilling and allow groundwater to recharge.

Researchers also found that irrigation practices were strongly shaped by farmer involvement in choosing and operating irrigation systems. So a follow-on study looked at the newly formed Water Users Associations (WUAs), designed to let farmers influence irrigation policies and water supplies more directly, and to help extension agents distribute information promoting efficiency.

Early results are promising. Disputes have been reduced, and the returns of WUA farmers are 50 percent higher than those of nonmembers. Women report they too get a better break inside WUAs. Still, WUAs reinforce traditional power structures; richer farmers benefit most. Despite the mixed results, this much is clear: irrigation efficiency could only be improved with the collaboration of farmers — and with practical insight into their daily experience on the land.

patterns, erosion vulnerabilities, and potential new irrigation approaches to support the increasingly sedentary Bedouin and their herds. But the research also confirms the harsh productivity limits imposed by drought in these environments, with scarcities made worse by the growth of local populations. And it reaffirms the determining importance of socioeconomic factors in successful water-management innovation. Once more, achieving new efficiencies — and improving human well-being — will raise political issues of popular involvement and consent.

Overall, projects in local management of surface water uniformly establish that soil and water productivity in dry areas can be increased with better techniques, extensive training, and the application of new technologies with local experience. In Peru, for example, researchers have applied mathematical models to the old Incan practice of irrigating trees with partly buried, permeable pots that can be refilled with collected water (maybe the world's first use of drip irrigation). This project looked at new materials for permeability and cost, and at methods of linking the pots with plastic pipes. What remains, in most of these contexts, is to develop systematic routines for disseminating the findings of research, and for entrenching them in policy at local and national levels.

## Subsurface water management

Men and women have been drawing water from below ground since Biblical times and before. For most of those centuries, of course, wells were limited to the depth of hand-dug holes (few deeper than 10 metres), or those drilled (to a few tens of metres) by human or animal power. Modern machines now drill hundreds of metres into the earth, tapping aquifers and water that runs deep through subsoils and along the bedrock. At these depths, great quantities of water can be pulled — enough for vast irrigation systems and urban populations. But that also means subsurface supplies are for the first time subject to catastrophic depletion on a wide scale. We have become (not for the first time) victims of our own invention.

Skilled management of subsurface water therefore turns on a detailed understanding of hydrogeology, geochemistry, and the other hard sciences of rock, soil, and water. More than that, it requires institutionalizing ways to prevent over-pumping and competitive drilling — and to promote the fair sharing of the resource and the costs of its conservation. Ultimately, subsurface water management demands as much knowledge about communities and their needs as about the engineering of deep wells.

By the late 1980s, it was evident that rapid urbanization in Latin America was breaching the limits of surface water supplies and forcing the exploitation of ever-deeper subsurface sources. Early research undertaken with IDRC support soon showed pumping rates were perilously underestimated. The next stage of inquiry focused on defining more accurately aquifer flows and quality. But this course of work proved limiting, mainly because of the great gap between the neat mathematical models of hydrogeology and the rough planning tools (and the rough politics) of urban development. Research accordingly expanded to broader areas of practical and applied management. In Brazil, for example, collaboration with the water commission of Recife introduced supply planning and training along with new and more efficient drilling techniques.

But alarming shortages of groundwater can occur even where rainfalls and river volumes seem abundant. Development in Cambodia's section of the Mekong Delta had proceeded for years on the easy assumption that monsoon rains and seasonal river flooding reliably recharge groundwater and the underlying aquifer. That assumption was mistaken; research now demonstrates that the Mekong replenishes only a narrow strip of the adjacent aquifer, and rainwater is quickly shed by a layer of impermeable clay. Without sound management, the rain-soaked and flood-bound Cambodians will run dangerously short of fresh water.

As in other approaches to local water management, research into subsurface water concentrated in the first stages on technical riddles of water quantity and quality. Later projects began to investigate the economics and social relationships of water use — and the politics of unequal access. Field work discovered that in some villages, for instance, income inequalities tended to be exacerbated by transitions to intensified groundwater use. Only richer farmers could afford pumps, or enjoyed access to credit. And even if poorer farmers could buy simple treadle pumps, they were commonly left with dry wells because of competitive drilling and falling water tables. Gender distinctions arose as well. Carrying water is almost everywhere a task of women, often attached to vegetable gardening and always to household work. When mechanical pumps are introduced, suddenly men begin to take a bigger role in water management, especially for irrigation. To see the full effects of technical change — even change for the better — it is wise to watch for differentiating effects on women and on men. Significant change is rarely gender-neutral.

### "Conjunctive" water management

Many communities around the world survive by exploiting both surface and subsurface water supplies — the conjunctive use that often alternates with the rhythms of seasonal rainfalls. Typically, households and farms draw water from below ground to prolong crop growth after the rainy season ends, but in some regions surface water is itself the temporary supplement to year-round groundwater and aquifers. What matters, for the health of communities and the productivity of their agriculture, is how these sources are proportioned, timed, and exploited in sequence.

Farm families were practicing conjunctive use of surface and subsurface water long before researchers appeared at their doors. Still, research in the past decade has delivered valuable new knowledge and new techniques for improving this old approach. We know now that hydrology, satellite sensing, geochemistry, and computer-aided meteorology can all work with local practice for better crop yields and better lives. We also know, better than ever, that success means taking into account the precise details of local irrigation patterns, farming systems, and available markets. The relevance of local detail is what invests local management with a unique significance in these settings.

Two projects in India reinforce these conclusions. One was carried out with some 10 000 very poor tribal families in three

### 4. Old Knowledge, New Strategies

On the Deccan Plateau, the rugged highland spine of central India, the tribal people of the Akole Toluka region are experts in the hardships of drought. In their driest season, February to May, women and children labour for most of every day collecting and carrying water to keep their families alive. Even when the monsoons come, from mid-June to early October, rainwater quickly runs off the hard basaltic hillsides. Ponds soon dry out, wells empty, crops wither, and the walks to retreating sources of water grow longer.

These people are not helpless. They know the land — where ponds form, where springs rise. They know to look for the umber trees, trustworthy indicators of hidden groundwater even in dry months. So researchers harnessed this local knowledge in powerful combination with new technologies — from bedrock fracture analysis aided by satellite imagery, to the best available meteorology. (The project was mounted by India's BAIF Development Research Foundation and Canada's University of Windsor.)

Outcomes have been substantial: healthier people; higher food production; rising incomes; stocks of water that last virtually all year. And villagers are embracing the new strategies demonstrated in the research.

Those strategies are fundamentally simple. Among other things, small diversion systems slow down runoff, reduce erosion, and let water pool and then infiltrate the ground. And rooftop harvesting and storage tanks were built, filled first by rains each year and later, in the dry season, by bullock-cart deliveries. Simple changes. But lives are better. And women and children no longer suffer the same long, anxious walks for distant water.

villages on the interior Deccan Plateau (see Box 4). The other was conducted in the wetter environment of North Bihar, among farmers who were less poor and less dispersed. Different people, different contexts — but strikingly similar outcomes. Agricultural production increased, and the availability of cleaner drinking water was enhanced. Soil and water conservation improved with better irrigation, storage, and distribution systems. (Significantly, comparable outcomes were also recorded in conjunctive-use research in Syria, though in a more controlled experimental setting.)

If there was one disappointment in the Indian projects, it was the failure eventually to forge lasting linkages between the Indian researchers and relevant government agencies where findings might have a continuing institutional impact. For benefits to reach beyond those communities directly participating in the research, researchers themselves need to engage government officials in charge of rural development and agriculture (along with interested NGOs) in the active work of knowledge diffusion and education. Applying the hard-won discoveries of research is invariably a multiphase enterprise, with many partners collaborating. Research results that emerge only in academic journals scarcely qualify as truly development research.

Part 3

# The Results:

## Propositions for Governance and Research

Strategies of local water management can constitute practical and indeed superior alternatives to the large-scale, centralized, capital-heavy approaches that have dominated in the past — and that too often failed to deliver on their promises. Local strategies can also serve invaluably as complements to wider reaching water-management approaches. But they are no panacea. To misread their uncertainties and limitations, or to neglect them, is to risk failures no less damaging than those of the past.

Research over three decades (some of it described in the preceding pages) has explored the promise and the problems of local water management. And it has generated real results — lessons immediately helpful for making better management decisions, and in marking paths for future investigation. Those results are reframed here as a short set of propositions. For convenience, these propositions are divided into two lists; the first is addressed to issues of governance, and the second to research itself. In practice, however, this distinction is just an organizing device. Only when the difficult issues of research and governance are considered together — when knowledge and policy inform each other — only then can the fullest potential of local water management be realized.

## For governance

### 1. Water management research can generate powerful consequences for politics and policy.

In the governance of water scarcities, as in the research itself, it is wrong to assume that knowledge is neutral. As a case in point, Wadi Allaqi is worth a visit.

Researchers from South Valley University in Aswan, Egypt, and Trent University in Canada, set out to explore the traditional uses and values of indigenous plants in Wadi Allaqi, the largest wadi on the eastern shore of Lake Nasser. Despite the fierce desert conditions, this area had always supported a bountiful biodiversity. But higher water levels produced by the Aswan High Dam made the land even richer — and more desirable to more people.

Research succeeded in defining the significance of water supplies in maintaining that biodiversity. It demonstrated, moreover, that local Ababda and Bisharyn people had always used the plant life of Wadi Allaqi for food, medicine, fodder, fuel, and construction materials. These results in themselves were useful. But the research turned out to be more than simply a gratifying project in ethnoecology.

Land rights here had been little valued — and uncontroversial — so long as the land itself yielded hardly more than a subsistence survival for local people. But rising water levels inexorably changed all that. Water enhanced productivity in the fields. At the same time, improved roads increased land values still more. Now there were agricultural surpluses, with profitable access to markets outside the area.

These same changes also had the effect of encouraging some Ababda and Bisharyn to take up semipermanent residence in Wadi Allaqi. But these people lived by diverse strategies of herding animals, charcoal production, and medicinal plant collection. This meant they would have to secure tenure rights in several local ecological zones, to ensure sustainable harvests in these different activities.

The Ababda and Bisharyn had to establish their claim to communal ownership of the land. The IDRC-supported research, confirming their traditional and continuous presence and work on the land over many generations, supplied the evidence they needed to prove their case. In Wadi Allaqi, new knowledge informed far-reaching political and policy decisions governing land, water — and lives.

### 2. Decision-makers too often dismiss small groups and small solutions. They make a big mistake.

Rational decision-makers are right to reach for economies of scale where they are available and sustainable. Nor is it worth denying that there may be political reward in concentrating one's energies where they might have the broadest and most prominent impact. Even so, it is a bad practice (and a common one at that) to dismiss the plight of small groups as unimportant — or to disparage a proposed remedy on the peculiar grounds that it is not sufficiently expensive or difficult. There are two kinds of reasons why these are serious mistakes.

First there are reasons of equity. Whether a child lives in a teeming squatters' settlement outside a big city, or in a remote aboriginal village, that child shares the same right as anyone else to safe and adequate fresh water (see Figure 4). It is a special quality of local management approaches that they can address this entitlement question with relative ease. Since they treat everyone at the scale of small numbers, they tend not to disfavour one group against another on the basis of numbers alone. (Other sources of political advantage — wealth, ethnicity — might well operate in distributing scarce water, even in the smallest communities. The only point here is that local management approaches are comparatively free of bias in favour of big-population constituencies.) When a cost-effective, fair, and environmentally sustainable — but small-scale — management innovation is recommended to policymakers, equity requires that it get the same hearing as any grander scheme that might attract more public approval (and which will certainly cost more money).

The second argument rests on reasons of utility. Addressing small groups and small solutions can produce the largest, best results

**Figure 4.** **Local management approaches are largely free of bias based upon age, gender, or wealth.**

in the end, for the greatest number. It was pointed out above that many developing countries have already reached the limits of large-scale, capital-intensive water management projects; they have few or no more rivers to dam; intensive irrigation is exhausting or poisoning soils; and excessive pumping is wrecking aquifers, in some cases forever. At small and local scales, however, large potentials lie in reserve. One example: IDRC-supported research in the Jordanian desert found small but useful volumes of groundwater at depths below those of hand-dug wells but generally missed by drillers aiming deeper. Such water will not solve scarcities in Jordan's cities, but it can enormously improve lives among Bedouin and rural villagers.

These small and local approaches are in many settings cheap. They are generally easy to learn, simple to administer, and therefore likely to appeal to the people who will have to use them. Their environmental effects, relatively benign, can be measured and moderated. And they can be replicated virtually indefinitely, with adjustments to local conditions.

Equity and practicality pull in tandem. Members of small or remote communities are as entitled as anyone to be heard, and to have their most basic needs addressed. Seemingly humble innovations, on the other hand, can produce surprisingly powerful and widespread benefits. Multiplier effects can invest innovating communities with new institutional capacities, or improve life for women and girls, or abate the impoverishing pace of local erosion. And the demonstration effects can be equally appealing — encouraging other communities in similar circumstances to adapt proven ideas to their own advantage. Community-to-community networks may be informal, but they can work well and fast.

### 3. Distributing the costs and benefits of managing scarce water imposes hard choices. Making those choices, and giving them effect, will require institutional capacity.

Scarcity by definition forces trade-offs. A litre of water consumed by one family or farm or factory is a litre denied to any other, at least for a time. But water exhibits two other qualities that make these choices even more complicated. First, water moves. And the movement of water sets up other rivalries to be resolved. When people upstream divert or pollute river water, people downstream may suffer. When a community uphill holds back runoff to improve cropping and prevent erosion, communities downhill are deprived of freshwater supplies. And second, aside from the water lost to evaporation or consumption in crops or products, water once used will return to the environment — but inevitably diminished in quality. Who should get what, when — and at what price?

Deciding these trade-offs grows harder still when they concern what are pre-eminently public goods — the protection of environmental quality, perhaps, or the conservation of an aquifer for later generations. In cases like these, the problem is not so much to reconcile competing private interests; it is to secure the public interest against immediate (and potentially destructive) private advantage. Preserving a life-giving river against a polluter is the everyday and too-familiar example.

Market dynamics can sometimes help resolve water scarcity choices. Or putting it the other way round, disrupting the market can sometimes hurt. Subsidizing the price of water — selling it below the real cost of conserving, collecting, and delivering it — encourages overuse and rewards waste. Worse yet, subsidies are notoriously susceptible to political insiderism, administrative inadequacy, and graft. Far from aiding the poor or politically weak, subsidies often and infamously favour the well-off and well connected.

But it never suffices simply to treat local water supplies as if by no management at all. The research is clear on this. In the absence of deliberate strategies of management, local water scarcities will be managed by default — by whatever faction of a society can seize control of the resource and its distribution. This applies acutely to the case of subsurface water. Management by default normally falls to industry, richer farmer-landowners, or developers with the finances or political leverage to secure control of groundwater or aquifers with deeper wells and bigger pumps. To say the least, management by default fails the test of good governance.

Good governance is open, participatory, and responsible. And it needs good information, of the kind that careful research can provide. Furthermore, to make and carry out sustainable resource decisions, good governance requires institutional capacity. That includes the capacity to gather and assess relevant information, to deliberate, to execute policies, and to answer responsibly to members of the community.

The importance of institutional capacity — indeed, its indispensability — is evident throughout the length and breadth of the research. On the smallest, simplest scale, institutional capacity represents a neighbourhood's ability to build and maintain a shared network that stores and distributes rainwater around a few city blocks. It is the forum where villages up and down a hillside can apportion seasonal runoff for maximum usage and minimum losses of water and soil. It is the mechanism that can mobilize a community's capital investment in a wastewater recycling plant or in new-technology groundwater pumping systems. It is the recognition that management involves administrative and financial tasks, as well as technical ones, that regular maintenance is as important initial construction, and that from time to time enforcement of rules and regulations will be necessary. It is the deliberation in which environmental quality is acknowledged as a value, and where the interests of future generations are heard and accepted.

In any society, one measure of good governance is the quality of the treatment of its poorest and most vulnerable members. And with respect to local water management, the condition of women, minorities, and the landless poor is a specific responsibility of institutional authority. These are the people who suffer the worst hardships of misgovernment — and whose lives are most improved by good water management. Perhaps not surprisingly, IDRC-supported research in Egypt found that girls and young women were not only the most receptive to new information about household water but were also particularly effective as agents of change.

If only for emphasis, it bears repeating that local water management is not the only response to scarcity. Local strategies work best as complements to two other efforts: (1) national and international programs of resource management and conservation, all informed by principles of sustainable development; and (2) scientific research and extension programs to develop and diffuse ways to increase the efficiency with which water is used, particularly in agriculture. But local water management is everywhere valuable, and it requires good governance to fulfill its potential.

### 4. There is one iron rule for managing groundwater and aquifer supplies: assume the worst.

Problems that are invisible rarely capture the focused attention of decision-makers until it is almost — or already — too late. This is natural, but dangerous. It is particularly dangerous in the management of groundwater and aquifers, by reason of two insidious realities. First, the risks of mismanagement (by over-pumping or pollution) are higher precisely because the early and accumulating effects of mismanagement lie buried out of sight and undetected. Second, the problems themselves (depletion, contamination) seldom become indisputably obvious until they are difficult if not impossible to correct.

This is the sorry history. What is the remedy?

The right policy is to presume from the start that the exploitation of any groundwater or aquifer will carry high risks of over-pumping and pollution, and that any resulting damage will exact heavy costs. The wrong policy is to assume all is well, and to disregard precautions until a disaster presents itself. The corollary is that appropriate funding and institutional energy should be directed to timely resource research and monitoring — before trouble strikes. The prudent (and self-protective) decision-maker will instruct researchers to raise early warning of impending shortages or contamination, with recommended options for corrective action. (Researchers, by the same logic, must set out their assessments and prescriptions in terms that members of the community, and nonspecialist policymakers, will grasp without delay.)

In areas where the use of groundwater is relatively new, there is a temptation to consume these novel supplies as if they were infinite. Managing invisible problems in these cases demands especially strong programs of public education and political discipline. Everybody in the community needs to know the hazards and costs of over-pumping and pollution — and the benefits of conservative prevention.

Planning for the worst, in the public interest, will usually mean regulating private actions: competitive drilling, investment in ever-deeper wells, and careless dumping of wastes. Here too, persuasive technical data, with quick decision and vigorous caution, will together improve the chances for successful governance.

### 5. Successful local water management requires, and deserves, close collaboration between communities and governments.

Evidence collected throughout the developing world demonstrates that local management of scarce water can yield great benefits. The evidence points with equal force to another conclusion:

communities attempting local water management approaches need supportive links with their "senior" governments. This is emphatically (but not only) important in the management of watersheds and aquifers that must be shared with others. As considered in Part 5, creating coherent relationships between local management and wider watershed approaches goes to the heart of good water management.

A few functional examples make the point.

It is one thing to discover through research splendid new ways to marshal and save scarce water, and another thing entirely to put those discoveries to work in households and fields. Government can encourage the diffusion of new and helpful knowledge, especially to its agencies and extension services. These arms of government have the organization with the expertise and resources to speed dissemination and promote education. By diffusing the results of research and development, governments multiply many times the value of new knowledge to local communities. So doing, with NGOs and others, they enlarge the national wealth and the welfare of citizens. Researchers can perform crucially as catalysts in these processes, introducing new research to decision-makers, families, and farmers — and introducing them all to each other.

Another function of government concerns coordination and reconciliation. When a government is open, participatory, and responsible, it is best placed to balance the divergent interests of different communities. It can also lay claim to legitimate authority in representing the interests of its communities in negotiations with other governments. Domestically, active government–community collaboration allows governments to coordinate the exploitation of shared aquifers, for instance, or water catchments supplying more than a single community. Internationally, government–community collaboration can facilitate the peaceful settlement of disputes over scarce water resources.

Communities are similarly well served when governments strengthen local water management by bringing to bear their unique capacities for analysis, financial management, and infrastructure support. In harvesting field water, for example, individual technologies are typically simple in themselves. But, as research in Jordan and Syria shows, managing several together as a coherent, integrated unit can require rather sophisticated skills. The same is true for conjunctive use of surface and groundwater, as confirmed by research in India. Developing large, community-wide assets (for storing and delivering drinking water, say, or distributing irrigation water) might take professional engineering advice or financial administration. And in poor communities especially, investment in water-saving technology probably calls for more capital than community members themselves can muster. In each such circumstance, governments can respond to real local needs with material contributions just as real — and just as urgent.

Finally, supportive and responsive governments can deploy their special authority for rule-making in ways that advance social equity and harmony.

➛ They can develop and maintain weather and hydrological stations expressly for the benefit of poor communities reliant on agriculture.

➛ They can correct the common over-emphasis on export crops and large-scale farming, which neglects smallholders and subsistence agriculture.

➛ They can expand agricultural extension services, so that the best and latest techniques reach farmers fast.

➛ They can amend land-use regulations and building codes, to foster wastewater recycling or neighbourhood rainwater storage.

- ➛ They can promote, and properly finance, childhood and adult education in the principles and systems of environmental protection and water conservation.
- ➛ They can redouble efforts of public health.

These are things that governments can do in everyday collaboration with local communities, in cooperation with NGOs and other agencies of education and activism. In fact, these activities signify good governance in any country. They testify to a society in which the difficulties and rewards of managing water scarcity are accepted together, understood, and shared fairly.

## For research

### 1. Hard data can pay rich dividends, even when outcomes disappoint.

Sustainable development in any realm is a multidimensional enterprise, but the best development research starts with facts on the ground: with geology, hydrology, agronomy, and the other "hard" disciplines in these cases, along with some basic and necessary economic and sociological analysis. Without sound data, wishful thinking (allied perhaps with strenuous self-interest) is all too likely to inspire bad decisions. On the other hand, the discovery of fresh and basic information can open new opportunities and resolve old problems.

Local management of aquifers in particular has been mightily strengthened by the careful geological and hydrological research that is essential to understanding the dimensions of scarcity — and the available remedies. Aquifer research and management are especially challenging because aquifer size, behaviour, and structure resist easy definition. Research in Mexico City, for example, showed that previous assumptions about the geometry of the aquifer were quite mistaken.

Sometimes, the significance of research is measured as much by the way new patterns suddenly fit together as by the magnitude of any discrete finding. Surface water research on Egypt's northwest coast ranged widely, from variables of cistern construction and grazing customs to soil characteristics, climatology, and resource endowments — all integrated with local knowledge and culture. The integration of disparate pieces of data reinforced confidence in the research conclusions and enhanced their persuasiveness both to local Bedouin and to government officials.

Economic variables are similarly salient. Here the lesson is straightforward: the costs and benefits of a particular water management approach must be calculated from the viewpoint of householders and farmers themselves, and of their communities, and not from the perspective of the visiting researcher. Otherwise, uptake of a seemingly rational innovation will very likely fall short of the optimistic predictions of researchers and their supportive administrators.

Even well-grounded expectations are now and again disappointed by outcomes. But disappointment can teach. Chilean villagers granted those fog-collection systems much less acceptance than the early experiments would have predicted. One reason, it so happened, was that from the villagers' point of view the nets and pipes of fog collection simply cost more in labour and money than the water itself was deemed to be worth. Given government willingness to truck water to them, villagers reasonably doubted why they should maintain a system that offered them no net gain. Sometimes it is government itself that is not listening. In urbanizing Latin America, research showed that pumping rates in almost every case were seriously underestimated; but excessive pumping persisted as a response to the demand for drinking water.

Effective development research aims ultimately to inform policy. But the best of it is rooted in this kind of basic knowledge.

## 2. Local participation, and local education, improve the chances for successful and effective research.

The energetic participation of local people in research on water management is not just a virtue in principle; it is a necessity in practice if the research is to have much lasting or significant effect. That participation must begin with a fluid, two-way communication among researchers and members of the community where they are working. Without a rapport between researchers and local people, the research work will be impaired and the results incomplete. Unless local people engage in the processes of discovery and learning, they will probably (and reasonably) remain indifferent to the outcomes.

All of this argues for integrating technical and socioeconomic variables from start to finish, from experimental design to later operational phases. The mundane practicalities of community-based water management are not something to be attached at the end, but considered from the beginning.

This approach undeniably complicates research design and execution, but not fatally. The problem of complexity overload can be mitigated by conceiving of research as a multiphase effort. Some phases might focus more on remote sensing, or drilling data, or chemical analysis, and therefore call for less public participation. Successive phases in the sequence (even if they overlap) can adapt to local responses, local learning, and the changing challenges of encouraging local participation. It is a mistake to delay participation very long. Researchers studying village water systems in Togo, for example, had to turn to a different technology when local people made it clear that complexity would decrease the rate of adoption.

A last point on participation: local people should always be involved in deciding the location and design of any test plot or construction. Again, this is more than a courtesy. It is a necessity if research outcomes are to be reliable and influential. Indeed, experience shows that local participation does not merely support the project, but can actually move it in surprising and productive directions.

### 3. Scaling up can generate welcome economies, and intensify inequalities. Both effects need to be understood.

Small might be beautiful, but a bit bigger can be even more so. Researchers often find that the cost-efficiency of traditional methods — field water harvesting, say, or wastewater recycling — can be improved markedly by scaling up from household to village or neighborhood size. Likewise, roofwater harvesting can be made more effective by installing cisterns large enough to store water for several houses or a whole city block.

But scaling up generally demands capital investment. Often, as in the case of urban-scale wastewater facilities, it calls for large tracts of land. These facts favour those who already have access to capital — and to the political power of land-use regulation. They tend to disfavour the poor and the relatively powerless.

Research that fails to account for these unequal effects is incomplete at least — and dangerously misleading at worst.

### 4. But scaling up can succeed where institutions are capable of distributing the gains, and the costs.

Imagine a rooftop water catchment system with enough storage to supply all the families in a block. Per unit of water delivered, this might be cheaper and more productive than any attempt to harvest the same water volumes one household at a time. But it would require institutional arrangements for buying and maintaining the physical plant, and for allotting shares in the water collected.

Consider a city-scale wastewater recycling plant, turning urban sewage into irrigation water for outlying farmers. Who pays? City-dwellers, pleased to be rid of their wastewater but indifferent to its eventual treatment? Or farmers, with new flows of irrigation water but with new costs (and new restrictions) attached to its use? These are the costs and benefits to be distributed through an institutional capacity for deliberation, decision, and administration — all at the service of people who might lack any experience of collaboration or common purpose.

It is important here to emphasize that local institution-building does not mean creating small-scale replicas of larger water management systems. To the contrary, strong local management requires structures, processes, and purposes that differ in kind from those of watershed or wider scale management approaches. By way of example, villagers in China's Guizhou province, working with researchers from the Guizhou Academy of Agricultural Sciences, were able to construct a village-managed drinking water system that defined the rights and obligations of all users and set out rules for sharing costs and benefits according to local norms.

### 5. Social and economic factors are always important in local water management, and sometimes paramount.

Research experience in nearly every setting and circumstance of local water management establishes this axiom: social and economic factors, not technical problems, ultimately present the worst obstacles — and the best instruments — in conducting and implementing research. The obstacles are many and imposing; more than a few of them have been suggested in these pages. They include cultural hostility to specific lines of inquiry, bureaucratic reluctance, political cleavage, socioeconomic division and strife, and institutional incapacity to absorb or execute change. But the capabilities of people and their communities to seize and exploit change are also diverse and impressive, even in the most disadvantageous situations. The obligation on researchers is to track these factors and understand them from the start as integral elements of the research endeavour.

None of these elements bears more directly on local water management than questions of gender, and none demands more sensitive treatment in applied research (see Box 5). In city and countryside, the work of carrying, storing, and using household water is almost everywhere primarily the work of women (see

### 5. Engaging Women in Research and Action

It is now recognized that women in poor communities must be involved in local water and sanitation management. They work longer hours than anyone else on domestic water and hygiene, and they are experts. But cultural differences across communities and countries will defy any single prescription for engaging women in managing innovation. In the Middle East, traditional values can work against women assuming public roles of authority.

In a Nile Delta village, researchers experimented with a strategy of "action research" through two multiphase projects aimed at improvements in water and sanitation. The project continued through 4 years of close work with local women, studying community conditions and practices contributing to disease.

The method was simple in outline: encourage local people to identify their own problems, frame solutions, and organize change.

Research found high correlations between inadequate water supply and sanitation, crowding, and concentrations of flies as disease vectors. It also found that children had a marked influence on household hygiene practices, and that hygiene information altered food preparation techniques.

As for organizing change, village women identified two problems for correction — a broken standpipe and a polluted canal. They fixed the standpipe, improving neighbourhood water quality, by getting help from local authorities and investing their own labour. They couldn't clean the canal, defeated eventually by the political and bureaucratic complexities of arranging garbage collection.

Perhaps most significantly, women and men discovered in village meetings that they could work together, within the bounds of traditional values, to secure shared benefits.

Figure 5). This is not just the labour of cooking, laundry, child-care, and cleaning. It extends to market gardening, community health, and other essential social and economic activities. To understand the dynamics of water use and conservation, therefore, requires a close understanding of what these women do and why. To change the ways water is harvested, stored, or used is likely to change women's lives — for better or worse. Not only are they entitled to a voice in that change, they are an indispensable source of knowledge about it. More than that, they will be essential participants in any successful attempt to secure constructive innovation. (In Kenya, a water-harvesting project conceived by women was organized so that they could control the use of water themselves in households and the local health clinic.) Capacity-building in these settings must reflect the particulars of differential gender roles in each community.

Institutional issues will be just as important in other respects. Familiar example: where water catchments straddle formal or traditional property lines, systems have to be organized to distribute the costs and benefits of utilization. The alternative,

**Figure 5.** **In Michoacan state, near Cheran, Mexico, women collect water from one of the reservoirs fed from the community's rainwater-harvesting system.**

too often, is beggar-thy-neighbour rivalry for a consequently diminishing resource. Similarly, legal and political ownership disputes over subsurface water require institutionalized rule-making and adjudication that are fair and effective enough to attract community adherence.

As earlier underlined, schemes that depend for implementation on extensive new civil institutions or capital-intensive infrastructures (reservoirs, big dams, and the like) run the danger of deepening political and economic inequalities. People with wealth and political power might well prosper by such projects, and the poor just as likely will not. Even where large projects do not accentuate inequalities, they can be defeated by their own complexity. Researchers do no favours to poor and capacity-weak communities by proposing projects too complex to manage. Keep it simple, at least to start.

Finally, the use of water, and the waste of it, are heavily influenced by price. Everything from health care to soil erosion can be affected by what people pay for water (or believe they pay for it, not always the same thing). Overt and covert subsidies alter these real and perceived prices in ways that alter behaviour. The effects can be malign. "Free" water may be delivered to city households by municipal pipe. But if only well-off households are connected to city water, the implicit subsidy confers no benefit on the poor; they are left to the higher prices and doubtful quality of the "private" market — ordinarily vendors bringing jerrycans through the neighbourhood. Leaving aside the plain issues of equity, pricing arrangements like this can dramatically reshape patterns of water consumption, environmental stress, and private well-being. These interactions always deserve analysis by water management researchers.

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**Part 4**

# Recommendations

No matter how rich or poor the country, no matter how content its people, there is much to be said for decentralizing the management of natural resources. This is not a statement of dogma, just an observation of what works. Experience teaches that local resource management more often than not yields results that are not just economically efficient but also socially equitable and environmentally sustainable.

Still, there is much yet to learn about the right extent and design of local water management. So far, most applications of local resource approaches have been directed not to water but to wildlife and forest management, and somewhat less often to fisheries and rangelands. Organized local management of water (as described in the foregoing pages) has been less tested, and remains least familiar to communities and to governments.

Furthermore, the studies of local water management that have been completed looked chiefly at smaller and simpler situations: rather isolated rural areas, and the management of surface water. What is significant about these is their encouraging outcomes. Systems that include associations of local water users (to cite one important approach) come closer to sustainable management than those directed entirely from above. But half the world's population now lives in cities. So the greatest unexploited potential for improvement is to be found in urban areas and in the management of subsurface water. It has to be asked whether critical conditions of city water scarcity (including bad water quality) could be improved by devolving at least some elements of water management to groups or neighbourhoods in urban areas.

The enduring challenge anywhere, of course, is to detect and understand the frictions among efficiency, equity, and environmental sustainability — and to accommodate all three values in any management regime. This must be a joint enterprise of governance and research. That is the thrust of the following recommendations — specific proposals for action in governance and research.

### 1. Up, down, and sideways: local water management should always be informed by a three-part economic analysis.

The community economics of water and scarcity need to be addressed in any attempt at applied research or governance. The conventional perspective for benefit–cost analysis — looking down from above — considers prices paid (or imputed) to measure relative values of inputs and outputs. And the results can be revealing. There is the finding, for example, that water harvesting is likeliest to be economical where rainfall averages between 100 and 500 millimetres per year. More rain than that, and costs exceed benefits; less than that, and benefits fail to cover costs.

The second necessary viewpoint for economic analysis is from below, looking up. What might strike government officials or researchers as an improvement can look far less beneficial to people in the community itself. Similarly, ground dismissed as "wasteland" by government accounting may actually yield value for informal gathering and grazing in the local economy. Nor are all the members of a community affected the same by economic change. Interventions will probably affect men in the community differently from women, as the nature and values of their work are altered. These and other aspects of local livelihoods often escape the notice of officials — and of researchers.

The third perspective — just as important — concerns the sideways interactions of economic interventions with noneconomic values. These other values might include maternal health benefits from the better availability of fresh water, or the empowerment that comes with enhanced local capacity and responsibility, or restoration of the local environment. They might also embrace entirely esthetic values: the beauty of a stream, the spiritual consolation of a clear lake. Such variables are inherently hard to measure. But they are no less crucial for that. They belong in any complete economic analysis of local water management.

### 2. Policy and research should shift focus from enlarging supplies of water to managing demand.

This might be the only incontrovertible statement in these pages: Water policy emphasis at all levels — national, regional, local — must turn from supply to demand. The actual quantity of fresh water that can be added to total supply will be limited; it will be increasingly costly; and it will be environmentally dangerous to extract. In most countries, as in most communities, the maximum extraction rates of accessible freshwater supplies are now within sight — where they have not been surpassed already.

The principal requirement, therefore, is to get the most from the water we have. This is the domain of demand management. Upper levels of government can encourage and finance better demand management — rewarding conservation, penalizing waste, inducing innovation. But the actual work of making do — of getting the most from the water we have — must be done by households, farms, factories, and communities acting individually and collectively. Moreover, the task goes beyond individual technologies. In many cases, the main points of leverage lie in the structure of livelihoods and regional economies, as with shifts away from water-intensive crops or even irrigated agriculture.

Policy and research should work at all levels to alter the decisions and structures that determine the demand for water.

### 3. Policy-making should always start by accepting social custom and cultural norms as given, but not sacrosanct.

On the whole, it is far easier to execute technical change than to alter customary practices and established beliefs. When initiating water management innovations, therefore, it is always wise first to examine carefully what is socially and culturally acceptable in the local community, and then to design and test remedies consistent with local tradition. When existing local patterns of water use are grossly and demonstrably inequitable or environmentally destructive (and only then), more energetic interventions should be considered to change beliefs and values.

Issues of water rights often present special problems. Such rights are sometimes recorded and protected formally, by law. But they frequently operate by local tradition. Then again, the existence of a right to water does not by itself demonstrate who gets what, or when. In many cases, water rights are intricately defined and enforced fastidiously by social, political, or legal sanctions; in other cases, they are subject to systematic cheating and even violence. Either way, the management of water rights becomes a crucial element of policy-making.

Generally, local custom and norms (taboos governing reuse of wastewater, for example) should be treated more as opportunities than as limitations. They reveal underlying values and habits of thought — and time-honoured survival strategies — that can shape and strengthen innovation. The too-common story of failed water development schemes is more often attributable to a misunderstanding of local life than to the shortage of water or absent technology. If proposed solutions do not build on locally traditional approaches, even if only to improve on those approaches, they stand a high risk of rejection.

That is not to say local people always know best; it is just as wrong to romanticize tradition as it is to exalt science. But local practices always spring from some rationality, and it is this rationality that needs to be understood. Moreover, local knowledge and traditional practice are not static; they may not change fast, but neither do they change randomly. They change when, and only when, people see the value of change.

**4. Beware of generalizations, but share knowledge promptly.**
It is always difficult to generalize from the particulars of cases into any theory of wider application, especially when the research explicitly engages local detail and local conditions. Policymakers and researchers alike should only generalize with vigilance — and humility.

From the scientific perspective, there is never enough information; from a political perspective, there is always the obligation to act. So policymakers and researchers, in each of their spheres, must try methodically to distinguish between results with general application across geographic and cultural boundaries and those unique to specific settings. In most cases, these necessary distinctions go to questions of culture and governance more than to matters of science and technology.

At the very least, experiences with research and adaptation should be shared. Usually, the processes of scientific inquiry and innovation — rather than the product — will find the fastest and widest application in other communities and countries. Even failures, systematically understood, can valuably inform research and governance elsewhere. This dissemination of well-grounded knowledge is an indispensable factor in advancing sustainable development.

Dissemination is these days powered especially in networks of widely separated NGOs, government agencies, educators, and many others, linked by the Internet. A vivid and productive demonstration of this potential is found in an educational program known as AQUAtox, launched by IDRC in 1998. AQUAtox has linked more than 90 primary and secondary schools in 26 countries to teach simple tests for measuring chemical and microbial pollution in local water supplies. The project, begun as a pilot project, is being devolved now to the NGOs, government agencies, laboratories, and academic centres that can best apply and diffuse the scientific and pedagogical results.

**5. To achieve good government, and good science, conduct evaluation that is transparent, participatory, and continuous.**
New is not always better. For example, water from "improved wells" often proves to be only marginally better in quality than water from traditional sources — and it generally demands a costly or risky change in management techniques. So monitoring is important: to determine the nature and extent of change, to see if technical results match expectations, and to tell whether new management methods are actually adopted. This takes time, if only because observation must extend through wet and dry seasons, across good years and bad.

Nevertheless, evaluation is too frequently neglected. This is a dangerous mistake, wasteful and undemocratic. Dangerous, because it can allow harms to accumulate undetected and uncorrected. Wasteful, because it allows costs and benefits to go untallied. Undemocratic, because evaluation is a central element of transparency and accountability in good governance.

Local NGOs, academic centres, and all variety of other groups outside government can collaborate in the evaluation function with especially good effect in local water management. (An evaluation of the AQUAtox project confirmed, among other things, that it performed best in schools where the local community participated through "open houses" and other outreach mechanisms.) Other research, some of it reported by the International Food Policy Research Institute, shows that water management projects with NGO participation have tended to perform better than those controlled exclusively by government at any level. Significantly, NGOs generally devoted years to their projects, whereas governments tried for short-term outcomes. As well, NGOs typically worked to help the poorest and weakest in the community; governments relied more on existing power structures. IDRC-supported research in Nepal and India has explored similar dynamics: nongovernmental "social auditors" identifying interests and arguments that might not be otherwise heard, and catalyzing informed discourse within and across communities. Monitoring and evaluation belong in every enterprise of applied research and governance.

Part 5

# Future Directions

Before suggesting future directions for policy and research in local water management, frankness requires this qualification. Not all governments, or government agencies, are equally keen to devolve authority to local communities or to NGOs. On the contrary, many of them have worked relentlessly persuading people to abandon local water sources and traditional methods — and so to surrender local control. Many "senior" governments still believe, or act as if they believe, that they alone should decide water policy, and that community members are incapable of managing local supply and demand. The alternative fashion (just as insidious) is to download water management obligations to local authorities without granting them corresponding resources. These attitudes represent formidable obstacles to improved water management, and they are misplaced.

The merits of the local management argument speak for themselves, in the evidence of research conducted across the developing world. Approaches that genuinely engage local users in water management are simply more efficient, more effective, more equitable — and environmentally more sustainable — than the usual top-down practices. And because local management elicits local commitment and promotes stronger local institutions, these same approaches contribute to the sustainable management of entire watersheds.

But this is not merely a choice between levels of government. There is another challenge to meet. It is conventional now to acknowledge the logic of planning at the scale of watersheds, defined not by political borders but as hydrological units. So how should policymakers reconcile the compelling advantages of watershed or basin management with the reality that political boundaries do exist — legal lines drawn between countries and communities, and traditional lines between tribes and clans? And how should policy-making reflect the fact that politicians are answerable first to their own communities for the management decisions they make?

The answers, in principle, are powerfully simple. Good water policy consists of planning at the watershed or basin level, and implementing at the local level. But the relationship cuts both ways. Watershed planning needs to be fully informed by local interests, local potential, and knowledge of local resources. Just as surely, local supply and demand are constrained by the biophysical and socioeconomic limits on the watershed overall. In the end, making good policy means arranging local implementation approaches in ways that aggregate across communities in a coherent integration of watershed management.

Simple in principle, yes. And difficult in practice. To a large extent, resolving these difficulties will describe the future directions of local water research and management.

To begin with, research itself — its conduct and results — must be translated much more fluently into language that policymakers and local communities can comprehend. Where research can be oriented to an already-identified need (as with supplying scarce water to growing cities, for instance) research will be avidly scanned by decision-makers for early application. Equally, the esoteric models of hydrogeology must be converted into the functional tools of urban planning and rural development.

Then there are questions of dissemination — speeding useful information from village to village, neighbourhood to neighbourhood, into the hands of people who need it. Often, diffusion is achieved better through village, neighbourhood, and NGO networks than by heavy-footed centralized programing. This is an important new direction in the dynamics of governance around the globe: networks of research, deliberation, and action, organized and carried out in fluid partnerships among governments, NGOs, scholars, business people, and many others with diverse interests and shared objectives.

Improving local water management, and nesting local approaches in wider watershed strategies, will also call for a livelier and more concentrated attention to problems of water pricing. Here the issues are part conceptual, part political. Some of the toughest conceptual issues flow from the awkward fact that water is both an economic good (with economic value) and a necessity of life, to which every person has a recognized right of access (see Box 6). Water should be priced to reflect its real cost, but it should also be affordably available in adequate quantity and quality to every human being. Beyond that, much of it needs to be left in place for uses that can be hard to price precisely (such as fishing and transportation). Still other uses of water will be all but “unpriceable”: sustaining the ecosystem, and the pure human pleasure of its presence. Water is everywhere a multipurpose resource, which is both a blessing and a confounding complication.

## 6. The Dublin Principles

In 1992, experts from 100 countries and scores of intergovernmental organizations and NGOs gathered in Dublin for the International Conference on Water and the Environment. The conference influenced preparations for the UN Conference on Environment and Development, held later that year in Rio de Janeiro. Its brief concluding statement remains an authoritative affirmation of the water policy agenda; it contained four "guiding principles," recited here with extracts of the commentaries that accompanied each.

1. **Fresh water is a finite and vulnerable resource, essential to sustain life, development, and the environment.** Effective management ... demands a holistic approach, linking social and economic development with protection of natural ecosystems ....

2. **Water development and management should be based on a participatory approach, involving users, planners, and policymakers at all levels.** The participatory approach ... means that decisions are taken at the lowest appropriate level, with full public consultation and involvement ....

3. **Women play a central part in the provision, management, and safeguarding of water.** Acceptance and implementation of this principle requires positive policies to address women's specific needs and to equip and empower women to participate at all levels ....

4. **Water has an economic value in all its competing uses and should be recognized as an economic good.** Within this principle, it is vital to recognize first the basic right of all human beings to have access to clean water and sanitation at an affordable price ....

The political issues of water pricing, some of them addressed in earlier sections of this publication, are never far removed from the practical problems of management. Here the trade-offs among rival interests and different objectives are coloured by the politics of class, caste, gender, and inequalities of power. The distributions of land tenure, property rights, and access are classic expressions of political relations in any society.

Nor is local management in itself a sure defence against the pernicious operation of power politics; sometimes politics operate more ruthlessly in small communities than in the interest-balancing hurly-burly of national policymaking. The IDRC-supported study of the socioeconomic aspects of South Africa's "Working for Water" program, for example, showed clearly that local conflicts are remarkably persistent and that they can challenge efforts to conserve water. Good water management — like good governance generally — is defined by procedural equity as well as by the equity of outcomes. This turbulence at the convergence of politics and economics will remain inescapable in water research and policy.

No discussion of this kind is complete without a consideration of global climate change and its dangers. With few exceptions (China, India, and Brazil among them) developing countries are climate takers, not climate makers. They must react to global warming, defensively as a general rule. To succeed, these responses will have to be well designed, well executed, and durable over several decades. Stopgap solutions will fail.

The lamentable truth is that the developing countries will suffer the worst expected effects of climate change, mostly in the form of longer and more extreme perturbations: droughts, flooding, storms, and so on. Dry areas will probably experience less rainfall; humid areas will suffer lower soil moisture. For semi-arid zones, it will be the sheer unpredictability of year-to-year variations that will endanger lives and threaten development.

And yet, despite these serious and imminent hardships, all the harms of climate change will be smaller in most countries than the damage done by mismanaging water. That is why any failure to explore and apply local water management approaches is so costly — and why the opportunities for local management command analysis and action. In every one of our communities, we all share this common imperative: to manage scarce fresh water with efficiency, with fairness, and with an abiding determination to conserve the environment that gives life to us all.

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**Appendix**

# Sources and Resources

The literature on the nature and implications of water scarcities is abundant, and expands by the day. What follows below is intended only as a quick guide to sources and resources likely to be helpful to the analysis and improvement of local water management.

The global scope and local effects of water scarcities, addressed in fluid and jargon-free prose, are the subject of *Water*, by Marq de Villiers (Stoddart, 1999; revised edition 2000). *World Water Vision*, by William J. Cosgrove and Frank R. Rijsberman (Earthscan, 2000) offers an exceptionally useful overview. Peter Gleick's *The World's Water: The Biennial Report on Freshwater Resources* (Island Press, 1998 and 2000) is a valuable and regularly updated treatment.

Thomas Homer-Dixon advanced the scholarly study of modern conflict and resource scarcity in his careful *Environment, Scarcity, and Violence* (Princeton University Press, 1999). The linkages between water scarcity and conflict — and the commoner phenomenon of water scarcity engendering cooperation — are sensibly summarized in "Dehydrating Conflict" by Sandra L. Postel and Aaron T. Wolf (*Foreign Policy*, September/October 2001, pp. 60-67). Two IDRC books focus on Israel and Palestine, where water is often cited a source of conflict: *Watershed: The Role of Fresh Water in the Israeli–Palestinian Conflict*, by Stephen B. Lonergan and David B. Brooks (IDRC, 1994) and *Management of Shared Groundwater Resources: The Israeli-Palestinian Case with an International Perspective*, edited by Eran Feitelson and Marwan Haddad (IDRC and Kluwer Academic Publishers, 2000).

Reliable statistics are reprised in *The State of World Population 2001*, published by the United Nations Population Fund. Chapter Two, "Water and Population," was downloaded Nov. 7, 2001, from **www.unfpa.org/swp/2001/english/ch02.html**.

Dependable sources of information and analysis (along with vigorous advocacy) are proliferating on the Web. Some of the currently useful water management sites include: The International Water Management Institute (**www.iwmi.org**), a user-friendly site well laid out with archived and recent research, and "tools and concepts" instructive for the nonspecialist; World Commission on Dams (**www.dams.org**), a fine demonstration of what global policy networks can accomplish, with access to its landmark report "Dams and Development," issued in 2000; the World Water Council (**www.worldwatercouncil.org**), an excellent single-source site, hotlinked to other relevant organizations and materials; the International Food Policy Research Institute (**www.ifpri.org**); and the World Resources Institute (**www.wri.org**), especially strong on data and maps.

The Dublin Statement on Water and Sustainable Development, cited in Box 6, was downloaded Oct. 17, 2001, from the World Meteorological Organization (WMO) at **www.wmo.ch/web/homs/icwedece.html**. The WMO, the World Resources Institute, and the World Water Council are among the many organizations contributing to the worldwide analysis and discussion of global climate change. Peter Gleick has produced a helpful climate change study, accessible at **www.pacinst.org/overview.html**. For a short review of the subject, consult E. Z. Stakhiv, "Policy Implications of Climate Change Impacts on Water Resources Management," *Water Policy*, vol. 1 (1998), pp. 150–175.

Deeply important questions of culture, custom, and religion are squarely faced by the contributors to *Water Management in Islam* (United Nations University Press and IDRC, 2001), edited by Naser I. Faruqui, Asit K. Biswas, and Murad J. Bino. Anil Agarwal and Sunita Narain persuasively examine the enduring value (and the costly loss) of traditional knowledge in their *Dying Wisdom: Rise, Fall and Potential of India's Traditional Water Harvesting Systems* (Centre for Science and Environment, 1997). The growing interest in options for local water management is reflected in *The Cooperative Management of Water Resources in South Asia*, edited by Tony Beck, Pablo Bose and Barrie Morrison (Institute for Asian Research, University of British Columbia, 1999). Two books examining local water management have emerged from IDRC research projects in Asia: *Rethinking the Mosaic: Investigations into Local Water Management*, by Marcus Moench, Elisabeth Caspari and Ajaya Dixit (Nepal Water Conservation Foundation and ISET, 1999); and *The People and Resource Dynamics Project: The First Three Years*, edited by Richard Allen and others (International Centre for Integrated Mountain Development, 2000).

For accounts of the IDRC-supported research projects that inform the preceding pages (whether specifically cited or not), go to **www.idrc.ca/waterdemand/idrcprojects_e.html**. For deeper and more extensive detail on the projects, visit IDRC's Web site (**www.idrc.ca**) or go straight to the Centre's library at **www.idrc.ca/library**. At the library, click on IDRIS, then search by subject (rainwater catchment, for example) or by country. The IDRIS system will respond with a project précis, including descriptor terms that can lead the curious to other projects and related subjects. Still more detail, with research results, lessons learned, and a catalogue of IDRC local water project numbers, is contained in "Local Water Supply and Management: A Compendium of 30 Years of IDRC-Funded Research," by David B. Brooks, Sarah Wolfe and Tilly Shames (IDRC, 2001). The compendium constitutes the primary source for this paper and is one of the resources to be found at **www.idrc.ca/water**.

IDRC publications on many of these and other subjects may be browsed online in the IDRC Booktique, at **www.idrc.ca/booktique**.

## The Publisher

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