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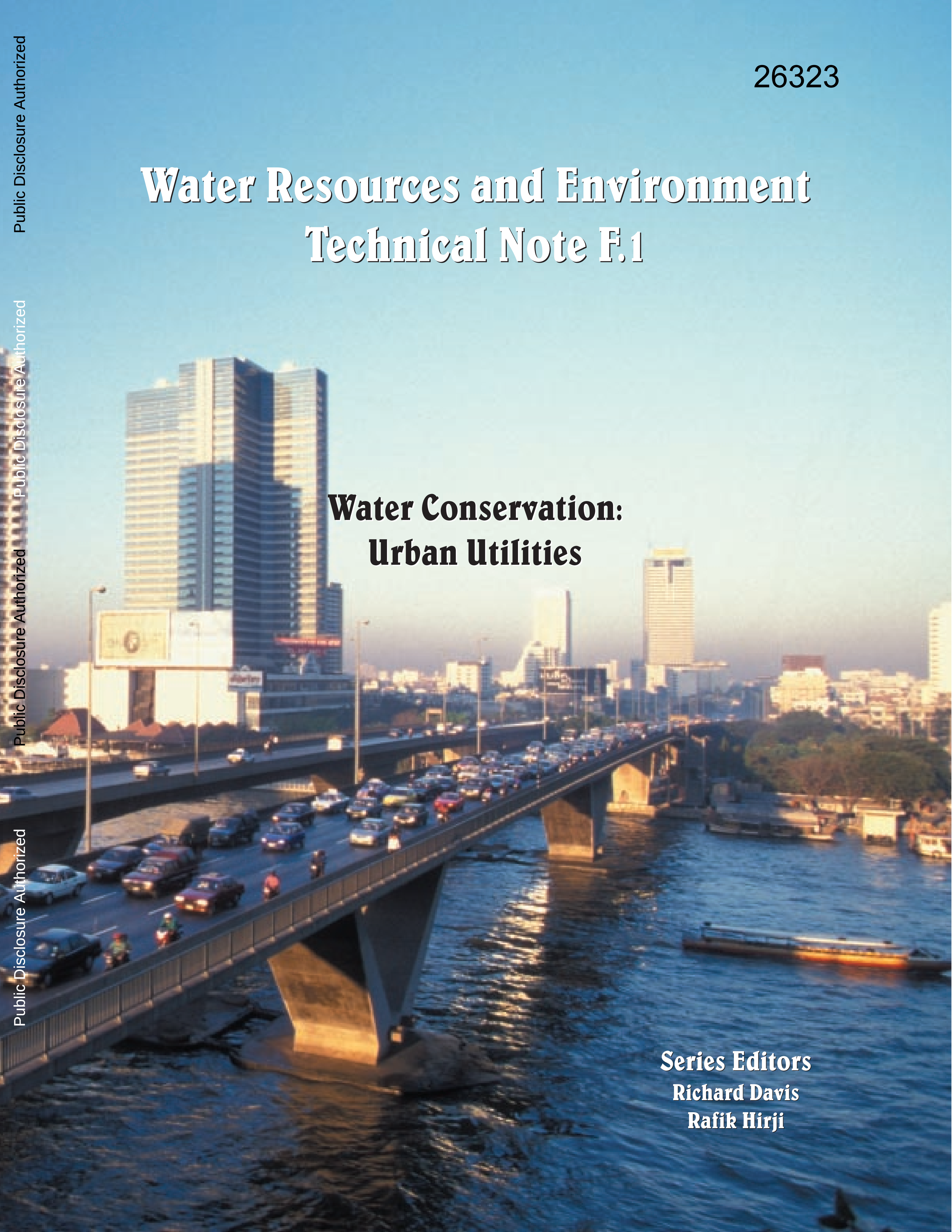

Water Resources and Environment
Technical Note F.1

Water Conservation: Urban Utilities

Series Editors
Richard Davis
Rafik Hirji

WATER RESOURCES AND ENVIRONMENT

TECHNICAL NOTE F.1

Water Conservation: Urban Utilities

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Contents

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Unless otherwise stated,
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Urban scene, Thailand

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FOREWORD

The environmentally sustainable development and management of water resources is a critical and complex issue for both rich and poor countries. It is technically challenging and often entails difficult trade-offs among social, economic, and political considerations. Typically, the environment is treated as a marginal issue when it is actually key to sustainable water management.

According to the World Bank's recently approved Water Resources Sector Strategy, "the environment is a special 'water-using sector' in that most environmental concerns are a central part of overall water resources management, and not just a part of a distinct water-using sector" (World Bank 2003: 28). Being integral to overall water resources management, the environment is "voiceless" when other water using sectors have distinct voices. As a consequence, representatives of these other water using sectors need to be fully aware of the importance of environmental aspects of water resources management for the development of their sectoral interests.

For us in the World Bank, water resources management–including the development of surface and groundwater resources for urban, rural, agriculture, energy, mining, and industrial uses, as well as the protection of surface and groundwater sources, pollution control, watershed management, control of water weeds, and restoration of degraded ecosystems such as lakes and wetlands–is an important element of our lending, supporting one of the essential building blocks for sustaining livelihoods and for social and economic development in general. Prior to 1993, environmental considerations of such investments were addressed reactively and primarily through the Bank's safeguard policies. The 1993 Water Resources Management Policy Paper broadened the development focus to include the protection and management of water resources in an environmentally sustainable, socially acceptable, and economically efficient manner as an emerging priority in Bank lending. Many lessons have been learned, and these have contributed to changing attitudes and practices in World Bank operations.

Water resources management is also a critical development issue because of its many links to poverty reduction, including health, agricultural productivity, industrial and energy development, and sustainable growth in downstream communities. But strategies to reduce poverty should not lead to further degradation of water resources or ecological services. Finding a balance between these objectives is an important aspect of the Bank's interest in sustainable development. The 2001 Environment Strategy underscores the linkages among water resources management, environmental sustainability, and poverty, and shows how the 2003 Water Resources Sector Strategy's call for using water as a vehicle for increasing growth and reducing poverty can be carried out in a socially and environmentally responsible manner.

Over the past few decades, many nations have been subjected to the ravages of either droughts or floods. Unsustainable land and water use practices have contributed to the degradation of the water resources base and are undermining the primary investments in water supply, energy and irrigation infrastructure, often also contributing to loss of biodiversity. In response, new policy and institutional reforms are being developed to ensure responsible and sustainable practices are put in place, and new predictive and forecasting techniques are being developed that can help to reduce the impacts and manage the consequences of such events. The Environment and Water Resources Sector Strategies make it clear that water must be treated as a resource that spans multiple uses in a river basin, particularly to maintain sufficient flows of sufficient quality at the appropriate times to offset upstream abstraction and pollution and sustain the downstream social, ecological, and hydrological functions of watersheds and wetlands.

With the support of the Government of the Netherlands, the Environment Department has prepared an initial series of Water Resources and Environment Technical Notes to improve the knowledge base about applying environmental management principles to water resources management. The Technical Note series supports the implementation of the World Bank 1993 Water Resources Management Policy, 2001 Environment Strategy, and 2003 Water Resources Sector Strategy, as well as the implementation of the Bank's safeguard policies. The Notes are also consistent with the Millennium Development Goal objectives related to environmental sustainability of water resources.

The Notes are intended for use by those without specific training in water resources management such as technical specialists, policymakers and managers working on water sector related investments within the Bank; practitioners from bilateral, multilateral, and nongovernmental organizations; and public and private sector specialists interested in environmentally sustainable water resources management. These people may have been trained as environmental, municipal, water resources, irrigation, power, or mining engineers; or as economists, lawyers, sociologists, natural resources specialists, urban planners, environmental planners, or ecologists.

The Notes are in eight categories: environmental issues and lessons; institutional and regulatory issues; environmental flow assessment; water quality management; irrigation and drainage; water conservation (demand management); waterbody management; and selected topics. The series may be expanded in the future to include other relevant categories or topics. Not all topics will be of interest to all specialists. Some will find the review of past environmental practices in the water sector useful for learning and improving their performance; others may find their suggestions for further, more detailed information to be valuable; while still others will find them useful as a reference on emerging topics such as environmental flow assessment, environmental regulations for private water utilities, inter-basin water transfers and climate variability and climate change. The latter topics are likely to be of increasing importance as the World Bank implements its environment and water resources sector strategies and supports the next generation of water resources and environmental policy and institutional reforms.

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This Note was drafted by Nico Versteeg and Janine Tolboom of DHV Water, the Netherlands. Andrew Macoun, David Hanrahan, and Hans-Olav Ibrekk of the World Bank reviewed the draft Note. Ronald Mckenzie of WRP Ltd, South Africa provided information on the Khayelitsha project.

INTRODUCTION

Access to sufficient amounts of clean water is increasingly recognized as the critical resource problem in the 21st century. The World Commission on Water estimates that the world's use of water has increased six-fold over the last 100 years, even though the population has only tripled. It predicts that, under current levels of demand, water usage will rise by 50 percent over the next 30 years. Three billion people will live in countries that will have less than 1,700 m³ water per capita–the recognized level of water stress–by 2025.

The World Water Council's recently released vision statement makes it clear that developing new sources of water will not be sufficient to meet this challenge. New sources will have to be coupled with wiser use of existing stocks of water through water conservation measures, water reuse, conjunctive use of surface and groundwater, and maintenance of water quality, so that drinking supplies and other essential uses are not compromised. Water conservation can be promoted by ensuring that prices are set to reflect the scarcity value of the water, by developing and installing water-saving technologies, and by encouraging stakeholders to take responsibility for water use. By promoting the correct policies and techniques, there is considerable scope for efficiency improvements in the three main water-using sectors–agriculture, industry, and municipal uses.

Photo by World Bank

Water seller filling cart, Viet Nam.

The World Bank's 1993 Water Resources Management Policy and the recent Water Resources Sector Strategy place a high priority on encouraging and assisting countries that are implementing demand management. Failure to use economic and regulatory instruments to manage demand and guide allocation often results in inefficiencies as well as significant externalities–reduced flows for downstream uses, pollution, and degraded ecosystems.

This Technical Note is one in a series of Notes prepared by the World Bank Environment Department. Note F.2 deals with water conservation in the irrigated agriculture sector and is a companion to this Note. This Note discusses the importance of saving water in an urban context; presents both physical and administrative measures to conserve water by increasing delivery efficiency; describes measures to conserve water though increasing end-use efficiency; discusses policy tools that can be used to encourage water conservation; and presents the steps that can be adopted to assess water demand and conservation measures hand-in-hand. A case study for the South African town of Hermanus illustrates the combined effect of implementing many of the tools for water conservation.

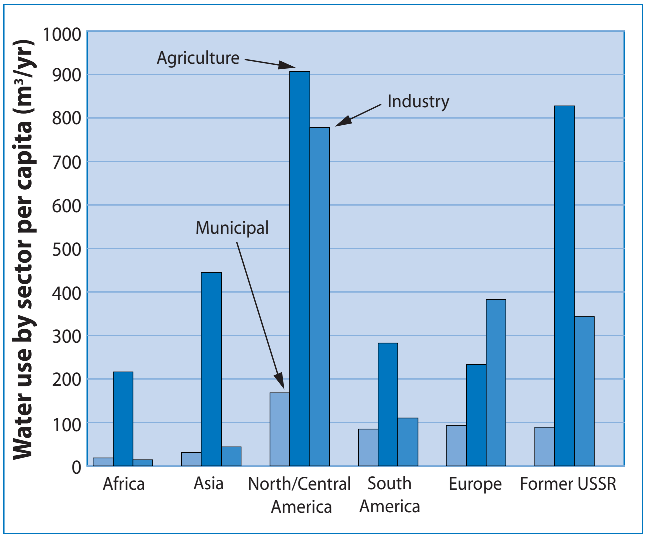
THE NEED FOR URBAN WATER CONSERVATION

Water is an increasingly scarce resource in many countries, as competition among agricultural, urban, and industrial users becomes more common. Worldwide, agriculture is the single largest user of water, accounting for about 69 percent of all use. About 23 percent of water withdrawals supply the industrial and energy sectors, and just 8 percent are used for domestic or household use. Thus, water withdrawals for urban consumption are substantial, but are significantly smaller than those for agriculture. Patterns of use vary greatly from country to country, depending on levels of economic development, climate, and population size (Figure 1). For example, in countries such as Kuwait and Zambia–with little industry or irrigated agriculture–households use nearly two out of every three liters of water consumed.

Household water consumption tends to increase with rising standards of living. In the United States, individuals typically use more than 700 liters each day for domestic tasks, compared to the average of 29 liters per head used in Senegal to meet household needs.

Industry uses water for cooling, processing, cleaning, and removing industrial wastes. Nuclear and fossil-fueled power plants are the single largest industrial consumers, using large amounts of water for cooling. While most of the water used for industrial purposes is returned to the water cycle, chemicals and heavy metals often contaminate it, or its temperature is increased. Industrial use varies from less than 5 percent of withdrawals in many developing countries to as much as 85 percent in Belgium and Finland. The proportion of water used for industrial purposes is often considered an indicator of economic development.

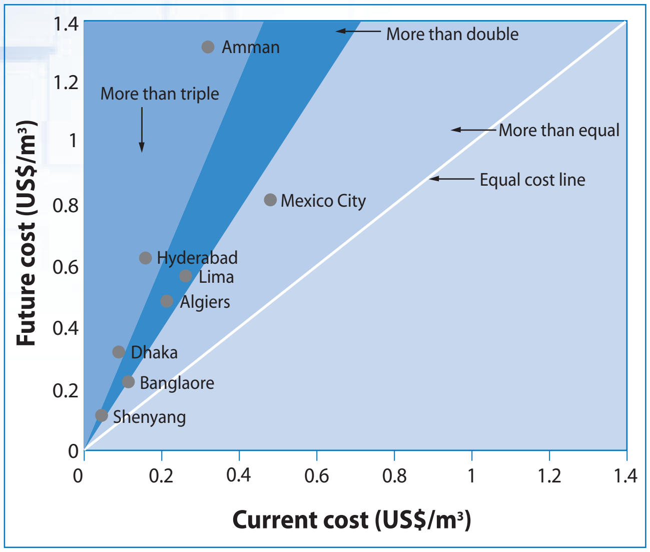
FIGURE 1.
REGIONAL WATER USE PER CAPITA BY SECTOR



Currently, about 1.5 billion people lack access to safe water. Given the predicted urban population growth rates, the demand for water supply to urban populations for domestic and industrial uses is expected to grow rapidly. However, there are major technical and financial difficulties in meeting this increasing demand in developing countries. Technical difficulties arise because a) the most accessible sources have already been tapped; b) water is allocated to other uses such as irrigation at much lower cost than for urban use; c) groundwater is exploited in a way that often exceeds replenishment (see Note G.1); and d) the quality of intake water has frequently deteriorated due to pollution (see Notes D.1–3).

Financial difficulties arise as a consequence of these technical difficulties. The unit cost of raw water is expected to at least double, and in some cases triple, in many cities as more distant and more costly sources of water supply have to be tapped. Figure 2 shows the projected unit cost of the next raw water supply scheme for a number of cities based on a 1990 World Bank study. As pollution increases, the increase in the cost of delivering treated water could be even greater once the increasing costs of treatment are incorporated. These technical problems, along with the generally poor performance of public water and sewage utilities–caused by problems such as unregistered connections, unaccounted-for water (UFW), and excessive numbers of employees–mean that many utilities experience a low degree of cost recovery. The upshot is that governments

FIGURE 2.
THE FUTURE COST OF WATER.



Source: World Bank 1992. *World Development Report: Development and the Environment*. Washington: World Bank.
Notes. Costs are in 1988 $ and are for raw water, excluding treatment and distribution. Current cost is the cost at the time the data were collected; future cost is the cost of a new development project. The most expensive example of current cost is Mexico City. Future investment costs per m^3 in Amman and Hyderabad are expected to increase by a factor of about 4 compared to current investment costs.

in developing countries are increasingly reluctant to finance the rising costs of water supply infrastructure, while water utilities are not able to meet costs from user charges. Consequently, the water supply and sanitation sector in developing countries either becomes increasingly dependent on the support of donors and international finance institutions or turns to the private sector for management.

As the cost of bringing new sources on-line increases, more efficient use of the existing supplies becomes an increasingly cost-effective alternative to supply augmentation (see Table 1). This demand management approach is termed water conservation. For urban water utilities, water conservation can take several forms. Where transmission and distribution losses are high, actions could include leak detection programs, rehabilitation of pipes, or pressure reduction projects. Where demand is high, actions such as awareness-raising programs, price incentives, and regulation may be effective. Compared to supply-based solutions, a demand management approach has the major advantage that it is designed to promote sustainability by changing public attitudes to water and water consumption over time.

TABLE 1.
SAN DIEGO COUNTY WATER SUPPLY COST COMPARISON

Source	Range ($ per 1,000 m^3) [a)]
Desalted Sea Water	973–1,612
Imported Water	566–670
Desalted Well Water	365–649
Reclamation [b)]	292–473
Conservation [c)]	162–567

Notes:
a) Figures reflect 1990 costs.
b) These costs are for water delivered to the end user.
c) Conservation measures used in calculation include installation of high quality water-conserving showerheads and ultra-low flush toilets.
Source: San Diego County Water Authority. 1991. *Economic and Financial Analysis, Clean Water Program for Greater San Diego, Phase 1 Water Reclamation Program*, in World Bank (1993).

INCREASING DELIVERY EFFICIENCY

As utilities struggle to use older and poorly maintained water distribution systems to meet demand, water supplies often become intermittent. Although intermittent operation can conserve water in the sense that empty pipes don't leak, this is not a desirable operational strategy, since the uncertainty is disruptive to consumers and can encourage them to use water inefficiently for the periods when it is available. In addition, intermittent operation is damaging to distribution networks because the cyclical stressing causes movement of pipes and greatly increases leakage. Water conservation and, if necessary, development of new water sources, is a more sustainable solution.

Maintenance is likely to provide a cost-effective means of water conservation where the supply system is old and poorly maintained. For instance, the Massachusetts Water Resources Authority (MWRA) has determined that leak detection and repair is among the most

Table 2.
Comparative costs of water supply and augmentation alternatives presented by MWRA

Alternative	Annual ($ per 1,000 m³)[a]	Capital cost ($ million)[b]	Yield (1,000 m³/day)
Supply Responses:			
Connecticut River	132–211	120–220	238
Millers/Tully Rivers	238	135	144
Merrimack River	423	600	454
Conservation and Demand Management:			
Leak Detection & Repair	37	30	114
Domestic Device Retrofit	61–148	10	19–45
Low-Flow Toilet Retrofit	872	200	64
Industrial & Commercial Conservation	13	0.1[c]	3[c]
Improved Use of Existing Supplies:			
Local Sources	90–343	16	1.5–30
Water Sharing	13–132	0.2[c]	3[c]
Sudbury Residential Treatment Plant	211	34–37	62
FY90 MWRA Water Rate	135	N/A	N/A

Source: Massachusetts Water Resources Authority. 1990. *MWRA Long Range Water Supply Program*, in World Bank (1993).
Notes: a) Annual O&M and amortized capital costs.
b) Figures reflect 1990 costs.
c) Yields and costs from first year's experience. Actual values will be higher.

economical means of balancing demand and supply within their service area (see Table 2).

A low rate of unaccounted-for water (UFW) is one of the important overall indicators that a water supply utility is successful. Rates of UFW vary from system to system. In 1994, Singapore's UFW of about 6 percent was the lowest in the world. In many other cities, rates of 20 to 40 percent are not unusual (Table 3). The amount of UFW in Mexico City's supply system is sufficient to supply a city the size of Rome.[1] Clearly, there are major opportunities to put this wasted resource to productive use and thereby postpone the need to develop new sources of water.

UFW includes two types of losses. Physical[2] losses include water lost from leaks in the distribution systems, in-house connections, and from overflows in distribution tanks. Administrative[3] losses repre-

Table 3.
UFW in selected cities

Country, city	Year	Unaccounted-for Water (%)
Brazil, Sao Paulo Metropolitan Area	1992	40
Chile, Santiago	1990	28
Colombia, Bogota	1991	40
Costa Rica	1991	45
Ivory Coast, Abidjan	1993	17
Guinea, Conakry	1993	53
Senegal, Dakar	1993	29
Togo	1990	22
Turkey, Ankara	1988	45
Pakistan, Karachi	1995/96	30
China, Shanghai	1995	14
Philippines, Manila	1995	44
Thailand, Bangkok	1994/95	38
Kyrgyz Republic, Bishek	1996	42
France, Bordeaux	1982	15
Canada (average)	1984	15
USA (average)	1984	12
Japan, Tokyo	1990	12
Macao	1991	11
Singapore	1994	6

Sources: Asian Development Bank. 1997. *Second Water Utilities Data Book, Asian and Pacific Region*. Other data from World Bank (1996).

[1] Falkenmark, M., and G. Lindh. 1993. "Water and economic development," in P. H. Gleick. 1993. *Water in Crisis: A Guide to the World's Fresh Water Resources*. New York: Oxford University Press.
[2] Sometimes called technical losses.
[3] Sometimes called non-technical or commercial losses.

TABLE 4.
COMPOSITION OF UFW IN SELECTED CITIES

Country/City	Year	Composition of UFW (%)		
		Physical	Administrative	Total
Singapore	1989	4	7	11
Spain, Barcelona	1988	11	12	23
Colombia, Bogota	1991	14	26	40
Costa Rica, San Jose	1990	21	25	46

Source: World Bank (1996).

sent water used but not paid for. They stem from unauthorized use of water (illegal connections), from faulty meters, and from tampering with the often-inadequate controls of the commercial system. Administrative losses often constitute a major portion of UFW (Table 4).

There are several means available to detect and estimate UFW. The most important measures are discussed in Box 1.

The goal should not be to completely eliminate UFW, but rather to reduce it to a point where fur-

BOX 1.
DETECTING PHYSICAL AND ADMINISTRATIVE WATER LOSSES

Physical

Estimating amounts of leakage
For those systems supplying water 24 hours per day, "nightflow measurement" provides a relatively straightforward way to obtain an estimate. This involves measuring rates of water flow into the distribution network at night, when actual water consumption by customers is very low. This approach does not work where water consumption may be considerable during the night, e.g. for filling ground or roof tanks. If those customers who use significant amounts of water during the night are known to the water utility, their consumption may be estimated. Leakage from the distribution system can be estimated once these demands are taken into account.

Locating the points of leakage (leakage detection)
Various methods for leakage detection are available:

1. *Visual inspection.* A stroll around the area served by the distribution network, especially in the dry season, will usually reveal a number of sources of leakage. Wet patches of earth, over or alongside the routes of pipelines, frequently indicate underground leaks.
2. *Step-testing.* This method can only be carried out where bulk water meters are installed. The technique of step-testing involves shutting off the supply to parts of the study area in consecutive steps by using "step valves."
3. *Listening for leaks.* When water, under pressure in a pipe, is allowed to escape through a small hole or crack, often it will produce a particular hissing sound. The sound travels both through the ground and along the pipe. It is often possible to detect leaks merely by listening for them. Leak noise correlates can pinpoint the location of the leak.

Administrative

Under-measurement of consumption
To reduce the under-measurement of consumption, a list could be prepared of those properties whose metered consumption seems suspiciously low compared to earlier records or to the metered consumption of their neighbors. The meters on those properties could then be inspected to check for any signs that they have been tampered with and/or that they need cleaning or repair.

Meter reading and recording losses
Other major causes of administrative losses can be incompetence, inadequate training, and/or corruption of meter readers. These problems are more common where poorly paid meter readers also collect the water bills. Ways to improve meter reading include better pay and incentives for staff, appropriate training, frequent verifications by supervisors, and regularly changing of routes covered by individual readers. Contracting out meter reading is also becoming more frequent. Modern methods of meter reading by hand-held computers or remote metering generally overcome these problems.

Non-registered connections
The extent to which the utility can check for illegal connections is determined by local custom and practice. In some countries, a group comprising government officials/elected leaders periodically visits and inspects properties suspected of having illegal connections.

ther benefits equal additional costs. This point will depend, among other things, on the relative scarcity value of water. As discussed in Note F.2, leakage from irrigation water distribution systems often supports beneficial uses (such as village water supply, groundwater recharge, and wetlands), so the correction of leaks in these supply systems should only be undertaken after a thorough analysis of the benefits and costs arising from leak reduction. However, these considerations are much less important in urban water supply systems, where there are fewer beneficial uses for leakage water. Consequently, there are greater net benefits from leak reductions programs in urban water distribution systems. Box 2 presents two case studies showing the cost-effectiveness of UFW programs in two different circumstances.

Leaks in both the distribution system and within households can be exacerbated by excessive water pressure. Where this occurs, reducing the pressure can produce highly cost-effective results, as is shown in the case of Khayelitsha in South Africa (Box 3). Not only was the original water use reduced by 43 percent, but the capital investment was paid off within the first two months of operation through reduced water use, and there were few complaints from the community over the reduced water pressure. Additional savings occurred in the sewage treatment plants. The planned upgrade of the Zandvleit Sewage Treatment Plant, which had a capacity of 60 ML/day and was running over capacity, was dropped because inflows to the plant were reduced by 20 Ml/day. The postponement of the upgrade is estimated to save R4.5 million per year in

Photo by R. Mckenzie, WPS Ltd, South Africa

Khayelitsha pressure reduction plant, South Africa.

addition to the R27 million saved in reduced water use. To date, there have been no incidents of vandalism or damage to the installation. These results can be largely attributed to the high degree of community involvement in the whole pressure reduction project, including the use of local labor wherever possible.

Asset management is increasingly being recognized as an essential function of water utilities. This focus derives not only from the need to meet regulatory requirements, but also from the need to produce long-term investment plans and to target capital expenditure in the most cost-effective manner. Most urban water utilities have a wide range of assets, such as sources, reservoirs, treatment works, water mains, pumping stations, and miscellaneous offices, depots, and workshops. For effective management of these assets, it is essential

BOX 2.
EFFECTIVENESS OF UFW PROGRAMS

The city of Murcia, Spain, with a population of 350,000 was faced with a high UFW level of 44 percent. By implementing a new commercial management system that better accounted for all water uses and users, the municipal company reduced unaccounted-for water to 23 percent over five years. The resulting water savings proved adequate to increase the number of water connections by 19,000 and achieve 100 percent coverage.

The city-state of Singapore, with a population of about 2.8 million, has scarce water resources. By sustaining a consistent metering and leak reduction program, the Public Utilities Board has succeeded in reducing UFW from the already low level of 10 percent in 1989 to 6 percent in 1994. In this case, the high value of freshwater makes a low UFW economically worthwhile.

Source: Adapted from Yepes, G. (1995).

BOX 3.
KHAYELITSHA PRESSURE REDUCTION PROJECT, SOUTH AFRICA

Khayelitsha, approximately 20 km from Cape Town, is one of the largest townships in South Africa. The area houses approximately 450,000 people in 43,000 serviced sites with both internal water supply and waterborne sewage, and a further 27,000 squatter shacks supplied from communal standpipes. The area is supplied with potable water from Blackheath Reservoir—situated at an elevation of 110 m—through two large water mains of 450mm and 1,065 mm diameter. The average head at the supply point is approximately 80m, which is excessive and has caused considerable damage to household plumbing fittings.

The minimum night flow (MNF) was 1,600 m^3/hr. Approximately 1,200 m^3/hr were leaking to the sewer system, indicating that the key problem was household leakage. The Khayelitsha Pressure Management Project was initiated in June of 2001 by the City of Cape Town to reduce the excessive water pressure in the reticulation system. In a first phase, pressure reduction valves (PRVs) were inserted into the water supply mains to reduce pressure. In the second phase, advanced electronic controllers were installed to manipulate the pressure during off-peak periods. Through the use of such controllers, it is possible to achieve larger savings than those obtained through the PRV's on their own.

The results were dramatic. Prior to the project, the average daily flow was 2,500 m^3/hr (21 million m^3/a, of which 75 percent was wastage) with a minimum night flow of 1,600 m^3/hr. After the first phase was completed, the average daily flow was reduced to 1,790 m^3/hr and the minimum night flow to 1,180 m^3/hr. The implementation of the second phase was to be completed by the end of 2002. Although final outcomes of Phase 2 have not been fully compiled, preliminary results achieved so far indicate that the MNF has been reduced by a further 430 m^3/hr (to 750 m^3/hr). The initial results suggest that the eventual savings will be in excess of 9 million m^3/yr out of the original 21 million m^3/yr.

Source: Mckenzie, R.S. 2002. "Khayelitsha Leakage Reduction Through Advanced Pressure Control, *MIESA Monthly Magazine, Journal of the Institution of Municipal Engineering of Southern Africa,* 27 (8): 43-47.

to know what assets are available, what they are meant to do, what condition they are in, and how they are performing. With this information, the water utility is able to make informed decisions on the investment required to maintain acceptable levels of service and UFW, while controlling costs and understanding the trade-offs between investment and business risks.

INCREASING END-USE EFFICIENCY

While the previous measures focused on conserving water by reducing losses in the water distribution system, this section focuses on conserving water through increasing end-use efficiency. End-use efficiency is the amount of service obtained per unit of water used. Within the urban context, end-use efficiency can be increased for water use in households and gardens or parks, or in industrial water use.

The four techniques described here have been pioneered in those parts of developed countries–such as the southwestern United States–that experience water shortages. They are less relevant to the developing world, where reductions in water consumption are more likely to occur through increasing water delivery efficiencies. However, household water-saving devices and industrial water savings may contribute to water savings in those developing countries where there is already an extensive reticulated water supply system and where the economy is sufficiently robust to allow the installation of water-saving devices. Low-water-use landscaping and multiple uses of water are included here because they may be applicable in specific instances in developing countries.

WATER-SAVING DEVICES

Water-saving devices can provide the same service using less water by restricting flow to increase the velocity of discharge. Some useful examples of common water-saving devices for households in indus-

Box 4.
Examples of household water-saving devices

Plumbing. Residential water users can conserve water by installing indoor plumbing fixtures that use less water. Low-flow plumbing fixtures and retrofit programs are permanent, one-time conservation measures that can be implemented automatically with little or no additional cost over their useful lifetimes. In some cases, they save the resident money over the long term.

Low-flush toilets. A traditional toilet is often the biggest water-using fixture in houses in developed countries. Ultra-low-flush toilets are required in new construction in many jurisdictions. Some water districts offer rebates to those homeowners who refit their homes with ultra-low-flush toilets. If toilet replacement is not possible, homeowners can conserve water by placing a brick, a stone, or a plastic bag or container filled with water in the toilet tank. This displaces some of the water and reduces the amount of water per flush.

Low-flow showerheads. After the toilet, the biggest household water user is the shower or bathtub. A shower-flow restrictor can cut the flow to less than half the normal flow. A low-flow showerhead offers even greater savings. Properly designed low-flow showerheads are available to provide the quality of service found in higher-volume models.

Faucet aerators. Faucet aerators, which break the flowing water into fine droplets and entrain air while maintaining wetting effectiveness, are inexpensive devices that can be installed in sinks to reduce water use. Aerators are easily installed and may reduce the water use at a faucet by as much as 60 percent while still maintaining a strong flow.

Pressure reduction. Because flow rate is related to pressure, the maximum water flow from a fixture operating on a fixed setting can be reduced if the water pressure is reduced. Homeowners can reduce the water pressure in a home by installing pressure-reducing valves. The use of such valves is one way to decrease water consumption in homes that are served by municipal water systems. For homes served by wells, reducing the system pressure can save both water and energy. A reduction in water pressure will have no effect on fixtures such as washing machines and toilets that operate on a controlled amount of water. A reduction in water pressure may also help reduce flows from leaking water pipes, leaking water heaters, and dripping faucets.

Source: US EPA. 2000. *Using Water Efficiently: Ideas for Residences.* Washington: USEPA

trialized countries are provided in Box 4. These water-saving devices may not be appropriate in developing countries because of low levels of water use, cultural values, or restricted income levels. Water-saving measures can be implemented in industries, businesses, and institutions. In these cases, identifying water-saving measures may be less straightforward and may require specialist studies (Box 5).

Box 5.
Example of water-saving measures in industry

The Massachusetts Water Resources Authority conducts water efficiency studies as part of its Industrial/Commercial/Institutional Water Management Program. The purpose of the program is to analyze water use in industrial facilities and identify cost-effective water efficiency measures that result in a payback on investments in roughly two years.

MicroSemi is an example of a company that has benefited from this program. The report provided by the MWRA proposed the following measures:
- replacing two of the filter membranes in the water purification system
- utilizing reject streams from the purification system for cooling-tower makeup
- reducing nonproduction-period losses (through increasing employee awareness)
- reducing rinse-water consumption.

When MicroSemi managers realized the long-term cost effectiveness of these measures, they wanted to go beyond the proposed measures and decided to upgrade the entire water treatment system. With an investment cost of $135,000, estimated water savings amounted to about 14 million m^3 per year. The estimated water, sewer, and heating savings were $55,600 in 1994.

Source: MWRA. 1994. *Water Use Efficiency Case Study: MicroSemi USPD Inc., Watertown, MA.*

LOW-WATER-USE LANDSCAPE

Derived from the Greek word "xeros" for dry, xeriscape combines creative functional landscaping, efficient irrigation, and water-thrifty plants to save water. Examples include grouping plants with similar water requirements and adjusting the watering schedule for each area of the yard. Such grouping prevents water from being wasted on plants that do not need it. Because grass uses considerable water, another technique is to use grass only when appropriate or useful, filling in other areas with attractive, water-thrifty groundcovers, perennials, and shrubs. Such measures may be taken at different locations, such as homes, hotels, government agencies, or industries.

MULTIPLE USES OF WATER

Some urban water uses, such as toilet flushing or irrigation of gardens, do not require potable quality water. Grey water[4], rainwater, surface water, or treated wastewater could be used instead, yielding water savings and possible cost reductions.

Grey water is most suitably used for subsurface irrigation of nonedible landscape plants. Grey water could supply most, if not all, of the landscape irrigation needs of a domestic dwelling in a semiarid region. Grey water can also be used for toilet flushing if the country's regulations on reuse of water and cultural beliefs allow.

Photo by Jean-Roget Mercier, World Bank

River, Colombia

Rainwater can be collected or harvested from paved areas, roofs, or gutters. Houses can be designed to maximize the amount of catchment area, thereby increasing rainwater-harvesting possibilities. Collected and stored rainwater can be used in toilet flushing and surface irrigation, especially in gardens where food is grown. In the United States, harvested rainfall is used mainly for irrigation and occasionally for other domestic uses. Rainwater harvesting systems can be quite simple and inexpensive. Directing rainfall to plants located at contoured low points is a very simple rainwater harvesting system. More complex systems include storage of rainfall. Box 6 includes an example of a project where rainwater harvesting techniques were included as an alternative urban water supply option.

[4] Grey water is derived from residential water uses such as the bath, shower, washing machine, and bathroom sink, which do not contain human wastes. Water flushed from toilets, where bacterial contamination may occur, is called black water.

BOX 6.
EXAMPLES OF IDENTIFYING FEASIBLE PROJECT OPTIONS INCLUDING RAINWATER HARVESTING

Three Indonesian villages, included in a water supply project, face poor groundwater quality and dry dug-wells in the dry season. Rainfall, on the other hand, occurs reasonably frequently. The least-cost analysis included the following options:
- rainwater collection (with storage)
- hand pumps, small bore well
- hand pumps, small bore well with upflow filter units
- piped water supply system.

By including all these options in the consideration of alternatives, the analysis explored not only conventional water supply approaches, but also an option that would help conserve traditional water supply sources.

Source: Asian Development Bank (1999).

POLICY TOOLS FOR WATER CONSERVATION

The previous two sections described the administrative and physical measures to increase delivery efficiency and end-use efficiency. This section discusses policy tools for water conservation. Some of the tools (e.g. higher unit prices for water supply) provide incentives to implement water saving measures; others make better use of existing sources of urban water supply. Other policy tools, such as mandatory rationing that rely on regulatory powers, are not discussed here.

INTEGRATED WATER RESOURCES MANAGEMENT

An integrated approach is widely agreed to be the most effective way of managing water resources so that the demands from all water users, including the environment, are taken into account. Higher-level government institutions may have opportunities to implement measures that improve or alter the management and allocation of water resources, thus resulting in more efficient use of the resource. For example, better management of source areas can improve both quantity and quality of water supplies, and thus postpone development of costly new sources of water.

Box 7 provides two examples where the costs and benefits of water use by multiple sectors were considered in an integrated way. In Song Quao, Viet Nam, water quantities were allocated among sectors in order to maximize the benefits from the available water. In Liaoning Province, China, inter-sectoral water quality improvements were identified that would lead to better water use. Independent decisions in each sector would not have resulted in economically optimal decisions.

PROGRAMS BY WATER SUPPLIERS

Specific conservation measures are seldom executed effectively in isolation. For example, tariff increases, supported by education and backed by legislation, are likely to be more effective in promoting the use of water-saving devices. The following sections discuss specific tools that can be used by water suppliers and governments in the implementation of urban water conservation programs.

Metering. Metering is a fundamental tool for water system management and conservation and a prerequisite for efficient pricing systems. It provides information on the delivery efficiency of the water system and offers incentives to consumers for water conservation.

Metering can be installed at different locations and for different purposes:

- *Source-water metering*. Both the supplier and the customer benefit from these installations. Source metering is essential for water accounting purposes.
- *Service-connection metering*. Service-connection metering informs customers about the quantity of water they are using. Suppliers can use these metering data to track water usage. Such metering is essential if consumer charges are to be based on the amount of water consumed.
- *Public-use water metering*. All water provided free of charge for public uses can be metered. This will allow the utility to account more accurately for water use. Lack of public-use metering undermines other conservation measures.

Service-connection metering in combination with charging by volume can result in significant water savings (Table 5). However, service-connection metering requires considerable capital cost. Meter testing, calibration, repair, and maintenance programs are fundamental to ensure accurate water accounting and billing. This is feasible when the country has sufficient technical capacity to maintain this technology over the long term. Box 8 describes the experience of installing water meters in two towns in Bangladesh, accompanied by a public education program.

Price Incentives. Water-user charges are often considered a central component of a water conserva-

Box 7.
Reallocation of water as a result of integrated water resources management studies

Song Quao, Viet Nam

The opportunity cost of obtaining municipal water supplies during the dry season (December to May) from the Song Quao irrigation scheme was determined for various crops. The opportunity cost was calculated at \$0.081 per m^3, of which \$0.102 per m^3 was for sugarcane, \$0.197 per m^3 for rice in the double rice system, \$0.062 per m^3 for rice in the triple rice system, and \$0.029 per m^3 for watermelon.

To maximize overall net benefits from these scarce water resources, the crops with the lowest net benefit per m^3 should be removed first, followed by crops with the next higher benefits, and so on. This meant that all 50 ha of watermelon should be replaced with nonirrigated crop cultivation, and an increasing part of the triple rice system should be taken out of production to meet the need for municipal water supply (117 ha for a piped water supply of 15,000 m^3/day, 178 ha for 20,000 m^3/day, and 299 ha for 30,000 m^3/day). The opportunity cost of raw water was estimated at \$0.060 per m^3 based on these crop areas. These reductions in agricultural production meant that the cost of reallocating water from irrigation to urban water supply would be about \$37,000 per year for the production of 7,000 m^3 of drinking water per day, \$113,000 for 15,000 m^3 of drinking water per day, \$168,000 for 20,000 m^3 of drinking water per day, and \$277,000 for 30,000 m^3 of drinking water per day.

Liaoning Province, China

Liaoning Province, in the northeast part of China, has a total land area of 145,700 square kilometers and a population of about 36 million, including some 25 million in urban areas. The province has a strong urban industrial base, but relies on farming for its basic food supply. The most important farm production areas are the twin basins of the Hun and Taizi rivers in the center of the province.

Water supply for industrial, domestic, and agricultural purposes is heavily dependent on flows from the two rivers, either from direct extraction or from groundwater recharge. Rapid industrial development combined with inadequate wastewater management has heavily polluted both surface and groundwater resources, seriously affecting drinking, industrial, and agricultural water quality. There is an urgent need to raise the quality of the water in the two rivers to a standard that makes it safe for both human and environmental use, while being economically justifiable.

Strategies for the effective utilization of the Hun-Taizi water resources were identified through a study completed in 1988. The study identified investments required for water resource development and water pollution abatement in specific cities. Furthermore, the study highlighted deficiencies in institutional arrangements for water resource management, inadequate urban environmental services, and the need for focused water and wastewater investments. The Liaoning Environment project assists the government in reducing pollution and improving operational efficiency through upgrading of technology, minimization of waste, and reuse of resources.

Table 5.
Estimated water savings due to metering and charging by volume

Location	Period	Savings due to metering (%)
Collingwood, Ontario, Canada	1986–90	Summer peak: 37
Leavenworth, Washington, USA	1988–91	Summer peak: 61
Oak Park, UK	1993–96	Summer peak: 50
New York City, USA	1991–95	Annual: 7
Portland, USA	1993–94	Annual 10-12
Isle of Wight, England	1988–92	Annual: 21
Barcelona, Spain	early 1990s	Annual: 13
St Peter's, UK	1993–96	Annual: 14

Source: Organisation for Economic Co-operation and Development (OECD). 1999. *Household Water Pricing in OECD Countries*. Paris: OECD.

Box 8.
Installation of service-connection water meters in Bangladesh

The objective of this water supply and sanitation project was to improve the performance of water supply utilities in 18 district towns in Bangladesh. As a pilot project, water meters were installed in two towns, each with about 75,000 inhabitants in order to increase the water revenue collection efficiency.

Through an education program, the public was informed that:
- Water supply was going to be improved: more supply hours; more value for money.
- Potable water is precious, so consumers have to pay for what they use.
- The tariff system will change; instead of a flat rate, consumers will pay for what they use. Water meters will be installed to measure the usage.
- Procedures will be implemented for the water meters, including water meter reading, billing, and other responsibilities.

Local nongovernmental organizations (NGOs) distributed this information to the public via leaflets, announcements in public places, door-to-door surveys, and letters to individual customers. The program was successful, with collection efficiency increasing. However, customers were less interested in the water-saving aspects of the program than the use of the meters to justify their payments.

tion strategy. If water consumption is metered, then price can be used to modify water demand.

The price elasticity of demand measures the responsiveness of demand to changes in price. It varies between countries, types of water users, and seasons. A price elasticity of –0.5 implies that if price increases by 10 percent, demand decreases by 5 percent. Typically, price elasticities for domestic consumers lie between –0.2 and –0.8; typical values for industrial consumers lie between –0.5 and –1.3.[5]

Increasing the price of water is invariably a politically sensitive issue. One of the common arguments for opposing price increases is that higher prices would prevent the poorer segments of the (urban) population from receiving essential water supplies. The validity of this argument is debatable. In many cases, the relatively richer segments of the population benefit from subsidized water supply, while the poorer segments–often living in semi-urban areas–are left unserved and depend on water vendors, who often charge many times the price of reticulated water. If the urban poor are dependent on reticulated water, there are several ways to protect them against increases in the average price of water, such as providing a minimum amount of water (a "lifeline" quantity) at a subsidized price. If these precautions are taken, increasing the price of water can allow the utility to enter into new service areas, thereby increasing rather than decreasing equity.

From an economic efficiency point of view, the price charged for water should equal the long-run marginal cost. In practice, achieving full financial cost recovery can be a major step forward in both developing and developed countries.

There are various water pricing structures, such as increasing or declining block rates, seasonal or peak rates, flat rates, and concessional rates for new users. Table 6 shows the general advantages and disadvantages of each structure, although the actual advantages/disadvantages should be assessed for each case.

An increase in the price of water, accompanied with other measures, can lead to long-term water savings (Box 9).

Household water demands are not evenly spread over time. Household water demand changes seasonally, as well as within the day and, to a limited degree, within the week. Large costs will be faced if supply systems are to be constructed, maintained, and operated to satisfy the maximum peak flows experienced.

[5] See World Bank. 1996.

TABLE 6.
ADVANTAGES/DISADVANTAGES OF DIFFERENT PRICE STRUCTURES

Criterion	One-time payment	Fixed fee	Variable fee	Rates: Constant	Rates: Increasing	Rates: Decreasing
Revenue stability		++	+	–	–	–
Equity	–	–	–		++	– –
Efficiency (marginal cost pricing)	– –	– –	+	++	++	++
Efficiency (incentives)					++	– –
Administrative feasibility	++	++	+	–	–	–
Administrative efficiency	+	++	+	–	– –	– –

Note: +, ++, –, – – means positively affected, strongly positively affected, negatively affected, and strongly negatively affected.

Revenue stability: Revenues should not be too dependent on variable demand.
Equity: Every person should have access to sufficient affordable water for survival. This applies within existing generations and between existing and future generations.
Efficiency (marginal cost pricing): The price structure should be such that it provides incentives to efficiently use water (which requires that the price should reflect marginal economic costs).
Efficiency (incentives): Prices should provide optimal incentive to engage in development of the water system and investment in water-saving technologies.
Administrative feasibility: The most theoretically desirable pricing structures, such as marginal cost pricing, may be administratively difficult. For example, the administrative costs of installing sophisticated water meters may outweigh the gains.
Administrative efficiency: Complex tariff systems may in practice be undesirable since they are expensive and may lack transparency.

Source: Dalhuisen, J.M., H. L. F. de Groot, and P. Nijkamp. 2000. "The Economics of Water: a Survey of Issues," *International Journal of Development Planning Literature*, 15 (1): 3-20.

If charging systems could be designed to even out demand patterns and reduce peak demand, then suppliers could reduce the capacity of their systems and so save capital and operations costs as well as reduce demands on the watershed. Peak-hour, peak-day, peak-week, and peak-month demands have all been investigated, as well as differential prices in dry years and over longer dry periods. Equity, technical feasibility, consumer understanding and acceptability, and risk all need to be considered before these temporal tariff structures are implemented. In practice, few attempts have been made to put these tariff structures into practice, although some OECD countries have commenced trials. There is insufficient evidence from these trials at present to report on their effectiveness.

Rebates and incentives. Utilities can offer rebates and other incentives in order to accelerate the replacement of older, less efficient fixtures. These programs can be targeted at the nonresidential and residential sectors, and to indoor and outdoor uses, depending on where the greatest savings are likely to be made. Various options include providing fixtures at no cost, offering a rebate for consumer-purchased

BOX 9.
INCREASED WATER TARIFF IN BOGOR, INDONESIA

In 1988, average increases in water tariffs of about 115 percent for domestic users and about 170 percent for nondomestic users were instituted in Bogor in central Java. The monthly consumption of water per household dropped from an average of about 38 m^3 to about 27 m^3 per month. This price increase was accompanied by an intensive public education program. Since then, consumption has been maintained below previous levels, even though real water prices subsequently declined as incomes continued to increase until mid-1997.

Source: IWACO-WASECO. 1989.

fixtures, or arranging with suppliers to provide fixtures at a reduced price.

The feasibility and effectiveness of replacements may depend on state and local plumbing codes. Experience shows that such programs can yield substantial water savings.

Information and education. Information and education are critical to the success of any conservation program, although their role in any savings may be difficult to estimate. Customers that are informed and involved are more likely to support water conservation planning goals. Information and education measures can directly produce water savings by persuading consumers to use less water, as well as support other conservation measures. For example, it is widely believed that information plays a role in how water consumers respond to changes in price.

Box 10 lists some common information and education activities.

Water use regulations and standards. Regulations can be used to manage water during droughts or other water-supply emergencies. Typical restrictions in developed countries include bans on nonessential uses (lawn watering, car washing, irrigating golf courses, etc); restrictions on commercial car washes, nurseries, hotels, and restaurants; standards for water-using fixtures and appliances; and bans or restrictions on once-through cooling. In some cases, utilities may find it desirable to extend water-use regulations to promote conservation during nonemergency situations. Not all of these are relevant in developing countries, where restrictions such as limiting access time to urban water are more common.

Another type of regulation is to impose standards on new developments with regard to landscaping,

BOX 10.
EXAMPLES OF INFORMATION AND EDUCATION ACTIVITIES FOR WATER CONSERVATION

Information dissemination. Water utilities can provide information pamphlets to customers on request. Consumers are often willing to participate in sound water management practices if provided with accurate information. An information and education program could inform water users about the costs involved in supplying drinking water and demonstrate how water conservation practices will provide water users with long-term savings.

Understanding the water bill. Customers can be helped to read and understand their water bills. Assuming that metering is installed, a water bill identifies volume of usage, rates, and charges. Comparisons to previous bills and tips on water conservation can help consumers make informed choices about water use.

School programs. Utilities can provide information on water conservation practices through a variety of school programs. These programs help educate young people about water conservation techniques, as well as help utilities communicate with parents.

Public education program. Utilities can use a variety of methods to disseminate information and educate the public on water conservation. Outreach methods include speakers' bureaus, booths at public events, printed and video materials, and coordination with civic organizations.

Workshops. Utilities can hold workshops for professions connected with water supply. These might include, for example, workshops for plumbers, plumbing fixture suppliers and builders, or for landscape and irrigation service providers.

Promotion of new technologies. Utilities can also become involved with promoting new technologies through manufacturers and distributors of fixtures and appliances. Demonstrations and pilot programs, and even contests, could be used to introduce and promote new products.

Advisory committee. A water conservation advisory committee is another way to involve the public in the conservation process; potential committee members include elected officials, local business people, interested citizens, agency representatives, and representatives of concerned local groups. The committee would provide feedback to the utility concerning its conservation plan, develop new material and ideas about public information, and support conservation in the community. In order for such a step to be useful, the utility must be receptive to ideas offered by the committee.

drainage, and irrigation practices. Many water systems, including privately owned systems, lack authority to implement this measure. Utilities that have such authority must exercise it carefully. In general, restrictions on water use should be justified by the system's circumstances and should not unduly compromise the customer's rights or quality of service.

Water-use audits. Water-use or end-use audits provide water utilities and their customers with invaluable information about how water is used and how usage might be reduced through specific conservation strategies. Water-use audits can be conducted for different users:

- *Large volume users (both commercial and industrial).* Audits normally start with identifying the categories of water use, and then identifying categories where water-use efficiency can be improved through alternative technologies or practice (see also Box 2).
- *Large landscape audits.* Audits for urban irrigation activities can provide the operators of these facilities with information on water usage and usage-reduction techniques. These audits can be used in conjunction with irrigation sub-metering and other landscaping efficiency practices.
- *Selective end-use audits.* Audits can be widened to include selective end-use audits by customer class, focusing on typical water-use practices within each class. Audits targeted to older housing, for example, are particularly beneficial in terms of identifying and fixing plumbing leaks.

All water audits should include a written report containing specific ideas for conservation. Water audits may be planned and implemented in conjunction with electric power companies or others interested in promoting conservation practices.

ASSESSING WATER DEMAND AND CONSERVATION OPPORTUNITIES

Successful projects are more likely to occur when water demand and conservation opportunities are assessed early in the project cycle–during identification, preparation, and appraisal. The U.S. Environmental Protection Agency[6] suggests nine basic planning steps that apply generically to water conservation planning.

Step 1: Specify conservation planning goals. Water conservation planning goals may include:

- eliminating, downsizing, or postponing the need for capital projects
- improving the utilization and extending the life of existing facilities
- lowering variable operating costs
- avoiding new-source development costs (see Box 11)
- improving drought or emergency preparedness
- educating customers about the value of water
- improving reliability and margins of safe and dependable yield
- protecting and preserving environmental resources.

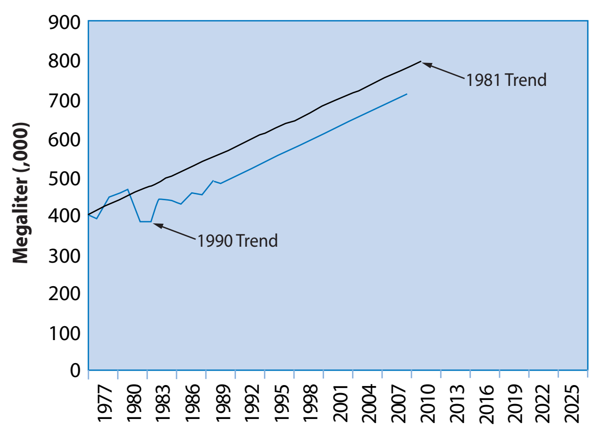
The process of developing and evaluating goals involves affected stakeholders as well as managers. An open process is particularly necessary with water conservation planning because many of the end-user measures–such as pricing reform or installation of low flow device–are not likely to be accepted by the community unless they understand the reasons for the interventions and fully support them.

Step 2: Develop a water system profile. The water system profile consists of system characteristics–service population, service area, annual water supply, service connections, water demand, water sales, average and peak demand, and pricing–and sys-

[6] USEPA (1998).

BOX 11.
WATER CONSERVATION AND INVESTMENT PLANNING IN AUSTRALIA

Melbourne, Australia used a combination of water conservation measures—such as water pricing reforms, water-saving devices, and public education—to defer investment of $25 million in infrastructure. As a result of the measures, Melbourne's current water demand projection differs substantially from the 1981 trend. The shift to the right of the water trend curve has delayed the need to invest in additional supplies by about 6 years.



Source: Bhatia, R., R. Cestti, and J. Winpenny, 1995.

tem condition–critical water supply area, shortages or supply emergencies, unaccounted for water, population and/or demand growth, and planning of improvements or additions.

Step 3: Prepare a demand forecast. Forecasts can be made for the water system as a whole; however, forecasts are more accurate when they are prepared for separate groups of water users. Demand-side conservation measures should not be included.

Step 4: Describe planned facilities. Preparing an estimate of the costs of meeting the water demand from improvements in supply without any conservation measures establishes the anticipated cost of supply-side improvements and additions. This cost estimate provides a benchmark for assessing conservation or demand-side activities.

Step 5: Identify water conservation measures. During this step, water utilities can identify the conservation measures that are relevant for their area.

Step 6: Analyze benefits and costs. A cost-effectiveness analysis compares alternative conservation measures in terms of dollars per liter of water saved. It can also be used to compare conservation measures with the supply-side options. A cost-benefit analysis can be used to determine whether the benefits of implementing a measure outweigh the costs.

Step 7: Select conservation measures. Cost-effectiveness is one criterion for selecting conservation measures, but other factors such as ease of implementation, staff resources and capability, environmental impacts, rate-payer impacts, environmental and social justice, water rights and permits, legal issues or constraints, regulatory approvals, public acceptance, and consistency with other programs should also be considered.

Step 8: Integrate resources and modify forecasts. The demand and supply forecasts made in steps 3 and 4 should be revised in light of the anticipated conservation savings.

Step 9: Present implementation and evaluation strategy. The plan should be kept open to modification as implementation progresses. The implementation strategy would normally include a preliminary schedule for monitoring and evaluating program results.

HERMANUS—A SOUTH AFRICAN CASE STUDY

The town of Hermanus in South Africa provides an instructive example of water demand management.[7] Greater Hermanus consists of 11,500 properties spread along a 25-kilometer stretch of coastline between the Bot River lagoon and the Klein River estuary. This is a winter rainfall area. The town is a popular seaside resort, world famous for whale watching. The estimated permanent population of about 20,000 increases threefold during peak holiday seasons. Water consumption during these peaks is very high. The water problem arises because the sharp summer peak demand is out of synchronization with the rainfall peak.

Water supply for Hermanus is derived from the De Bos Dam, from which the local authority has an annual allocation of 2.8 million cubic meters. At the time of construction in 1976, it was estimated that this allocation would be sufficient until the year 2010. However, a property boom during the 1990s meant that during 1994–95 the water allocation was exceeded at a time when only some of the demarcated plots had been developed. A new analysis of the problem indicated that demand in a dry year could be as high as 4.9 million cubic meters. A hydrological analysis showed that the yield from the De Bos Dam could not be increased significantly, thereby eliminating that supply-side solution. The cost of treating and distribution of groundwater made that source infeasible. Similarly, desalination was discarded as a supply-side solution due to the high energy costs involved.

Consequently, a demand management strategy was adopted as the best solution to the problem. After a series of intensive consultations between the local authority and the South African Department of Water Affairs and Forestry, a 12-point plan, the Greater Hermanus Water Conservation Programme, was developed. The plan included reforms of the pricing system, technical improvements to reduce water use, education programs, provision of better information, and policy changes.

[7] Adapted from Turton, A.R. (1999).

PRICING REFORMS

The old water tariffs in Greater Hermanus were perverse, providing an increasing subsidy as more water was used. Under the new tariff structure, an "assurance of supply charge" was instituted to deliver the message that a tariff was needed to cover the fixed costs arising from having a supply of water on tap. This charge was levied as a three-tiered tariff because of South Africa's great disparity between rich and poor. The rate of R40.00 per month was levied for the period 1996–97 for the typical consumer (called economic tariff). The charge of R2.00 per month was levied for those in dire financial situations (called the indigent tariff), while an intermediate rate of R10.00 per month was charged for sub-economic households.

An 11-point escalating block-rate tariff was developed, based on the principle that those who tend to drive the marginal cost of water upwards should be charged at the marginal rate (Table 7). While the assurance-of-supply tariff depended on the income level of the household, the block tariff did not. However, in keeping with the overall national goal of using the water sector to promote social stability, the lower end of the tariff scale (the life-line

TABLE 7.
THE NEW WATER TARIFF IN HERMANUS, SOUTH AFRICA.

Kiloliter range	Cost (R) per kl	Total cost*
0–5	0.30	0.00–1.50
6–10	0.70	1.50–5.00
11–15	1.20	5.00–11.00
16–20	1.80	11.00–20.00
21–25	2.40	20.00–32.00
26–30	3.00	32.00–47.00
31–40	4.00	47.00–87.00
41–60	5.00	87.00–187.00
61–80	6.00	187.00–307.00
81–100	7.50	307.00–457.00
101+	10.00	457.00–

Source: Brochure, Greater Hermanus Water Conservation Project, Department of Water Affairs and Forestry, 1998.
**Note:* (Add R2.00, R10.00, R40.00 assurance-of-supply charge for indigent, sub-economic and economic users respectively.)

tariff) was set to be affordable to all consumers. As part of the reforms, the local authority became more vigilant in dealing with those consumers who did not pay for water–a widespread practice in South Africa at the time, originally justified as a contribution to antiapartheid activities. Water was cut off to those consumers who had not paid their rates within seven days.

Technical Improvements

Given that 50 percent of total demand was from in-house use, the Greater Hermanus Water Conservation Programme planned to retrofit all homes and other buildings that had piped water with modern, water-efficient devices at no direct cost to the consumer. The retrofitting policy included the following:

- assisting residents to check their meter for accuracy
- assisting residents to monitor and repair water leaks
- assisting consumers to perform water-audits, from which conservation strategies could be derived
- encouraging consumers to have the safety and efficiency of their hot-water geysers checked
- retrofitting water-saving devices where possible and desirable by the owners.

Retrofitting hardware included the installation of dual-flush toilet mechanisms, low-flow shower heads, and tap aerators. One invention consisted of a wash basin built into the toilet cistern lid. This recycled the water used to wash hands directly to the toilet cistern.

This component of the program has been controversial because it only targets middle- and high-income homes (most low-income homes rely on communal water facilities). Low-income households felt that they were being left out.

Education Programs

An important issue in water demand management is to ensure that the people have a good understanding of where the water is used within the household. The program has focused on educating children, rather than adults, to promote a long-term change in attitudes. Every school child in the Greater Hermanus area participates in a water audit at their school.

This strategy is based on two distinct phases. The first phase focuses on the school environment. The children are encouraged to monitor the schools' water meters over time. Once they have obtained a reasonable understanding of water usage, the children are encouraged to investigate ways in which the overall consumption levels can be reduced. This is also linked to energy and waste disposal. The second phase then involves the children applying this newly learned skill to their home environments. This expands the auditing approach into virtually every home in the area.

A Water-Wise Gardening project has been developed in conjunction with the local nursery industry. This project is focused on planting indigenous vegetation, which tends to be more water-efficient, coupled with overall improvements in irrigation techniques.

Many of the local residents have limited financial means. For this reason the potential use of greywater for water-wise food production has been integrated into the overall water demand management strategy. This involves some simple hardware modifications, which are made possible through the retrofit program.

Better Information

Accurate metering is essential if the block tariff system is to be successful. An innovative, pre-payment water and electricity meter has been introduced to help change the prevailing attitude of nonpayment for services. The meter is linked to a central console. It provides a high level of control by the consumer, providing crucial information on how much water and electricity the consumer has used, how much credit they have left, and how their level of consumption compares to the overall pattern in their area. It can also warn of a leak and disseminate other information as needed. The new technology even provides for a panic button, which is linked to a volunteer community group (ambulance, fire, or police).

One of the most successful aspects of the overall water demand management strategy has been the introduction of informative billing. This is based on the assumption that people are willing to cooperate if they get regular feedback about the impact of their actions. The monthly statement shows the level of consumption over the past year, how their individual consumption pattern compares with the average for their area each month, and a measure of the influence of rainfall on consumption.

Underlying the water demand management strategy is a strong commitment to communication between the local authority and the consumer. This uses instruments such as press releases, talks with residents, displays, signs, newsletters, a hotline facility, and passing on information to other local authorities.

POLICY CHANGES

Strong political institutions are needed to back up urban water conservation measures. In the post-apartheid period, South Africa introduced a plethora of new legislation based on a strong constitution and bill of rights. Hermanus has chosen to adopt the National Water Regulations as a bylaw, thereby ensuring that the rights and responsibilities of the local authority and residents are given the full force of law. Some of the consequences of this are:

- the local authority performs an audit of its own performance in water management
- a ban on watering gardens between 11 a.m. and 3 p.m., when there is a peak in water lost to evaporation
- a ban on washing down paved surfaces with water
- strict guidelines on the energy and water-use design parameters for new houses and developments.

HERMANUS WORKING FOR WATER PROJECT

Although part of supply augmentation rather than demand side management, Hermanus has joined in the national Working for Water Project to remove high-water-using alien vegetation in the catchment of the De Bos Dam. By clearing these plants, it is hoped there will be increased runoff, which will substantially improve the yield of the dam, while stabilizing the overall ecological functioning of the Onrus Lagoon and other local aquatic ecosystems. This element of the program complements the demand reduction actions by increasing supply during the dry season when demand levels peak.

EFFECTIVENESS OF THE PROGRAM

The Greater Hermanus Water Conservation Programme has achieved many of its goals. In the short term, attitudes to water consumption have changed through the provision of information that lets consumers make decisions that save them money. There was an 11 percent fall in annual average consumption in the two years after the program was implemented (Table 8). The increase in water use in September and October 1997 and 1998 is possibly due to seasonal differences between the base year of 1996 and later years. However, it is too soon to know whether these reductions will be maintained in the longer run.

In addition, nonpayment for water has been significantly reduced. This has resulted in a budget surplus for the local council. The surplus has been redirected to fund the retrofit scheme, which consequently has been completed sooner than planned. Nevertheless, the stricter enforcement of water charges has been controversial. Some low-income families have found that even the relatively low block tariffs for minimal water use are too expensive; others object to paying for water, which they regard as a right under the new South African Water Law. To this extent, the new tariffs have exacerbated the social and economic gap between the high- and low-income groups.

TABLE 8.
PERCENTAGE CHANGE IN WATER CONSUMPTION, HERMANUS, USING NOV 1995-OCT 1996 AS BASE YEAR

Period	1993	1994	1995	1996	1997	1998
January	—	16	18	0	–10	–2
February	—	1	1	0	–23	–16
March	—	–4	5	0	–15	–15
April	—	0	–20	0	–18	–19
May	—	–22	–18	0	–27	–23
June	—	–32	–15	0	–15	–15
July	—	–3	4	0	–11	–7
August	—	–23	15	0	–7	–1
September	—	1	17	0	2	7
October	—	31	2	0	23	18
November	17	–1	0	–35	–23	—
December	5	21	0	–14	–16	—

CONCLUSION

Worldwide, municipal water supply for industrial and household use is the second largest water-using sector after agriculture. Given urban growth rates in the developing world, this sector will experience rapidly increasing demand over the next 20 years. In developing countries, typically 30 to 50 percent of this water is currently lost through leaks in distribution systems. Given the increasing financial and environmental costs of tapping new sources of water supply, it is often economically sensible to reduce the extent of leakage and thereby avoid these high development costs. In the case of Singapore, where new sources are only available at very high cost, it was economically efficient to bring levels of unaccounted water down to just 6 percent.

It is also possible to reduce urban water demand through technological improvements, policy changes including pricing reforms, and educational programs. These various elements normally support one another, and so are packaged into integrated demand management programs. For example, pricing reform will only be successful if educational activities bring consumers into the program and water saving technologies are made available to offset increasing unit prices for water. Such programs have had considerable success in reducing municipal water consumption in both the developed and developing world, as shown in the cases of Melbourne, Australia, and Hermanus, South Africa.

Conservation measures are typically adopted through water utility reforms. However, if they are adopted in isolation from broader water sector reforms, then opportunities for achieving overall efficiency gains are unlikely to be fully realized. Faced with increasing municipal water demand, the most cost-effective and most equitable solution can only be decided within the framework of integrated water resources management. Typically, municipal water conservation measures will be coupled with reductions in agricultural water demand and improvements in water supply, together with institutional reforms and water quality improvements.

FURTHER INFORMATION

The following references provide general information on water conservation, including planning for conservation

Gleick, P.H. 1998. "The changing water paradigm." *The World's Water 1998–1999: The Biennial Report on Freshwater Resources*. Pacific Institutes for Studies in Development, Environment and Security, Oakland CA. Washington: Island Press.

U. S. Environmental Protection Agency. 1998. *Water Conservation Plan Guidelines*. Washington: USEPA.

World Bank. 1993. *Balancing Water Demands with Supplies, The Role of Management in a World of Increasing Scarcity*. World Bank Technical Paper Number 189. Washington: The World Bank.

World Bank. 1996. *Indicators–Water and Wastewater Utilities*. Washington: World Bank.

Guillermo, Y. 1995. *Reduction of unaccounted for water, the job can be done*. Washington: The World Bank.

Financing urban water supply activities is discussed in:

Asian Development Bank. 1999. *Handbook for the Economic Analysis of Water Supply Project*. Manila: Asian Development Bank.

Serageldin, I. 1994. *Water Supply, Sanitation and Environmental Sustainability: The Financing Challenge*. Washington: The World Bank.

Various case studies are described in:

IWACO-WASECO. 1989. *Bogor Water Supply Project: The Impact of the Price Increase in June 1988 on the Demand for Water in Bogor*. Rotterdam, NL: Royal Haskoning.

Bhatia, R., R. Cestti, and J. Winpenny. 1995. *Water Conservation and Reallocation: Best Practice Cases in Improving Economic Efficiency and Environmental Quality*. A World Bank-ODI Joint Study. Washington: World Bank.

Turton, A.R. 1999. *Water Demand Management (WDM): A Case Study from South Africa*. MEWREW Occasional Paper No. 4, School of Oriental and African Studies. London: University of London.

Massachusetts Water Resources Authority (MWRA). 1994. *Water Use Efficiency Case Study: MicroSemi USPD Inc., Watertown, MA*

Some useful websites for particular techniques and experiences are:

Welcome to WaterWiser
http://www.waterwiser.org/

Cleaner Water Through Conservation
http://www.epa.gov/OW/you/intro.html

American Water Works Association (contains links to further U.S. sites with water conservation information)
http://www.awwa.org/community/links.cfm

International Water and Sanitation Centre
http://www.irc.nl/