MANAGEMENT OF WATER DEMAND: UNRESOLVED ISSUES

Ben Dziegielewski
Department of Geography
Southern Illinois University

The sustainable use of water resources to support the needs of a growing population cannot be accomplished without a better understanding and the careful management of urban water demands. Urban areas must compete for freshwater resources with the environmental and agricultural interest and the uncontrolled growth in water demands can place cities at a disadvantage in that competition. While it is true that the irrigated agriculture is responsible for the major portion of freshwater withdrawals (about 85 percent on the global scale), the geographical concentration of urban demands creates a major challenge for water resources planners who must find reliable sources of water to supply the increasing, and, in some regions, exploding populations of urban areas. Because of the high density of resident population and the high concentration of water needs to support urban economic activities, many cities have exhausted the available local supplies and must depend on water that is imported from distant sources. Since urban areas require water of the highest quality, they look for and capture the most pristine water sources even if these sources can be found only far from the cities that they will supply. Urban areas thus create "ecological footprints" that can extend several hundred kilometers beyond the city limits to the headwaters of streams and rivers, and also hundreds kilometers downstream as the water brought to supply urban needs is discharged as wastewater into the environment.

Management of urban water demands has captured the attention of water planners and the general public as a promising alternative to the continuing augmentation of urban water supplies. This issue of *Water Resources Update* focuses on our experience with water demand management during the last three decades with an aim of identifying the future role and most promising strategies for advancing water conservation. The contributed papers reflect on the past efforts and experiences in water conservation and point out the lessons that we learned or should have learned. These lessons should help us identify the role that water demand management should play in the next century. Achieving the sustainable use of water resources would certainly be one of the important goals of water conservation.

The purpose of this introduction is to provide an overview of the water demand management experience and to summarize the outstanding issues that are discussed by the authors of the contributed papers.

THE EMERGENCE OF DEMAND-SIDE ALTERNATIVES

During the 1970s, an array of environmental and economic conditions has contributed to the decline of the viability of traditional supply-side approaches to the provision of urban water. Environmental legislation has introduced significant barriers to the continued expansion of off-stream uses of water for agricultural and urban purposes. The expansion of housing developments into upland regions of high quality water sources has led to significant legal and political resistance to water exports. Other factors such as the physical scarcity of high quality sources, the depletion and contamination of groundwater sources, difficulties in financing major facilities for transmission, treatment and distribution of water, especially the increasing costs of treatment for regulated contaminants, have also made supply-side options less viable.

While the feasibility and attractiveness of supply augmentation were diminishing, a concomitant interest among water planners in demand-side alternatives was gradually increasing. The droughts of the mid-1970s and late 1980s in the United States and Great Britain had demonstrated that urban water demands can be restrained at least in the short term. In the early 1980s, several urban water supply agencies began to pursue opportunities for achieving long-term conservation. These opportunities arose as a result of sevaral factors.

First, urban water supply planners have recognized that demand-side alternatives offer multiple benefits.

Reductions in demands can result in (1) energy savings for heating water as well as for pumping and treatment, (2) reduced costs of water treatment and distribution system capacity (including the capacity of infrastructure for the collection and treatment of wastewater), (3) savings in capital expenditures because of deferred or downsized new water supply projects, and (4) environmental benefits of reduced withdrawals of water from streams and aquifers which leave more water available to preserve the ecological resources of streams, wetlands and estuaries.

Second, new or improved water-efficient fixtures and appliances such as ultra-low flush and dual-flush toilets, horizontal-axis washing machines and drip or micro-spray irrigation systems have appeared on the market and become available at competitive prices. *Third*, the expertise and service capacity of the private sector has evolved and water supply agencies could find outside contractors to plan, evaluate and implement water conservation programs.

Finally, the last decade has produced marked improvements in the available "know-how" for planning and evaluation of demand management alternatives. Numerous studies have been devoted to the development of econometric water use models and advanced statistical techniques for measuring the water savings achieved by conservation programs. Urban water utilities have improved their practices in (1) forecasting water demands, (2) performing benefit-cost analysis of demand management alternatives, (3) developing least-cost water supply plans that integrate both supply-side and demand-side alternatives, and (4) setting up procedures for monitoring water demands over time.

The growing attractiveness of demand management has led to its acceptance as at least a partial solution to water supply problems of many urban areas. During the 1990s, the United States and Canada have increasingly promoted a greater role for water conservation in the planning and management of their freshwater resources. In fact, there has been an explosion of interest and activity relating to water conservation. One manifestation of these was the participation of water professionals in the triennial conferences of *Conserv90, 93, 96 and 99*, sponsored by the American Water Works Association. The number of papers and participants has been increasing with each meeting and much progress and many new experiences were reported.

Conservation activities in the last two decades came in the form of legislative mandates, conservation programs adopted by water institutions, and measures adopted by individual water consumers. Water conservation mandates have become almost ubiquitous; nearly all federal water agencies have been given water conservation responsibilities through many federal laws. Similarly, legislatures in many states have passed statutes or developed guidelines that are aimed at improving the efficiency of water use. These mandates, while often seen as a critical factor in the adoption of water conservation, usually offer no specific direction for water agencies on how to design, implement, or evaluate demand management programs. Water supply agencies have initiated many kinds of demand management programs either as a result of their assessment of the need to control demands and meet their water management objectives, or in response to the governmental mandates. Finally, individual consumers have adopted measures as a result of their perception of the need to protect the natural environment or in response to the encouragement and economic incentives from their water providers.

UNRESOLVED CONSERVATION ISSUES

The adoption of demand management in the urban sector continues to be limited. Water supply agencies that embarked on ambitious demand management programs did so based on assessment of their potential to balance future demand and supply at a cost below the economic and environmental cost of new supplies. Today, many of these agencies have water conservation programs with dedicated staff and significant budgets. However, the majority of urban water providers are somewhat reluctant to make a serious commitment to water demand management. Several issues can be identified as critical to the adoption of the demand-side strategy as a viable water resources management approach. The most frequently cited concerns include:

- The lack of clear criteria for assessing desirable level of investment in water conservation and the role of tangible and intangible benefits of long-term water conservation measures in investment decisions
- The choice of effective economic incentives for conservation in public and private water utilities
- The importance of price as the fundamental economic incentive for water customers

- The role of water conservation in achieving the goal of sustainable use of water resources on a watershed and river basin scales

Although these issues do not exhaust all possible practical difficulties with implementation of demand management, they provide a focus for the discussion that is presented by the authors in this issue of *Water Resources Update*. A brief summary of the background information for each of the main issues is given below.

The Optimal Levels of Demand Reduction

The term *water conservation* is currently used almost exclusively in the context of reducing water use by achieving improvements in efficiency of various uses of water. In engineering practice, the term *efficiency* describes *technical efficiency* and is generally defined as the ratio of output to inputs used. When investing in water conservation measures, water utilities, as well as individual water users, usually want to know how much conservation is warranted. Technical efficiency of water use for various purposes, while useful in comparing various products or processes, offers little guidance as to how much reduction in water use is enough. While some technical benchmarks can be used to designate quantities of water use that are "efficient," in theory some benchmarks could be set at a zero use value since many water uses can be substituted with fixtures that do not use water, e.g., a dry composting toilet or a waterless urinal. The efficiency concept is useful in making investment decisions only if the inputs and outputs are measured in *value* terms. This expression of efficiency is referred to as *economic efficiency.*

Economic efficiency, while not free from the subjective determination of values of inputs and outputs, does offer an answer to the question: How much reduction in demand is enough? Within the least-cost framework of water supply planning, the desirable level of conservation would be reached when the incremental cost of demand reduction would be the same as the incremental cost of supply augmentation. In other words, under this criterion, water utilities would try to meet the projected increases in future demands by investing in water conservation programs until the conserved water would become more expensive than new supplies. This rule establishes the appropriate level of demand reduction when all the costs of water conservation and supply augmentation (including environmental and other external costs) are measured and accounted for. Also, all external benefits of both demand-side and supply-side options should be accounted for and used to offset the costs before comparing the marginal costs of supply and demand alternatives.

William O. Maddaus explores the benefits and costs of water conservation programs in order to verify that utilities who implemented these programs have realized the benefits that were promised by conservation planners. He provides a set of practical ways of accounting for the various types of costs and benefits of water conservation measures and offers three case studies to illustrate the kinds and magnitudes of costs and benefits involved in reducing peak-day demands. Maddaus approaches the question of the appropriate level of investment in conservation measures on the basis of the foregone costs of investments in water supply (and wastewater disposal) infrastructure. While this test of economic feasibility makes water conservation measures cost-effective from the utility perspective, some measures may not be beneficial when viewed from other accounting perspectives, as in cases where some of the costs of conservation are borne by utility customers, or the society at large. Also, the utility accounting perspective may view some measures to be economically infeasible only because the benefits of those measures accrue to other parties. Maddaus recognizes this issue by pointing out the environmental benefits of reduced water withdrawals.

Despite some shortcomings, the economic analysis criteria used within the framework of benefit-cost analysis may offer the best guidance as to the desirable level of demand reduction. By implementing conservation measures that result in a beneficial reduction in water use or water losses, water utilities and communities will avoid the danger of over-investing in water conservation. An important caveat here is that the relevant accounting perspective is the all inclusive accounting stance of the society. In some instances water utilities and their customers may be encouraged to pursue additional conservation even when they cannot capture all the benefits. As long as the social benefits are equal to or greater than social costs, the additional conservation is warranted.

In his paper, Maddaus challenges conservation researchers and practitioners to publish information on the costs and benefits of water demand management measures. Without an adequate understanding of the economic and social criteria for appraising the value of water conservation savings, it will be difficult to answer the question: How much water conservation is enough?

Water Conservation in Private Utilities

The effect of private ownership of water utilities on the adoption of water demand management can be viewed as an extension of the issue of proper accounting perspectives for benefits and costs of conservation measures and the presence or absence of economic incentives to pursue conservation. The recent trend toward privatization of urban water supply systems causes some concern among conservation planners that under the private ownership of water industry, there will be little interest on the part of the water utilities to promote conservation as reduced demands simply translate to lower revenues and lower profits.

David A. Howarth reviews the effects of the privatization of the water industry in England and Wales on the management of water demand. Some of the consequences of the change of ownership from public to private include: (1) reduction of the staff that was employed in the detection and repair of system leaks, (2) a decline in the relationships between water utility and the community due to the remoteness of staff from the communities they serve, (3) a shift in alignment of interests of the four principal stakeholders (i.e., shareholders, customers, community and environment) toward the interests of the shareholders. While under the current regulatory regime, private water utilities lack a direct economic incentive to reduce demands (i.e., expenditures on water conservation measures are not allowed to be counted in the capital expenditure on which the company is guaranteed a rate of return on investment), there are opportunities to create a regulatory structure that would provide strong incentives to invest in conservation. Howarth also reports some aspects of privatization that helped the cause of water demand management. The helpful factors include a stronger regulatory environment with a clearer division of roles between the regulator and the regulated entities, greater transparency of information on the performance of water utilities, including information on the efficiency of water use, and the ranking of utilities by their performance.

Based on the experience in England and Wales, the effects of privatization on water demand management must be presented in the context of economic regulation of water utilities which are natural monopolies. Although the primary purpose of economic regulation is to defuse monopolistic tendencies and ensure that the public receives services at competitive costs, regulatory bodies are in the position to create both incentives and disincentives for private utilities that would make the utilities more responsive to the interest of all stakeholders, and would ensure an environmentally sustainable water resources policy. Howarth offers suggestions for regulators on how to accomplish this.

The Role of Pricing

Before any discussion of the role of pricing, it is important to acknowledge that water is an economic good, which has an economic value in its uses. The theme of this issue, *water demand management,* contains an implicit acknowledgment of the economic nature of water because *water demand* is an economic concept which assumes that the quantity of water used is a function of its price and other economic variables such as income. The implication is that if water is priced correctly, then consumers themselves will seek and find ways to use water efficiently and water utilities and governments will not need to encourage consumers to reduce water use since all wasteful practices will be eliminated. On a macro scale, if an economic market for water can be created and can function properly, the available supply will go to the highest bidder and the uses which produce the highest value.

Unfortunately, the real world does not seem to operate under these straightforward economic principles. Water is often considered to be not only a *commodity* but also a *natural resource* and a perceived human *entitlement.* These other characteristics of water tend to complicate the issue of water pricing. From the perspective of water resources management the major concerns are: (1) a purely economic market approach may not adequately protect natural ecosystems because environmental values (recently referred to as ecological services) are rarely quantified or transacted in the market, (2) true markets for water cannot be established within the existing complex system of water laws and water rights, and (3) water marketing can cause economic dislocations in economies that depend on water but which cannot compete with the highest bidders (for example rural economies may lose access to water that would be transferred to higher value uses in urban areas). From the water utility perspective, appropriate water pricing cannot be used in areas where water is not metered. In areas where the water used by each customer is metered, finding an appropriate rate structure design is very difficult because water rates are expected to fulfill several incompatible objectives, some of which represent "blurry concepts."

Three contributions to this issue tackle the problem of water pricing. **Janice A. Beecher** and **Peter E. Shanaghan** consider the pricing problem in the context of sustainability of water supply systems. The authors define a *sustainable water rate* as a price (and rate structure) that balances optimality, viability, equity and efficiency. The authors encourage consideration of sustainable pricing by water systems as an integrating principle for balancing the multiple objectives of water pricing. They argue that while efficiency is a fundamental goal of water pricing it is a necessary but not sufficient element of sustainability pricing. The sustainable price must be low enough to be affordable so that the systems can be supported financially by their customers in the long run and high enough to ensure sufficient revenues and cost-based price signals to guide consumption and production decisions.

Jeffrey L. Jordan examines the nature of water rates and the process of charging for the consumed water to conclude that there are real theoretical problems in determining the *behaviorally relevant* measure of price (that can be derived from a complex rate structure). Jordan argues that because of the nature of billing procedures and the difficulty that consumers usually encounter in recognizing the marginal price in complex rate structure, a simple uniform price is more effective in sending the price signal to consumers than complex rate structures that are designed to satisfy the competing multiple objectives of utility pricing.

Jack C. Kiefer focuses on current rate setting practices as a promising avenue for determining rate designs that will meet the competing objectives of utility pricing, and still be acceptable to consumers and regulatory or governing bodies of water utilities. This is an important consideration because even if a sustainable water rate can be determined by a rate analyst, this rate will need to be instituted through reform of the existing rate structure. Kiefer proposes a model of a multicriteria decision making process that can be used for constructing acceptable water rates and rate structures.

The need to use water pricing as a tool to achieve efficiency in water use is highlighted in all three papers. Pricing to encourage more efficient water use is an important, and possibly the most important, measure in managing water demand. Econometric studies of water demand clearly show that the price elasticity of aggregate urban water demand is generally in the range of –0.2 to –0.5. These elasticity values imply that while the demand for water is inelastic, a 10 percent increase in price would be expected to result, on average, in a 2 to 5 percent reduction in demand, when all other factors that affect demand are held constant. The demand reduction effect can be even greater when a price increase is accompanied by programs that both encourage consumers to reduce their water use and provide them with the necessary know-how and technology to do so. Price is a powerful motivating factor in the array of incentives and disincentives that can be used to achieve efficient water use.

Water Conservation and Sustainable Development

Improvements in the efficiency of water use are viewed by many water resources planners as an important ingredient in achieving sustainable development in various regions and water basins. Since water conservation potential in urban and agricultural uses of water is substantial, the widespread implementation of conservation measures can be a relatively inexpensive and effective way of reducing water withdrawals thus making more water available for environmental purposes.

Cindy Dyballa reports on the important role of water conservation as an alternative in achieving the goals of watershed management. This role of demand management is not apparent when a narrow perspective of an urban water utility or an irrigation district is used in judging the costs and benefits of demand reduction. The third party effects and environmental consequences of water conservation become readily noticeable when all stakeholders in the use of water resources sit down together, voice out their concerns, and outline their goals for the sustainable uses of available water supplies. Dyballa illustrates the role of water conservation in watershed management using five cases from large river basins in the western United States. In all five basins, water conserved by cities and irrigation districts benefited aquatic ecological resources by restoring fish populations and riparian and wetland habitats thus demonstrating how water conservation can benefit the environment. The value of these benefits is often the driving force behind the push of governmental agencies and the environmental community to mandating water conservation as a pre-condition for the approval of additional water withdrawals. However, in some cases, especially in irrigated agriculture, water conservation may also have unintended negative consequences such as the loss of wetlands that receive water from agricultural drainage. Urban conservation may also have unintended environmental consequences where efficient water use and wastewater reuse diminish the dry weather flows into receiving rivers.

While the importance of water demand management in planning for sustainable development is indisputable, water conservation initiatives should not be considered in isolation. Instead, they must be integrated into long term water resources management plans at the relevant geographical scale and within the appropriate political subdivisions. The cases described by Dyballa include stakeholders that represent different economic sectors, the environmental sector, and state and federal governmental agencies.

OUTLOOK FOR THE FUTURE

The place of water conservation in water management during the next century will depend on our ability to address the outstanding issues that were discussed above as well as other challenges that will appear as the need to achieve the sustainable use of water and related land resources becomes more urgent. A look at our experience and accomplishments in managing water demands during the last two or three decades of this century should offer some insights into the challenges that lie ahead.

Amy L. Vickers takes a brief look at the advances and milestones in the field of urban conservation to provide insight into the critical issues and challenges for the future. She identifies seven important developments that took place during the 1980s and 1990s. These developments started with the mandates of the U.S. Clean Water Act that forced industry to conserve and recycle water in order to reduce wastewater discharges. This was followed by the national water efficiency requirements of the 1992 U.S. Energy Policy Act. The most recent mandate for water conservation are the provision cotained in the 1996 Amendments to the Safe Drinking Water Act. These mandates provided at least a stimulus, if not a driving force, for the development of water efficient urban landscapes and efficient plumbing fixtures and household appliances. New technological developments combined with educational efforts and the use of conservation pricing provided additional opportunities to improve the efficiency of water use. In spite these developments, and considerable conservation-related activity, Vickers judges the performance of water demand management as disappointing. Very few urban areas in the United States have reported significant system-wide water demand reductions. Only Boston, New York City and Albuquerque have reported significant water savings and wastewater volume reductions.

Vickers' conclusion about the meager performance of water conservation programs can be confirmed by examining the national statistics, collected by the USGS, on water withdrawals and use. While the total water withdrawals in the United States between 1980 and 1995 have decreased by 9 percent, urban water use has increased by 18 percent and rural supplies have increased by 59 percent. These increases are greater than the 16 percent increase in total population during the same period. If we have achieved significant reductions in urban demands, these reductions must have been offset by the growth of demands caused by improvements in living standards and the continuing expansion of urban economies. The national statistics show no evidence of any reduction in urban water demand relative to historical levels. This indicates that in order to gain control over growing demands, we must run in order to stay in the same place. It also indicates, as Vickers points out that "we have yet to see the full potential of water conservation."

All the papers in this issue point out, in one way or another, the future potential for the management of water demand and offer a prescription for achieving significant water savings in the future. The recurrent formula includes greater emphasis on the tangible (and realized) benefits of water conservation that accrue to water agencies, as suggested by Maddaus, and the thoughtful and effective regulation of private water suppliers, as suggested by Howarth. The future conservation potential of sustainable and efficient water pricing also remains untapped. Beecher, Jordan and Kiefer offer proposals for maximizing the use of this important option for managing future water demands. Dyballa brings forth a new role of water conservation to support integrated water resource management within watersheds and river basins. Finally, Vickers considers the potential for reducing urban water use by capturing system water leakage that ranges from 15 to 25 percent, and, in some older systems, can exceed 50 percent of total urban water deliveries. Since the recommended guideline of a maximum permissible system losses is set at 10 percent, up to 40 percent reduction in urban water use could be achieved in some systems. Reductions in demand from the repair of system leakage would clearly overshadow the potential savings of any other conservation practice or any combination of practices, including efficiency pricing.

The potential efficiency gains in urban water use are considerable and can be achieved by an appropriately guided management of water demand which relies on water pricing and the integration of water conservation into long-term water supply planning within the framework of watershed management. Within the integrated water resources planning framework, water demand management may be the best tool for achieving the goal of sustainable water use in many regions which are experiencing, or will soon experience the conditions of water scarcity.

Ben Dziegielewski is an Associate Professor in the Department of Geography at Southern Illinois University at Carbondale. He also serves as the Executive Director of the International Water Resources Association and the Executive Editor of *Water International*. Dr. Dziegielewski has 20 years of experience in planning and evaluation of urban water conservation programs including econometric forecasting of water demand and reliability planning for urban water supply.