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Water Demand Management in Canada: A State-of-the-Art Review

D. M. Tate

Social Science Series No. 23

Inland Waters Directorate
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Ottawa, Canada, 1990

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The National Research Council of Canada's Associate Committee on Hydrology identifies, solicits, and promotes the preparation of state-of-the-art papers on hydrological topics that require research. The Committee has requested the preparation of this report and is pleased to bring it to your attention. The views expressed in it are the author's.

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Abstract

This paper presents an in-depth review of water demand management with emphasis on Canadian applications. Water demand management is defined as any socially beneficial measure that reduces or reschedules average or peak withdrawals from surface- or ground-water sources while maintaining or mitigating the extent to which return flows are degraded. The demand management approach differs from traditional supply-oriented approaches in placing its emphasis on social and economic policies to influence the uses to which water is put. This approach should be viewed as complementing, not replacing, supply management. Economic concepts, such as effective water pricing and charges based on waste effluent characteristics, are viewed as central to introducing demand management as one of the fundamental approaches to water management in Canada.

The demand management theme is developed for four water use sectors: municipal, industrial, agricultural, and nonwithdrawal uses. The role of realistic water pricing is developed in the municipal chapter as an effective means of rationalizing water demands. The industrial chapter examines demand management measures for effluent control, finding that measures such as pricing offer valuable adjuncts to regulatory approaches. Issues of public policy are examined in the agricultural chapter, where it is concluded that high water use in irrigation is sanctioned by public development policies with only secondary attention to matters of resource economics. The chapter on nonwithdrawal use focuses on the value of water and the role of demand management in enhancing this value. Later chapters include an outline of international experiences in demand management and an outline of strategies that can be used to implement a comprehensive water demand management program in Canada. The overall conclusion is that demand management is currently in its infancy in Canada and that the approach, when used in tandem with current approaches, offers the prospect of improved water management in the future.

Résumé

Les concepts et les approches de la gestion de la demande d'eau sont examinés, et une attention spéciale est accordée à leur application au Canada. On définit la gestion de la demande comme une mesure sociale avantageuse visant à réduire ou à réaménager les prélèvements moyens et de pointe d'eau de surface ou souterraine tout en maintenant ou réduisant le degré de dégradation de l'eau restituée. L'approche de la gestion de la demande diffère des approches traditionnelles de gestion des approvisionnements en ce qu'elle fait intervenir principalement des politiques sociales et économiques pour influencer les utilisations de l'eau. Elle devrait être considérée comme complémentaire et non comme un substitut à celles-ci. Des concepts économiques, comme la tarification et l'imposition de redevances en fonction des caractéristiques des effluents, sont jugés essentiels pour son instauration comme l'une des approches fondamentales de gestion de l'eau au Canada.

Le thème de la gestion de la demande est développé dans quatre chapitres consacrés chacun à un secteur d'utilisation de l'eau : services municipaux, industrie, agriculture et utilisations sans prélèvement. Dans le chapitre sur les services municipaux, on examine le rôle de la tarification comme moyen de rationaliser les demandes d'eau. Dans celui sur les besoins industriels, on se penche sur la gestion de la demande comme mesure de lutte contre la pollution des effluents et on conclut que des mesures comme la tarification pourraient représenter des compléments utiles à la réglementation. Des questions touchant l'ordre public sont examinées dans le chapitre sur les utilisations agricoles; on arrive à la conclusion que les forts prélèvements d'eau pour l'irrigation sont sanctionnés par les politiques de développement public et que les aspects économiques ne sont pris en considération que secondairement. Dans le chapitre sur les utilisations sans prélèvement, il est principalement question de la valeur de l'eau et du rôle de la gestion de la demande pour l'accroissement de cette valeur. Dans les chapitres qui suivent, on décrit notamment des expériences de gestion de la demande dans d'autres pays ainsi que des stratégies qui pourraient être utilisées pour mettre en place un programme complet de gestion de la demande au Canada. La conclusion finale du rapport est que la gestion de la demande n'en est qu'à ses premiers pas au Canada; appliquée en combinaison avec les approches actuelles, elle pourrait permettre une meilleure gestion des eaux à l'avenir.

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Introduction

Water management in Canada has traditionally focused on manipulating the country's massive supplies of fresh water to meet the needs of Canadians. This "supply management" approach has made itself felt in every sector of the economy, from municipal water supply to navigation. Increasing development costs, capital shortages, government fiscal restraint, diminishing sources of water supply, polluted water, and a growing concern for the environment have forced water managers to begin to rethink traditional approaches to management and to experiment with new ones.

All of these pressures are the result of one fundamental fact: namely, that resource scarcities are growing in number and severity as economic growth and development continue. The research conducted by Barnett and Morse (1973) demonstrates that society is capable of meeting these scarcities, but only through rising social resource costs. In the water resource field, where prices have remained low, the resource scarcity is only now beginning to be recognized. Water demand management is one strategic response.

This paper examines in detail the concepts and approaches of water demand management. A recent report (Brooks and Peters, 1988), which was used extensively in preparing the present report, defined water demand management as "any measure which reduces or reschedules average or peak withdrawals from surface or ground water sources while maintaining or mitigating the extent to which return flows are degraded." This definition is used here with the addition that the measures should be socially beneficial, in the sense that the benefits to society of adopting the measures should outweigh the costs of adoption. The aim is not to save water as such, but rather to increase net social welfare through water demand management.

Water demand management is a strategy that encourages increasing flexibility in planning and decision making by taking systematic account of various socio-economic and political parameters, as well as more traditional physical factors. It encompasses not only water quantity, but also water quality by casting new perspectives on waste discharge and pollution.

It must be stressed at the outset of this paper that water demand management complements rather than supplants the more traditional supply management techniques that are still required to manage water effectively. The approach advocated here broadens the options available to water managers by building demand considerations into the decision-making process.

OVERVIEW

This paper consists of eight major sections, each of which describes an important dimension of water demand management.

Chapter 2 discusses the principles of the demand management approach, provides a general overview of the major techniques available and used for managing water demand, and highlights the benefits of water demand management. Chapter 3 describes the basic data collection and research programs that provide the knowledge needed to institute water demand management.

Chapters 4, 5, and 6 examine three important water use categories: municipal, industrial, and agricultural. For each category, basic information on water use and current and emerging problems are identified. This is followed by a more in-depth review of the range of techniques available to water demand management and the consequences of the water demand management approach.

Chapter 7 examines the impact of water demand management on nonwithdrawal water uses. The methods and difficulties in trying to value water for uses in this category are highlighted. The second half of the chapter focuses on recreation as an example of a nonwithdrawal use in the water demand management context.

Demand management approaches have been tried periodically with varying degrees of success in other countries. A brief review of some of these experiences is the topic covered in Chapter 8.

Chapter 9 outlines major strategic actions required to integrate water demand management fully into the way in which Canadians manage their water resources. Basic principles and programs required for effective water demand management are identified in a general overview as well as for the major water use categories. Special attention is directed to the importance of research and data collection. A number of research opportunities are identified.

The final chapter summarizes the current state of water demand management in Canada and offers suggestions on what steps should be taken to ensure the effective implementation of the approach.

Principles of Water Demand Management

CONCEPTS OF WATER DEMAND MANAGEMENT

A number of concepts underlie the philosophy of water demand management. These include an examination of basic resource allocation mechanisms used in Western societies, an expanded range of alternatives for water management, a workable and measurable definition of water conservation, and the encouragement of sustainable resource development. Each of these concepts is described briefly below to provide an overview of some of the underpinnings of the demand management approach.

Resource Allocation Mechanisms

Western societies rely in a major way on economic markets to allocate goods and services to consumers and resource inputs to producers. Although public interventions into private sector markets occur frequently in response to public pressure or to inequities that arise in an unfettered free market, the price system is a principal mechanism for resource allocation. Recognizing this basic characteristic and building programs based on it are fundamental to the demand management approach and should be considered further at the outset of this paper.

When Charles Schultze was chairman of President Carter's Council of Economic Advisors, he argued for greater use of the economic system in public matters such as environmental control. In developing his argument, Schultze (1977) identified a critical choice to be made in intervening in the market system once a problem warranting public intervention was perceived. On the one hand, intervention can take the form of grafting a "command and control" module onto the private enterprise system to correct the perceived problem. On the other hand, the private enterprise system itself can be used, as far as possible, to solve the problem. In nearly all cases requiring public intervention, including water management, the former option has been chosen, with "seldom any attempt to design techniques of intervention which preserve some of the virtues of the free market" (Schultze, 1977, p. 6). Few signals are sent to the public as to the causes of or solutions to the problems. Few marketlike analogues are developed to aid in problem solving. By not receiving accurate signals about the true costs of resource use, the public inevitably fails to employ available resources in an optimal manner or in a manner even remotely related to optimality.

According to Schultze, by failing to use some of the characteristics of market allocation in approaching public problems, Western societies forego certain advantages. First, the unanimous consent arrangements of the marketplace cannot be employed in seeking solutions. Rather, legal and regulatory wrangles are commonplace, with the result that problems often get tied up in court, can be thrown out of court altogether, or generally tend to persist with little modification. Second, current strategies often require hard-to-get information, whereas, in market situations, each of the parties concerned makes appropriate adjustments according to individual circumstances while simultaneously working toward problem solving. Third, market-oriented solutions often direct innovation in socially desirable directions, whereas regulation more frequently does not induce nearly the effort to seek new, efficient solutions. Solow (1957) showed that the operation of economic markets was extremely important in promoting technological change, which, in turn, was responsible for 85% of the growth in the U.S. economy between 1909 and 1949. The problem of regulation, which tends to distort market processes, is particularly serious in connection with the environment, since it is probably process change and technological development that offer the best chance for environmental control. Indeed, a recent report by the Organisation for Economic Co-operation and Development (OECD, 1984, p. 7) stated that "in the long run, economic instruments quicken the pace of pollution reduction innovations. The use of charges and other economic instruments such as marketable permits, in addition to the traditional regulatory instruments, simply creates a more pronounced incentive to reduce costs."

The message of Schultze's argument is that the application of private market principles to public problems offers certain advantages, and that incremental movements toward the adoption of some of these principles in public management practices would be beneficial. For example, market principles accelerate the optimal rate of adoption of water-saving technologies. The argument is not a plea for wholesale changes, for, as noted above, the operation of an unconstrained private market system is not always superior to regulation. Rather, it is a reminder that one of the most fundamental underpinnings of our society should not be ignored in the process of public management.

Water demand management builds upon this basic concept in trying to bring some market forces to bear on environmental problems. The following chapters of this paper outline a number of situations in which principles flowing from market concepts can be used to diagnose and help solve environmental problems. If demand management were to have one main message, it is that market principles are an important, but largely untapped, set of techniques for managing water that should be examined in detail through research and application in the future.

Expanding the Range of Alternatives in Water Management

Water management is the task of selecting specific actions from among a range of available alternatives for meeting the water demands of society. In other words, every water resource problem offers a number of possible solutions, with effective management being the art of choosing wisely from among these possibilities.

Professor Gilbert White (1961) and his colleagues at the University of Chicago have developed a methodological approach to water problems that calls for broadening the range of alternatives examined in the course of developing management approaches. Much of this work evolved from managing problems of flooding and floodplain development. Under White's approach, for example, the manager should consider not only structural alternatives (e.g., dykes, dams), but also nonstructural ones (e.g., zoning, open space policies) in planning for floodplain development. Similarly, in the present context, managers dealing with water supply problems should take account of the opportunities presented by demand management in addition to those from supply manipulation. Widening the range of alternatives in this way should lead to better, more effective, and less costly decision making, and thus to more effective management. Examples in the following chapters are aimed at substantiating this viewpoint.

Arguably, expanding the range of management alternatives is a function of the economic system. As resources become more expensive, an increasing range of alternatives for using them becomes feasible. Nevertheless, in the water resource field, where economic (as opposed to financial) factors have never been afforded much credence in allocative decisions, it is important to emphasize that ranges of choice can be expanded, often to the benefit of both water management and the economy.

Defining Water Conservation

Baumann et al. (1980) examined the conservation movement and its implications for water management. He found many confusing and mutually contradictory definitions of conservation, few being much use in approaching water management problems analytically. Insisting upon the importance of being able to measure and track conservation efforts, Baumann envisaged water conservation in a benefit-cost framework. Thus, he defined water conservation as "the socially beneficial reduction of water use or water loss." In this context, socially beneficial implies trade-offs between the benefits and costs of a water management action, and, accordingly, is measurable using benefit-cost methods. In addition, it specifies the beneficiaries of conservation efforts and encompasses the broad range of withdrawal and nonwithdrawal uses. As indicated at the outset, this definition of conservation, when combined with the demand management concept, provides a focus for the entire demand management strategy, namely, that the aim is to increase social welfare, not to curtail water use per se.

In regions where water shortages occur or are threatened, a social objective may in fact be to save water itself. Uncertainties about future needs, the value of keeping development options open, and the benefits of maintaining ecosystems may not be adequately reflected in monetary terms. This fact requires that "socially beneficial" be broadly interpreted to include intangible benefits. The Baumann et al. (1980) definition of conservation given here nevertheless still applies.

Encouraging Sustainable Resource Development

Water demand management supports the principle of "sustainable development," a term introduced in the 1980s with the preparation of the World Conservation Strategy by the United Nations. The concept of sustainable development is summarized as

the modification of the biosphere and the application of human, financial, living and non-living resources to satisfy human needs and improve the quality of human life. For development to be sustainable it must take account of social and ecological factors, as well as economic ones; of the living and non-living resource base; and of the long term as well as the short term advantages and disadvantages of alternative actions." (IUCN, 1980, p. 1.)

The sustainable development concept was an attempt to answer critics of the conservation movement, who maintained that conservationists were, by definition, against resource development. By putting forth the concept of sustainable development, the World Conservation Strategy attempted to integrate conservation and development to ensure that modifications to the environment secured the well-being of all people. The Brundtland Commission report, *Our Common Future* (World Commission on Environment and Development, 1987), is a comprehensive attempt to show how the economy and the environment are closely related, and to demonstrate the centrality of the sustainability concept. A recent report by the Canadian Council of Resource and Environment Ministers (1987) also supports sustainability as a major management concept for the future.

Water demand management promotes and encourages the objective of sustainable development. According to Postel (1985, p. 7),"only by managing water demand, rather than ceaselessly striving to meet it, is there hope for a truly secure and sustainable water future."

Implications and Responses

All of these underlying concepts coalesce to form the underlying rationale for water demand management. The incentive system of the private market system, if adopted as a working model, suggests new methods of allocating water in situations of scarcity. At the same time, this system of allocation should lead to a broader range of alternatives for management decision making. Conservation concepts, although defined in a confusing manner in the past, suggest a raison d'être for demand management, namely, increasing social welfare through socially desirable decreases in water use. The aim in Canada is to save resources in the economic context, not to save water as an end in itself. Finally, and perhaps most vitally, the need to achieve sustainable development suggests the global rationale for demand management. Water resources are limited, even in the Canadian context, either through straightforward supply shortages and degraded water quality, or indirectly through constraints on development capital. Water development must eventually take place on a sustainable basis, and demand management strategies are one means of achieving this.

TECHNIQUES AVAILABLE FOR WATER DEMAND MANAGEMENT

Water demand management relies upon a range of tools and techniques, which can be divided into three categories: economic, structural and operational, and sociopolitical. This classification of techniques is similar to the one suggested by a U.S. Congressional Research Service report on the methods of attaining water conservation by urban users (Flack, 1981).

An overview of each type of technique is presented below. More detail on them as they apply to specific water uses is given in Chapters 4, 5, and 6. It is important to note that water demand management techniques encompass the concerns of both water supply and waste disposal.

Economic Techniques

Economic techniques rely upon a range of monetary incentives (e.g., rebates, tax credits) and disincentives (e.g., higher prices, penalties, fines) to relay to users accurate information about the value of water. The aim is to promote better water use practices in the sense of moving toward increasing conservation and sustainability in the use of water resources. Realistic water pricing is one of the most fundamental keys to water demand management and is central to many of its options. Water pricing is one of the main strategies of Canada's Federal Water Policy of 1987, which endorses the concept of realistic pricing as a direct means of controlling water demand and generating revenues to cover costs (Environment Canada, 1987a, p. 8). Millerd (1984, p. 8) examined the concept of pricing in the water management context. He stated:

> *Prices perform two essential roles in a market system: rationing and production motivation. Rationing is necessary since scarcity precludes both the satisfaction of all needs and the unlimited production of goods and services. Goods and services must be rationed to consumers and factors of production must be rationed to producers. The price system allows bidding for scarce goods and services and factors of production, thereby ensuring that goods and services are allocated to the highest valued users and that factors of production are allocated to that use where they bring the largest return. Prices perform their production motivating role by indicating what consumers are willing to pay. Producers react to this, directing their production to those products most profitable to them.*

Simply stated, prices send "signals" to both consumers and producers about the economic value of the resource use.

Structural and Operational Techniques

Structural techniques are those that alter existing structures to achieve better control over water demand. Examples of structural measures include metering, retrofitting, controlling flow, and recycling. Metering is particularly important because it is the necessary first step in moving toward effective pricing arrangements. Without metering, any attempt at demand-based pricing and demand management will be futile. The metering issue will be considered in more detail in Chapter 4. Structural techniques also include changes in practices of a physical nature, such as using native species of plants to reduce sprinkling requirements or improving sprinkling equipment, which would permit the application of less water. Operational techniques are actions by water users to modify existing water use procedures to control demand patterns more effectively. They include leakage detection and repair and water use restrictions during periods of water shortages.

Sociopolitical Techniques

Sociopolitical techniques in a water demand management context refer to policy and related measures that can be taken by public agencies to encourage water conservation. Techniques include public awareness programs, laws such as building codes and appliance modifications, and government economic policies. These are designed to obtain cooperation from the public in moving toward improved water management practices. Thus, one of the most important techniques in this field is effective public education.

Interrelationship of Techniques

Demand management techniques are often interrelated, as emphasized by Postel (1985, p. 42) in the context of municipal water management.

Successful efforts to curb per capita demand invariably include some combination of water-saving technologies, economic incentives, regulations, and consumer education. These measures are mutually reinforcing, and they are most effective when implemented jointly. Higher water rates, for example, encourage consumers to install water saving devices in their homes and apartments and to opt for native landscaping when purchasing a new home. Education is crucial to gain support for conservation, and to make people aware of the easy and cost-effective ways they can save water.

CRITERIA FOR EVALUATING WATER DEMAND MANAGEMENT METHODS

In adopting new strategies of management, a central issue concerns effective evaluative procedures. In the definition of water demand management given earlier, two criteria have suggested that the methods adopted must reduce water use or consumption and must also be socially beneficial in the benefit-cost sense. This section, which is based upon Herrington's work for the Organisation for Economic Co-operation and Development (OECD, 1987a), examines these and other evaluation criteria that can be used in assessing various water demand management measures.

Technical Evaluation

Any method of demand management should be subjected to a technical evaluation in order to obtain an estimate of the actual reduction in water demand or discharge resulting from using the method. Technical evaluations may involve the concept of "engineering efficiency," which basically measures the ratio between water pumped into a system and water delivered to consumers or end uses. However, economic and environment factors may also be involved. "Thus technical effectiveness may in one sense be subsumed under the economic and environmental criteria. But it is probably still worth separating out the technical criterion, since a proposed measure may sometimes be abandoned without proceeding to the economic calculations" (OECD, 1987a, p. 11). In addition, consumer acceptance and political factors may comprise other factors for consideration in a technical analysis.

Economic Evaluation

From the policy viewpoint, where water development costs and competition for available capital are rising, the concept of engineering efficiency is limited by its inability to address the value of any specific use of water (e.g., for in-house residential use) in relation to alternative uses for the same water (e.g., lawn watering or industrial use). An exclusive emphasis on improving the engineering efficiency of a given water use, therefore, may lead to unproductive expenditures if the value of that use is less than the value of some other use of the same water.

The second part of the water demand management definition given earlier highlights a second type of efficiency concept. When prices reflect the value of resources used in production and demanded by consumers, an "economically efficient" allocation of resources is said to occur. Economic or allocative efficiency addresses the value of scarce resources available to society. Thus, concern with the economic efficiency of water use creates a concern about net values of water in alternative uses and whether existing institutions are flexible enough to permit the allocation of existing supplies in such a way that society as a whole derives maximum value from those supplies. The achievement of economic efficiency would form a rational prerequisite for the development of new supplies. In practical terms, increasing the economic efficiency with which existing water is allocated can mean increased incomes and jobs, as well as improvements in the quality of life. The achievement of economic efficiency in resource use is a major economic policy aim, for it means that the economy is approaching maximum productivity in the context of available resources.

Financial Evaluation

Financial analysis is conducted solely on the basis of cash flows. From a financial point of view, a particular project would only be considered as feasible providing that the rate of return of the project in terms of the investment exceeded or equaled the opportunity cost of the capital as reflected by interest rates. Financial appraisals must have a positive net present value that is the present value of all future cash flows. The rate of return should be greater than the cost of the capital.

Environmental Evaluation

Environmental impact studies attempt to capture the intangibles that are not included in the other appraisals, e.g., quality of life, decreasing wildlife populations, and aesthetics. In the demand management context, environmental considerations may be important. Demand management implies an attempt to carry out management functions (e.g., water supply and waste disposal for an urban area) using smaller volumes of water. This in turn implies a concentration of wastes at higher levels than prior to the demand management action. These types of issues would be addressed under the environmental evaluation criterion.

An additional example relates to large water diversion schemes that exist or have been suggested for various purposes, principally the alleviation of water shortages. The environmental disruption implied by such schemes is normally quite large. The extent to which demand management can forestall or even prevent development would be considered under environmental appraisals.

Social/Political/Institutional Evaluation

The social/political/institutional appraisal focuses on the balances between various sectors in society, with resource allocations going to the most powerful group. In the demand management context, this type of evaluation might tend to discourage such measures as higher water pricing. A recent study of municipal water pricing (Tate, 1989) found that "political acceptability" was probably the most important criterion in the setting of water rates.

One important issue in evaluating demand management actions relates to the equity implied by a prospective action. Equity concerns the achievement of a desirable distribution of income among participants in society. The equity of any management action is difficult to address because no single criterion has been developed to assess the degree to which a given action is equitable. What can be shown, however, is how existing practices are inequitable and how demand management moves toward achieving greater equity. The fact that many municipalities in Canada continue the practice of flat rate water pricing is instructive in this regard. On the surface, and certainly at the political level, flat rates appear to epitomize equity. Each residential customer, for example, pays the same amount for water. This stance, however, completely ignores the fact that some customers may use significantly more water than others and, therefore, place higher burdens on the system. Industrial usage, priced the same way, is subsidized to an even greater extent. The large water users determine the size of the water system required in the municipality, and thus systems tend to be oversized (and more costly) just to meet the needs of a few. Thus an apparently equitable system is actually inequitable. The same type of reasoning can be applied to other aspects of water use, for example, indiscriminate waste discharge into watercourses.

BENEFITS OF WATER DEMAND MANAGEMENT

The essential feature that must be understood about water demand management is the attempt to make water development funds cover as many initiatives as possible. Society always has limited funds to spend in any undertaking such as water development. In Canada at the present time, fiscal restraint programs by governments are indications of funding limitations. Efficiency, in the economic sense, means trying to achieve given ends as cheaply as possible in order that as many of the competing demands for funding can be achieved. This is why broadening the range of alternatives and conceiving of water conservation in a benefit-cost context will be important in the future. Thus, making available development funds stretch as far as possible is the fundamental benefit of water demand management.

In addition, other benefits to municipalities of water conservation include lower average peak water system loading and significant energy savings.

Several benefits would accrue from the adoption of water demand management in industry. These include:

1. better control over the throughput of water and wastewater systems generated by the need for better accounting;
2. changes in attitudes toward the use of water as costs begin to show on accounting records;
3. improved technology as R&D expenditures for water handling become profitable, and development of new or expanded industries to provide that technology; and
4. revenue generation, for example, from by-product recovery.

Data Collection and Research on Water Demand

Most fields of resource management study require basic data and inventories as the basis for informed and effective action. It is appropriate here to outline briefly the nature and progress of efforts to establish reliable Canadian water use data as the basis of future water demand management actions.

Water use data and estimates have been integral components of water projects throughout Canadian history. Indeed, the justification for construction projects in the water field arises almost entirely from human needs. But, until recently, development objectives have been met almost solely by manipulating water supplies through dams, diversions, and similar structural means. In the course of planning these projects, water uses were normally estimated using data from secondary sources. Systematic examinations of the nature of water demand using Canadian data are fairly recent developments.

The first studies of water requirements on a systematic basis were conducted by J.F.J. Thomas of the Department of Mines and Technical Surveys, parts of which became Environment Canada (see, for example, Thomas, 1959). Thomas's studies focused on quality requirements for industry and how they were met in the various river basins of Canada. These studies made no attempt to examine water demands from a quantitative viewpoint.

Water use investigations in Canada from the quantitative point of view began systematically in the early 1970s with the collection of industrial water use data and with the completion of several pieces of academic research. The first Canadian industrial water use survey was modelled closely on surveys by the U.S. Bureau of the Census. The initial survey took place in 1972, with subsequent re-surveys in 1976, 1981, and 1986 (Tate, 1977, 1983; Tate and Scharf, 1985). Surveys subsequent to 1972 attempted to gather data pertaining to the economics of water use, in addition to the volumetric information on the water uses themselves. Some of the provincial water management agencies have collaborated in these industrial water use surveys.

Similar surveys were conducted in the municipal sector in 1976, 1983, and 1986 (see Tate and Lacelle, 1978, 1987). The municipal surveys also collected data on water rates, which could be used to analyze the price responsiveness of municipal water demands.

Table 1. Water Use in Canada, 1981 (MCM per annum)

Water use by major sector

Sector	Intake	Recirculation	Gross use*	Discharge	Consumption †
Agriculture	3125	—	3 125	713	2 412
Mineral extraction	648	2 792	3 440	470	178
Manufacturing	9 937	10 747	20 684	9 443	494
Thermal power generation	19 281	1 868	21 149	19 113	168
Municipal	4 263	—	4 263	3 623	640
Total	37 254	15 407	52 661	33 362	3 892

Water intake by region

Region	Agriculture	Mineral extraction	Manufacturing	Thermal	Municipal	Total
Atlantic provinces	12	86	640	1 837	307	2 882
Quebec	82	107	2 319	308	1 369	4 185
Ontario	148	124	4 414	14 930	1 450	21 066
Prairie provinces	2 338	197	382	1 846	579	5 342
British Columbia	545	134	2 182	360	558	3 779
Total	3 125	648	9 937	19 281	4 263	37 254
% of total intake	8.4	1.7	26.7	51.8	11.4	100

*Intake plus recirculation.
†Intake minus discharge.

No comprehensive national surveys on other user sectors (e.g., agriculture, rural, domestic) have been done. However, estimates of water use in these sectors have been carried out at the national and regional levels. For example, the Prairie Provinces Water Board (PPWB) (1982) examined agricultural water use in the region as part of a larger study of current and historical water use. Table 1 illustrates the amount of water use and consumption by major category users. Water intake is defined as the amount of water withdrawn from the source of supply. Water consumption is the difference between water intake and water discharged back to its original source of supply.

Limited efforts have been made at the national level to estimate the volume of water required for nonwithdrawal users. All of these efforts have focused on determining the minimum flow required for the maintenance of nonwithdrawal use. Although determination of these flows can be a complex problem, initial efforts have focused on general guidelines for flow maintenance at the large drainage basin level. Reliable streamflow can be defined as the flow available in a stream 19 years out of 20. A few studies in the past (Alberta Environment, 1977; Tate, 1987, p. 53) have used 50% of this flow as an estimate of nonwithdrawal use. Much more work is required on this subject.

Some major regional studies focusing on water demand data collection have been carried out. One notable example is the water demand study of the Prairie Provinces Water Board (1982). This study compiled water use data for all withdrawal and nonwithdrawal activities in the Saskatchewan-Nelson basin. The time period of study was 1951 to 1978. While some analyses of time trends were carried out, the approach used for data analysis was relatively unsophisticated and no forecasting was done. Similar, though less extensive, water use data studies have been carried out for river basins in British Columbia by the Inland Waters Directorate of Environment Canada (see, for example, Sherwood, 1986).

Concurrent with efforts to measure resource use, a variety of research studies have focused on different aspects of water demand. Grima (1972), Sewell and Roueche (1974), and Kitchen (1975) presented analyses of municipal water demands, attempting to calibrate demand functions under various water use conditions. Renzetti (1987) did the same type of study for industry. Earmme (1979) and Tate (1984) examined the structure of water demand in river basins and economic regions using input-output techniques. Hess (1986) studied ground-water usage throughout Canada. Thus, in addition to collecting basic data on water demands, a small number of research studies have begun to define the characteristics of Canadian water demands. However, the number of these studies is small in comparison with the efforts made to measure and understand the physical nature of the resource.

Municipal Water Demand Management

BASIC FACTS

Municipal water use supply is considered in this paper as water that is supplied and distributed by municipalities with populations of 1000 or more. Users can be classified into residential, commercial, institutional, or industrial categories. The latter category includes only those industries connected to municipal supply systems. By far the bulk of the industrial water use in Canada takes place at plants that have their own supply sources. These are dealt with in Chapter 5.

The 1986 average daily flow of all municipal water utilities in Canada serving populations over 1000 totalled 12.4 million cubic metres (MCM) (Tate and Lacelle, 1987). Surface water provided 90% of this total (11.1 MCM), while ground water provided the remainder. Ground water was used predominantly by smaller municipalities.

Return flow (discharged effluent), defined as measured intake to waste treatment facilities, totalled 7.6 MCM for the average day, or 61% of intake. The 39% of pumpage not accounted for by return flow was made up of untreated flows discharged directly to ambient water courses, fire flows discharged via storm sewers, evaporation from lawn and garden irrigation, or leakage from distribution systems. (The leakage factor is offset to varying degrees by infiltration into the water systems.) Based upon studies carried out in the past (e.g., PPWB, 1982, Appendix 2), it is estimated that, on average, about 20% of unaccounted flow is attributable to leakage from distribution systems and other forms of waste.

In terms of domestic water use per capita, Canada is a relatively high water user, exceeded only by the United States (Table 2). The per capita usage across Canada shows significant spatial variation, from lows of around 250 litres per day in the semiarid western interior to highs of over 500 litres per day in some areas of Atlantic Canada. These per capita figures include usage for all purposes, not just domestic. A typical breakdown of municipal usage is shown in Table 3.

CURRENT AND EMERGING PROBLEMS

Canadian municipalities currently face a number of serious, interrelated problems concerning water-related infrastructure. Many of the water supply systems predate World War II, especially in the larger urban centers. With postwar economic and population growth, public agencies were under increasing pressure to provide funds for construction of adequate waste treatment facilities, resulting in the federally sponsored Canada Mortgage and Housing Corporation (CMHC) municipal infrastructure assistance program. The federal government alone spent some $2 billion on this program by providing low interest loans and grants to municipalities. This assistance resulted in substantial improvements to the waste treatment infrastructure.

Table 2. Municipal Domestic Use by Selected Country, 1983

Country	Pumpage per capita-day (L)
United States	425
Canada	360
Sweden	200
United Kingdom	200
West Germany	150
France	150
Israel	135

Source: For all countries except Canada, Postel (1985, p. 40). For Canada, Tate and Lacelle (1987, Table 3).

Table 3. Municipal Water Use by Major End Uses

Use	Percentage of total pumpage
Total	
Domestic	40
Commercial/institutional	16
Industrial	18
Losses/unaccounted	26
Domestic	
Lawn watering	30
Toilets	40
Bathing/personal	15
Laundry	10
Drinking/cooking	5

Source: Tate and Lacelle (1987).

Since the demise of this program in 1978, much less effort by most levels of government has gone into this area, although Quebec has actually accelerated its expenditures. Many of the systems installed now require major renovations. The need for renovation and upgrading applies even more to water supply systems. One piece of evidence for this need lies in the large volume of municipal water pumpage that cannot be accounted for in return flows, which suggests substantial system leakage. This renovation will be a costly undertaking.

The Federation of Canadian Municipalities (FCM) (1985) estimated that $6 billion would be required to improve the water-related parts of municipal infrastructure (including both water supply and waste treatment). This amount was raised in 1987 to $7.5 billion to account for inflation and changes in the tax structure affecting building materials. Based upon deficiencies in the FCM study methodology, combined with the need for system expansions to cover new growth, this estimate is probably in the $8 billion to $10 billion range.

Concurrent with the need for improved infrastructure are fiscal restraints being faced by senior levels of government. Spending on an array of public programs, as well as other macroscale economic factors, have created substantial government deficits, a rapid expansion in the national debt, and a climate of fiscal restraint. Current federal government policy (McMillan, 1987a, 1987b) states that there is little likelihood that the federal government will sponsor a major municipal infrastructure financing program like the former CMHC program, although it will provide leadership in research, technology development, and basic data collection. Thus, at a time of acknowledged need for large expenditures to improve water and wastewater systems, senior levels of government are hard-pressed to find the required funds.

These economic and financial problems are heightened by a greatly increased public concern for the environment, which consistently registers among the top concerns in public opinion polls. Increasing volumes of waste, the concern about toxic chemicals in drinking water supplies, and deteriorating systems have combined to create this increase in public concern.

MUNICIPAL WATER DEMAND MANAGEMENT TECHNIQUES

This brief outline of current and emerging problems of municipal water use suggests that traditional management approaches are no longer as effective as they once were and that new ones are required. Water demand management is one of these new approaches, suggesting a fairly wide range of measures for coping with these problems. Many of the individual concepts and techniques outlined below have been known for some time. What is new is the concept of combining them into a coherent management strategy.

Economic Techniques

Economic techniques for municipal water management focus on using water pricing policies to influence the level of water demand. The effects of pricing on municipal water use vary, depending upon economic characteristics of water demand in particular communities. One common indicator of pricing effects on demand, which can be measured empirically, is termed the "price elasticity of demand" for water. Price elasticity of demand measures the impact of changing prices on water demand by taking the ratio of the percentage change in the quantity of water demanded to the percentage change in price. Elasticity is normally discussed in terms of values between zero and one and values greater than one. An elasticity value in the former range means that the good or service is price inelastic, in the sense that an increase in price leads to a less than proportionate change in demand. Elasticity values greater than one imply that the changes in demand are more than proportional to the causitive change in price. In actual fact, since the demand curve for goods or services is downward sloping to the right, elasticity values are often negative in value. By convention, however, the values are discussed in absolute terms. The demand curve for water is inelastic over the initial quantity of water used. This means that price change affecting this range of water use will not be very effective in inducing a decrease in water demand. Intuitively, this makes sense because the initial demand for water, for example, in the household, is considered essential to the user. Increased water demand occurs as less and less essential uses come about. As water uses become less essential, the price elasticity of demand increases. In fact, some water uses, such as those for lawn and garden areas, have elasticity values greater than one. It is in this range of use where price increases can have substantial impacts on decreasing water demand.

Table 4 gives typical elasticity measures for various residential water uses. Assuming that these elasticity measures were valid, Flack (1981, p. 92) estimated that doubling the price from 11 cents to 22 cents per cubic metre would reduce the water demand by 32% in his hypothetical western study area. The effects would be somewhat less in more humid areas. This is only a hypothetical

Table 4. Typical Residential Price Elasticities

Water use	Elasticity
Residential (composite)	-0.225
Domestic (in-house)	-0.26
Lawn watering (west)	-0.703
Average day	-0.395
Maximum day	-0.388

Source: Flack (1981, p. 92).

result and impacts vary considerably among communities, but it does show that significant water savings could result from improved municipal water pricing practices.

Realistic water pricing, in the sense of recovering the full costs of water infrastructure, including repair, upgrading, and expansion costs, is the key factor in establishing demand management as a major tool in managing water resources. This subsection contains background information on the past and present pricing schedules used in Canada, including rate schedules used by municipalities, data on unit and total water prices, and a brief discussion of proposed water pricing schedules.

Water Rate Schedules Used by Municipalities

Municipal water users in Canada pay for their water through rates set by the individual municipalities, a system that has produced a widely varied set of practices. These diverse rate-setting practices can be divided into two groups: flat and volume-based.

Flat rate schedules levy fixed periodic charges for water to consumers regardless of the volume of water used. The principal disadvantage of a flat rate structure is that it promotes excessive water use because the marginal, or extra, price of an additional volume of water (e.g., 1 m^3) is zero. Much research (e.g., Kellow, 1970; Kindler and Russell, 1984), as well as recent internal work within the Inland Waters Directorate of Environment Canada (Tate, 1989), has shown conclusively that flat rates lead to excessively high water use. Customers may take as much water as they choose; this leads to wasteful water use practices such as excessive lawn watering or failure to replace dripping faucets or valves. In other words, customers have no incentive to conserve water, and the municipality has little control over water demands, except through administrative measures such as lawn-watering restrictions.

Volume-based rate schedules relate the amount paid for water servicing to the amount of water supplied. Several different methods can be used for establishing this linkage, the simplest being a constant rate per unit (e.g., cubic metre) of water used. This type of pricing arrangement is referred to here as a "constant unit rate." More commonly, however, volume charges vary with the level of water use or among user groups (e.g., residential, industrial), and are combined with certain fixed charges. These schedules fall into two types: declining block rates and increasing block rates.

Declining block rates, the more common of the two, divide water use in each billing period into successive volumes or "blocks," with use in each successive block charged at a lower price than in the previous block. Typically, one or two initial blocks cover residential and light commercial water use, with subsequent blocks containing heavy commercial and industrial uses. The lower cost per unit associated with subsequent higher blocks means that declining block rates provide no incentive for water conservation. In fact, they provide a disincentive. In other words, this type of rate schedule has declining marginal costs and presents the consumer with a decreasing incentive to lower water demands.

Less commonly used is the increasing block rate schedule. In this case, the prices in successive blocks of the rate schedule increase. In other words, the marginal price of water to consumers increases progressively through the blocks of the rate schedules. In these cases, consumers have an incentive to conserve water to avoid the rates in the upper blocks. Increasing block rates affect large water users (e.g., industries) the most. Alternatively, high rates may be imposed in the summer to curtail seasonal peak use. Large water users and those contributing to peak flows have the most impact upon water system sizing, so increasing or even-level block rates should significantly lower system costs. Peak load pricing on other than a seasonal basis might be difficult currently because of the implied special metering requirements.

Most volume-based rate schedules have a fixed or flat rate component, frequently called a minimum bill. In some cases, a given volume of water is associated with the payment of the minimum bill. Frequently, the size of this volume is sufficiently great that the consumer faces what amounts to a flat rate charging system.

Water prices in Canada are low in comparison to other countries. Table 5 illustrates that some European countries have municipal water rates two to three times that of Canada, and that Canada has the lowest rate among the world's developed nations. Referring to

Table 5. Comparison of Average International Water Prices, 1986

Country	Cost (¢/1000L)
United States	53
Canada	25
France	75
Belgium	70
United Kingdom	50
Sweden	50
Australia	165
Germany	99
Italy	17

Source: Inland Waters Directorate internal files.

Table 6. Frequency of Pricing System Use in Canadian Municipalities, 1986

Province	Flat rate	Volume-based rates: Constant unit rate	Declining block rate	Increasing block rate	Total
Residential					
Newfoundland	10	0	0	0	10
Prince Edward Island	4	0	4	0	8
Nova Scotia	12	0	18	0	30
New Brunswick	13	2	6	0	21
Quebec	70	20	6	4	100
Ontario	99	62	70	2	233
Manitoba	1	3	11	0	15
Saskatchewan	1	8	7	2	18
Alberta	9	24	15	1	49
British Columbia	54	17	30	2	103
Territories	2	2	0	0	4
Population size group					
1000 – 4999	82	23	37	2	144
5000 – 9999	73	43	40	1	157
10 000 – 49 999	94	40	69	6	209
50 000 – 99 999	18	17	10	2	47
>100 000	8	15	11	0	34
Total	275	138	167	11	591
Commercial					
Newfoundland	2	4	2	0	8
Prince Edward Island	0	0	4	0	4
Nova Scotia	0	0	18	0	18
New Brunswick	5	2	7	0	14
Quebec	33	41	21	4	99
Ontario	60	65	96	2	223
Manitoba	0	3	6	0	9
Saskatchewan	1	5	6	1	13
Alberta	2	21	14	1	38
British Columbia	42	21	38	3	104
Territories	0	2	0	0	2
Population size group					
1000 – 4999	50	32	48	0	130
5000 – 9999	45	52	52	1	150
10 000 – 49 999	38	50	83	8	179
50 000 – 99 999	9	18	16	2	45
>100 000	3	12	13	0	28
Total	145	164	212	11	532

Source: Tate (1988).

Table 2, the reader will note that, even at this coarse level of detail, the nations or areas with the lowest water prices tend to have the highest use. Table 5 does not include the cost of waste treatment. In Canada's case, this would raise the unit cost to 47 cents per cubic metre.

Canadian Data and Pricing

A recent review of municipal water pricing practices (Tate, 1989) used water rate information for 470 municipalities across Canada. The following tables cover the types of charging practices in use (Table 6), retail prices per cubic metre to residential and commercial water users (Table 7), and total retail prices to residential users for selected volumes of water per month (Table 8), and include combined water and sewer expenses.

The survey also showed that 420 of the 1123 rate schedules analyzed (37%) used flat rate schedules (Table 6). An additional 454 of the volume-based rate schedules incorporated some element of flat rate charging, usually through meter rental charges and/or wide first blocks. In such cases, even though the rate schedule is technically volume-based, the customer in effect faces a flat rate schedule. Thus, just over 80% of the rate schedules in use in Canada have flat rate characteristics.

There are substantial variations in unit water prices across the country and, to a lesser extent, across urban size ranges (Table 7). First block prices are consistently greater than last block prices, indicating the predominance of declining block rate pricing structures. The variations among provinces in the degree to which wastes are treated may account for some of the differences observable in Table 7.

Perhaps the most important observation is that both unit and total water prices are low relative to the prices of other goods and services, like energy, that can also be deemed central services in the economy. Not enough data are available to conclude definitively that water prices are "too low." But comparisons of prices with other common liquids, such as those in Table 9, as well as the current problems that have arisen with infrastructure financing, suggest this is the case.

The relative cheapness of water is illustrated well in Table 9. The consumable liquid priced closest to water, cola, is 1675 times as expensive! Even considering the extremes (i.e., the 90th percentiles) of prices in Table 7, a typical monthly supply of delivered and removed water would cost, on average, less than a case of beer. Although tap water is used for a variety of purposes, it is not, admittedly, a perfect substitute for beer or any of the other liquids listed in the table. Also, the degree of value added to a product like whisky far outweighs the

Table 7. Retail Water Prices (¢/m^3) for Residential and Commercial Customers by Province and Population Size Group

	Constant unit prices				First block[1] prices				Last Block[2] prices			
			Percentiles				Percentiles				Percentiles	
Province	Mean	Median	10th	90th	Mean	Median	10th	90th	Mean	Median	10th	90th
Newfoundland	64	50	-	-	34	-	-	-	17	-	-	-
Prince Edward Island	-	-	-	-	30	29	29	32	22	21	21	23
Nova Scotia	-	-	-	-	88	90	21	124	43	33	13	84
New Brunswick	127	160	61	160	110	110	33	202	53	55	2	82
Quebec	24	20	11	49	22	23	11	31	21	15	5	31
Ontario	40	37	17	67	43	35	23	67	24	22	11	42
Manitoba	77	79	62	89	89	80	35	198	58	50	22	165
Saskatchewan	56	64	29	72	54	54	24	75	39	35	8	71
Alberta	56	54	22	91	72	70	25	121	46	46	12	74
British Columbia	19	16	8	35	24	21	13	45	13	10	7	28
Territories	115	68	53	159	-	-	-	-	-	-	-	-
Population size group												
1000 – 4999	39	29	16	72	55	35	17	124	36	23	8	84
5000 – 9999	40	33	11	73	52	42	21	117	28	24	11	55
10 000 – 49 999	38	31	12	68	42	34	16	72	27	21	8	50
50 000 – 99 999	29	24	11	66	39	24	14	110	23	17	7	55
>100 000	47	47	23	68	55	42	13	158	24	22	6	48
Canada	38	31	12	71	48	37	17	100	29	23	8	55

[1] The first block is defined as the first segment of water use for which a non-zero price is charged. Thus a community with a three-block schedule, for which the first block corresponds to a minimum bill is considered here as having a two-block schedule.

[2] The last block identifies the remainder or excess water use block corresponding to the last and usually the lowest unit price. Where there are only two blocks, the upper limit of the first block equals the lower limit of the last block.

Source: Tate (1988).

Table 8. Total Price ($) to Residential Water Users for Selected Volumes of Water by Province and Population Size Group

	10 m^3				35 m^3			
			Percentiles				Percentiles	
Province	Mean	Median	10th	90th	Mean	Median	10th	90th
Newfoundland	7.97	7.08	5.50	12.00	7.97	7.08	5.50	12.00
Prince Edward Island	11.26	11.42	10.36	12.75	14.93	12.75	11.60	19.34
Nova Scotia	10.06	9.65	5.92	12.72	13.26	12.98	7.04	18.05
New Brunswick	14.87	15.00	5.83	21.72	17.75	17.00	5.83	35.28
Quebec	8.12	4.00	7.50	12.50	9.54	8.48	5.42	15.00
Ontario	11.49	9.13	4.80	20.90	17.39	15.35	7.91	30.00
Manitoba	11.76	10.71	6.53	21.36	31.91	30.39	20.44	38.25
Saskatchewan	12.59	10.92	3.43	18.75	26.26	28.84	10.33	37.59
Alberta	18.04	15.00	8.86	30.00	29.86	29.75	12.72	47.18
British Columbia	8.62	8.00	3.83	13.85	10.09	9.00	4.67	17.31
Territories	19.80	18.29	6.80	31.10	33.19	23.80	19.80	58.04
Canada	10.90	9.25	4.80	19.53	16.08	12.71	6.60	30.00
Population size group								
1000 – 4999	12.96	10.67	5.83	24.74	17.62	12.50	7.08	35.73
5000 – 9999	11.03	10.00	4.80	16.67	16.40	14.00	6.60	26.08
10 000 – 49 999	10.54	9.30	4.79	17.67	15.82	11.63	6.25	29.75
50 000 – 99 999	9.41	7.36	3.78	19.53	13.57	10.63	5.67	28.99
>100 000	8.34	7.30	3.70	13.74	15.91	15.40	5.00	28.99

Source: Tate (1988).

value of raw water. Furthermore, the price of water given includes only a processing and delivery charge, not a charge for the liquid itself. In other words, the water

Table 9. Typical Prices for Popular Liquids

Liquids	Cost ($/m^3)
Beverages	
Tap water [1]	0.47
Cola	787.00
Milk	900.00
Perrier water	1 333.00
Beer	2 000.00
Wine	6 000.00
Whisky	18 000.00
Gasoline	550.00

[1] Based on the Canadian monthly water price of 35 m^3 (Table 8).

Note: All beverages except water have to be collected by the consumer, whereas water is delivered to the home and wastewater is removed at no inconvenience to the consumer.

charges relate to the cost of providing a service and exclude any charge for water. Nevertheless, this depiction of the cost of water conveys effectively the fact that water is extremely cheap in comparison with other common liquids in use.

The effects of low prices and the predominant Canadian rate-structuring practices are significant in their water use effects. Looking first at a static situation, consumers receive the wrong signals about the value of water used — that it is a cheap commodity that need not be conserved. Thus, water is viewed as a requirement to be met, not as a demand that can be changed through pricing practices. Artificially high demands mean that operating and maintenance costs, including energy costs, are inflated. Prices fail to reflect the total costs of system construction, maintenance, and renovation. The deteriorating condition of water-related infrastructure is proof of this. Declining block rates or, even worse, flat rates fail to recognize large water users as the ones who are primarily responsible for overall system capacity, design, and costs. Thus, in reality, there are implicit subsidies to large water users from the general public.

In a dynamic situation, the effects of low prices are compounded. Because they are low, prices are rarely taken into account in projecting water demands. Many consultants and analysts assume a constant, or even increasing, water use per capita, and then multiply these "coefficients" by projected population to generate projected water "requirements" in the future. These requirements then become design parameters and lead to systems being expanded or built that would be too large if water prices were more reflective of actual resource values. These systems, being in place, have to be used, which forms an incentive for keeping prices low. Thus the cycle of low prices/high demands/over-building is self-reinforcing. This is a waste of scarce public resources. Postel (1985, p. 40) summarized this argument well, stating:

> *Planners have typically projected future water demands based on the historical rate of growth in per capita water use and the projected population. They then plan to meet this estimated demand by drilling more wells or building new reservoirs, and expanding the capacity of their water and wastewater treatment plants. Rarely have planners focused on reducing water demand as a way to balance the long term supply/demand equation.*

Improving Water Pricing Schedules

Having established that water demands decrease with increasing prices, and that municipal water prices in Canada are not sufficiently high to recover the full costs of water systems, the question arises as to how prices should be raised. The following material suggests briefly how an improved pricing system would look, based upon the premises that (1) no revenue shortfall should occur and (2) the rates should both meet the efficiency criterion and treat customers in an equitable manner.

Table 6 showed that in Canada the prevalent forms of municipal water charges in 1986 were flat rates and declining block rates. In cases where flat rates prevail, a basic step is to institute metering and to begin charging on the basis of water use. With all municipalities having the ability, then, to base water charges on use, the next step is to build a new pricing structure and determine the most appropriate level of prices. Based upon reviews of this problem by Hanke (1978) and McNeill (1988), the simplest system of pricing would be a two-part tariff. The first part would be a fixed charge, which would cover overhead and administration. (Fire system charges might appropriately be considered as a fixed charge to the system.) These fixed charges would be shared equally by all customers. The second part of this structure would be a constant commodity charge per unit of use. (This would correspond to the "constant unit rate" of Table 6.) This constant charge would be based upon the marginal cost of water supply, which can be demonstrated theoretically to meet the efficiency criterion. Examples of marginal cost calculations are given in Hanke (1978). An alternative methodology was outlined by the OECD (1987b, pp.131-133). The problem of preventing revenue shortfalls is covered well by McNeill (1988, pp. 30-35).

Thus the suggested structure and level of a reformed municipal water pricing structure are quite simple. The fixed charge would recover the fixed component of system costs, shared equally among all users. The constant commodity charge would cover all variable costs and would be based on the marginal cost of supply, adjusted slightly to overcome potential revenue shortfall problems. Also, to overcome the problem of low income consumers, the utility could include a small "lifeline" volume of water with the fixed portion of the charge, allowing consumers to avoid the commodity charge altogether if their usage was small enough. This suggested system meets the main rate-setting criteria for success: cost recovery, efficiency, and equity. Assuming that all cost factors are accounted for, this pricing scheme would permit full cost recovery. Because prices would reflect the actual costs of developing water supplies, consumers would receive accurate signals about the value of their resource use and would be motivated to use water rationally. By including the "lifeline" component and by making large water users pay in proportion to their water use, the pricing system outlined would satisfy basic equity criteria.

Resource Pricing and Technological Change

In an earlier section, the general relationship between the economic incentive system presented by market-type economies and technological change was mentioned. It is appropriate at this point to discuss this idea in more detail, since the possible technological offshoots of using economic techniques to influence water demands are potentially very large.

Schultze (1977, p. 31) stated the issue quite succinctly:

> *Living standards in modern Western societies are, by an order of magnitude, superior to those of the early seventeenth century. Had the triumph of the market meant only a more efficient use of the technologies and resources then available, the gains in living standards would have been minuscule by comparison. What made the difference was the stimulation of new technologies and resources.*

Similar observations are given, through a series of vignettes by Howe (1979). The general finding of a strong relationship between market-type arrangements and technological progress is important, since it helps diagnose a basic problem with the municipal water industry.

For the most part, this industry uses traditional technology (Wade Miller Associates, 1987, p. 22). While processes have been modernized, technological breakthroughs or scientific revolutions, in the sense of Kuhn's (1970) usage, are rare. This adherence to tradition, exemplified by the failure of many communities to use metering, has occurred while many other utilities (e.g., transportation, energy production) have advanced substantially. The failure of prices to reflect the value of resources used in the production of water supplies and in environmental protection is a significant factor in explaining the current problems of the water "industry." It also suggests a fundamental curative action that could be taken, namely, the raising of water prices to more realistic levels.

Structural and Operational Techniques

Metering, retrofitting, using dual systems, and repairing infrastructure leaks are examples of structural and operational methods to reduce water demand in the municipal sector.

Across Canada, only about 50% of connections to municipal water systems are metered, an overwhelming impediment to pricing based on water use. With a total urban population of 20 million in 1986 and an average of three persons per connection, this would mean that there are about 6.7 million residential connections to municipal water systems. Therefore, to achieve full metering, over three million additional meters would have to be installed. Using MacLaren's (1987) estimated meter installation cost of about $200 per connection, the cost to undertake this task would be between $650 million and $700 million. While this is a large amount of money, it is small in comparison with the $8 billion to $10 billion required for infrastructure repair and upgrading, and, if coupled with price re-structuring, would contribute to the municipalities being able to meet their water system costs efficiently and equitably.

Several studies have found metering alone can substantially reduce water use and allow easier detection of system leaks. Flack (1981, p. 89) stated that "metering has the effect of reducing total demand by 21 percent; sprinkling by 29 percent; and return flow, by 29 percent." Loudon (1986, pp. 3–4) cited experiences in several Canadian municipalities (Table 10). Thus, it appears that metering alone could reduce municipal water use by 15% –20% over premetering levels. This is actually a pricing effect, since, presumably, after installing meters, the municipality can base its rates on

Table 10. Effects of Metering on Municipal Water Pumpage

Municipality	Pre-metering pumpage[1] Per capita-day (L)	Post-metering pumpage Short term Per capita-day (L)	Short term Change (%)	Long term Per capita-day (L)	Long term Change (%)
Kingston, Ont.	1003	638	-36	748	-25
Brockville, Ont.	889	–	–	752	-15
Ottawa, Ont.	597	–	–	433	-27
Calgary, Alta.[2]	1171	–	–	802	-31

[1]All pumpage figures are total water use, not just domestic. They are accordingly significantly higher than those given in Table 2.

[2]Estimated effects only. Metering choice defeated in 1966 plebiscite.

Source: Loudon (1986).

volume of use. Consumers therefore would have a basic incentive to conserve their use of water.

Retrofitting various parts of the water-related infrastructure constitutes another structural technique for achieving reductions in municipal water use. Residential retrofitting involves replacing high water use fixtures and equipment with water-saving devices. This can be done inexpensively for shower heads, toilets, and fixtures. In an experiment in Waterloo, Ontario, Robinson (1980, p. 5) found an average 20% drop in water use in households using the water-saving devices. This reduction percentage appeared to hold over a long-term period.

Barclay (1984) cited experiences in retrofitting apartment blocks with water-saving devices. Shower heads were found to be the most rewarding candidates for retrofitting, since both energy and metered water cost savings resulted. "As most low flow shower heads reduce water flow by 40–50 percent, the new shower head can pay for itself in a year" (Barclay, 1984, p. 46). He summarized the issue, as follows:

> *Retrofitting apartment buildings to reduce costs and water demand can be successfully carried out within a reasonable payback period. The shower head, kitchen and bathroom faucets as well as the toilet tank... should be retrofitted with low flow devices.* (Barclay, 1984, p. 47.)

Barclay also says building owners would require adequate ongoing maintenance programs to benefit from retrofitting. The incentive for this continuing maintenance could be increased water prices.

At the system level, retrofitting can also contribute to substantial reductions in water demand. Leak detection, both into and out of water and sewer systems will result in substantial savings in many municipalities. Hennigar (1984, pp. 52–53) wrote that in addition to water savings, sonic leak detection would help in establishing regular maintenance programs, lowering pumping equipment and fuel costs, improving underground safety, and fostering better public relations.

Postel (1985, pp. 44–45) tackled the retrofitting issue from a slightly different angle, namely, energy savings. She stated that the simple installation of a water-saving shower head in a family residence, of which the cost is little more than a conventional head, could decrease the annual electricity bill for an average family of four with an electric hot water heater by $100.

Dual water systems and so-called "grey water" systems offer other alternatives for reducing municipal water demand. Dual water systems are made up of two separate sets of piped water supply: one potable for drinking, cooking, and other functions that require the highest water quality; the other sub-potable to serve purposes like sanitation, irrigation, fire control, and other functions that can operate on lower water quality. The sub-potable system would be considered safe and would present little health danger if accidentally ingested. The principal saving of implementing a dual system is in the cost of chemicals to "polish" the water normally to the potable level.

Grey water, or recycling, systems are those individual household systems that collect wastewater from clothes washers and showers for use in flush toilets or for lawn irrigation. Haney and Hagar (1985) reported a 39% water saving in a household retrofitted with a grey water system.

Sociopolitical Techniques

Sociopolitical means of moving toward demand management include promotion of sound water pricing practices, promotion of R&D, public education, and investigation of the advantages and disadvantages of water system privatization.

The mechanics of water pricing have already been discussed. Managers, administrators, and politicians have a vital role to play in establishing the importance of pricing. Their role relates to promoting improved water pricing. The issue was first raised in Canada by the report of the Inquiry on Federal Water Policy, which called for a thorough study on appropriate pricing for municipal water and wastewater services, including universal metering. The Federal Water Policy followed on the heels of the Inquiry in making realistic water pricing one of its five main strategies. These policy documents have been used in formulating the federal government's approach to the municipal infrastructure financing problem. This approach is aimed at generating funds for upgrading water systems from the user of water services rather than from general tax revenues. These policy initiatives should have a substantial long-term impact on water management.

The second sociopolitical technique focuses on public education. Education and public awareness have an important role to play in municipal water conservation. Profligate habits concerning the use of water are deep-seated in the consciousness of most Canadians, who expect water "on tap" 24 hours a day, year round, and at very low prices, as shown in Table 5. Groups such as the National Survival Institute (1985) and the Education Department of the Province of Alberta have begun this educational process. Also Pearse et al. (1985, ch. 16) recommended a concerted federal public education program aimed toward water conservation. Robinson (1980, p. 4) said education programs alone could account for a decreased water use of up to 10% of pre-program levels.

The third sociopolitical technique is privatization of some or all municipal water systems, a relatively new suggestion designed to take advantage of the greater efficiency of private over public operations and of the private sector's ability to raise the capital required for water system renewal. This proposal is neither supported nor rejected in this paper, but the potential of this new management strategy, which embodies the philosophy of Schultze outlined in Chapter 2, should be investigated in more detail.

The principles underlying the drive toward privatization were given by Hanke (1983) and Hanke and Fortin (1985). Proponents believe that private sector firms can operate more efficiently than public sector ones. For example, Hanke (1983, p. 30) stated that

> *privatization of infrastructure is the cutting edge of a new movement in the United States. . . . Virtually all these so-called public works should be privatized. . . . The cost of delivering these services privately is less than the cost of delivering them publicly.*

Hanke's contention that the private sector can perform traditional public sector functions at less cost is based upon the ability of the former to levy charges and to establish incentives based upon the true costs of supplying water services. Wade Miller Associates, in a study for the U.S. National Council on Public Works Improvement (1987, p. 134), examined the privatization issue, summarizing their findings as follows:

> *While privatization . . . offers a private investor a number of tax advantages and non-tax economies which create a return on investment, the advantages to a municipality are even broader. First, the municipality obtains needed facilities without using municipal expenditures, without having to go to the voters for a bond issue, and without negative effects on the municipality's bond ceiling. Second, financial risk is shifted to the investor, who is contractually obligated to operate and maintain the facility and to comply with all regulations. (In addition) the private investor is able to provide the same service at an estimated 10–20 percent lower cost due to reduced construction cost and timing efficiencies, operational advantages and tax benefits. Effectively the municipality retains control and realizes financial savings without the burdens of ownership.*

Doctor (1986, p. 48) stated that privatization generally led to a 10%–30% cost saving to the municipality, and in some cases significantly more.

Privatization has precedents in France, where large, viable engineering companies rebuilt and rehabilitated several large water utilities after severe wartime damage (Deschamps, 1986, p. 34). These companies, which now serve over 60% of France's total population, have not only achieved efficiency and high performance, they have also produced research and innovation to improve operations. As stated in the introduction to a series of articles dealing with privatization in the Journal of the American Water Works Association (AWWA, 1986, p. 33),

> *these companies often manufacture and supply the equipment needed to implement their new technologies. Their staffs are well trained, their management streamlined, their experts respected throughout the world.*

Pricing of water services in France is based primarily on declining block rates. There are two common systems of pricing water. The first consists of two parts: a fixed charge to cover overhead and a charge based on usage, which declines with higher levels of usage. A second type of rate consists of an annual fee, paid in advance, for a fixed amount of water, with excess usage charges billed according to use over the fixed amount.

No assessment is made here about the effects of privatization on supplying municipal water. Advantages for the municipality are lower financial burdens, cuts in administrative costs, and the opportunity to take advantage of technological innovations. Disadvantages are the loss of direct control by municipal authorities, environmental quality control, and public ownership of water systems. However, Westerhoff (1986, p. 44) said these disadvantages could be overcome through effective contract negotiations.

PROBLEMS WITH DEMAND MANAGEMENT IN MUNICIPALITIES

The incorporation of the water demand management concept into municipal operations is not without problems, notably during the short-run adjustment period. Loudon (1986, pp. 6–7) referred to the "conservation conundrum" and summarized this issue as follows:

Water costs are relatively inelastic to demand (levels). A reduction in water demand will not have a proportional decrease in costs. An effective conservation program will result in a need for increased water rates to meet financial obligations, which have decreased very little, and which, depending upon the cost of the conservation program, may have resulted actually in increased costs. Customers will understandably not be pleased to see their efforts rewarded with water bills which don't decrease.

The lack of obvious short-term financial reward from conservation efforts is a very real problem which can derail conservation efforts aimed at a longer-term benefit.

Emergency or short-term conservation efforts do not have the same financial impact.

The difficulties in matching revenues and expenditures and of having to increase rates to generate sufficient revenues in the face of falling demand have given many municipalities second thoughts about conservation options that directly involve customers.

Hirschleifer et al. (1960, pp. 94–98) dealt in detail with this potential imbalance between revenues and costs. They showed revenue balancing could be achieved for the most part through changing rates over time to reflect changing cost conditions, arguing that economic efficiency was achieved when prices were set at short-run marginal costs. They recognized the "prejudice" against changing water prices to reflect current cost and revenue positions, but emphasized that

it is just that, a prejudice. No buyer has any reason to expect that prices will remain fixed while conditions of supply and demand change, unless . . . he is willing to bind himself to a long term contract. So, while recognizing the prejudice to the extent that it exists, water authorities should not tamely submit to it but rather attempt to educate the public as to the wastes and social costs thereby imposed on all.

In an earlier section, it was suggested that municipal water rates would be improved by using a two-block structure: the first block to account for fixed costs of system operation; the second to be a constant unit commodity charge. Under this system, revenue shortfalls can be averted.

CONSEQUENCES OF WATER DEMAND MANAGEMENT FOR THE MUNICIPAL SECTOR

Severe potential problems in financing, water supply, and water quality have emerged in the municipal sector, problems that will require long-term commitments of billions of dollars. Thus it is important for all water management options to be examined carefully so that the most efficient solutions can be found. Water demand management offers some positive outlooks and suggestions for dealing with these problems.

The thesis presented here is that, for any substantial progress to be made in handling the problems of municipal water use, universal water metering must occur, coupled with improved pricing practices, which would probably lead to moderate increases in water prices. Prices are the key signals to consumers and planners as to the value of the resources, and, as shown in this chapter, the traditionally low municipal water prices have reflected a substantial undervaluing of the resource. More realistic water pricing practices are the key to better, more efficient municipal water management in the future. Other steps, such as leak detection and repair programs, are also important in developing water demand management in municipalities. It is suggested here, however, that this can only be accomplished in the context of sufficient revenue generation, which is primarily a function of pricing.

Several effects would follow such a price rise. In the short term, water usage, on average, would fall in varying degrees depending upon the size of the price increase and the price elasticity of demand. Most figures indicate an initial decline in water usage of 25% or more, with a rebound, as users adjusted their water use habits, to a longer term decrease of 15%–20%. Various means, such as retrofitting of plumbing fixtures and other conservation measures outlined earlier, would be the means for reducing water use.

Some short-term revenue shortfalls might result, calling for temporary financial assistance to municipalities, but this should not be allowed to interfere with the long-term movement to more rational water use. In any event, these shortfalls could be overcome under the reformed pricing system suggested above. With more rational water pricing in place, demand forecasts would be lowered, thereby delaying or even postponing the need for infrastructure expansion. Lower operating and maintenance costs would result, including decreased energy costs as less water would be treated or pumped, and waste treatment needs would fall. Higher water rates, assuming price elasticities less than one, would generate needed capital for infrastructure renovation and improvement. Geographically, urban centres might become more concentrated as new developments became responsible for the full marginal costs of water supply. Finally, higher municipal water rates would induce industries connected to the municipal system to institute water conservation measures, resulting in decreased system demands and reinforcing the trend to lower residential water use.

Industrial Water Demand Management

Industrial water use, for the purposes of this chapter, includes only water that is supplied by the industry itself. The most common uses for water in industry are cooling and condensing, processing, and sanitation. Cooling and condensing uses are concerned with conveying heat from process operations and with the condensing of spent steam from power production. For the most part, water used for cooling and condensing is contained in separate circulation systems and remains relatively pollution free, except for a rise in temperature (typically 10°C–15°C). Process water consists of water that comes into contact with, or is incorporated into, intermediate or final products. It carries most of the polluting materials generated during production and may also contain substantial amounts of heat. In 1981, cooling, condensing, and process water accounted for nearly 98% of total water intake by Canadian manufacturers. In thermal power generation, cooling and condensing accounted for just under 100% of intake. Sanitary uses were minor, servicing the needs of plant personnel.

Industrial water use encompasses a very wide range of economic activities, from mineral extraction firms to food and beverage manufacturers. In addition to encompassing all types of goods production, water uses in this category occur under diverse technological conditions, related often to plant age, process technology, and the like. Thus, any discussion of industrial water use involves many generalizations, which may or may not apply in specific cases.

Many of the principles outlined in the last chapter, particularly in connection with water pricing, apply to industry as well. This material, which mainly concerned input pricing, will not be emphasized here. Rather, the material presented here concentrates on two dimensions of industrial water use: a demand management interpretation of the industrial water pollution problem and a brief examination of the concept of water recycling.

BASIC FACTS

In Canada, the mineral extraction, manufacturing, and thermal power generation sectors, which make up Canada's industrial economy, withdrew 30 130 MCM of water in 1981, the latest year for which complete statistics are available (Table 11). (Statistics from a 1986 survey are currently being compiled.) Of this amount, nearly 16 000 MCM were recycled, allowing the total intake to meet a gross water use of over 46 000 MCM. Wide variations occurred in the average number of times water was recycled (i.e., the use rate), from a high of 5.31 in mineral extraction to a low of 1.10 in thermal power generation, with the aggregate use rate for all

Table 11. Characteristics of Industrial Water Use, 1981 (MCM)

	Volumes					Engineering efficiency measures	
Sector	Intake[1]	Recirculation[2]	Gross water use	Consumption[3]	Discharge[4]	Use rate[5]	Consumption rate[6] (%)
Mineral extraction	648	2 792	3 440	179	469	5.31	0.28
Manufacturing	10 201	11 258	21 459	507	9 694	2.10	0.05
Thermal power	19 281	1 868	21 149	168	19 113	1.10	0.01
Total	30 130	15 918	46 048	854	29 276	1.52	0.03

[1] Water entering an industrial operation for the first time.
[2] The arithmetic difference between gross water use and intake.
[3] The arithmetic difference between intake and discharge.
[4] The total amount of water discharged from an industrial operation.
[5] An index of recirculation; the ratio of gross water use to water intake.
[6] An index of water consumption; the ratio of consumption to discharge.
Source: Tate and Scharf (1985).

Table 12. Industrial Water Costs by Component and Industry, 1981 ($ '000)

Sector	Acquisition	Intake treatment	Recirculation	Wastewater treatment	Total cost
Mineral extraction	11 460	11 209	9 928	14 378	46 975
Manufacturing	108 908	86 156	46 422	109 498	350 984
Thermal power	11 311	11 678	0	0	22 989
Total	131 679	109 043	56 350	123 876	420 948

Source: Tate and Scharf (1985).

industry being 1.52. Likewise, consumptive water use varied widely, from 28% of intake in mineral extraction to under 1% in thermal power generation, with the cross-industry average being 3%.

Water costs to industry in 1981 totalled $421 million (Table 12). Costs of water to manufacturers ($351 million) dominated the total and can be used to demonstrate the economic insignificance of water costs to industry. In 1981, the total cost of all inputs to manufacturing amounted to $191 billion (Statistics Canada, 1985, p. 516). Accordingly, water accounted for only 0.2% of total manufacturing input costs.

CURRENT AND EMERGING PROBLEMS

It is probably no accident that Canada's major industrial areas are located in the more humid areas of the country. While it is too simplistic to maintain that water availability is the sole determinant of industrial location, large industries certainly demand huge volumes of water. This is one major reason they are located along water bodies such as the Great Lakes. In contrast, the really large industries are seldom found in the semi-arid areas, for these areas lack both the water supply and the proximity to markets and labour supply. Quantity may be a problem in specific areas and for industries supplied from municipal sources in connection with infrastructure provision. This problem is closely related to earlier material given on municipal infrastructure. One fact that does come into play when industries are self-supplied is that, for the most part, the financing problem is a private sector one and tends not to impinge as much on issues of public finance as municipal water problems. One is led to conclude that industrial water supply, from the viewpoint of overall water availability, is not a substantial, broad-based concern in Canada.

A more serious issue with respect to industrial water use is that of water pollution. One of the consequences of an advanced industrial economy is that water courses in industrial areas have become seriously degraded. Water demand management can play a major role in correcting these problems.

INDUSTRIAL WATER DEMAND MANAGEMENT TECHNIQUES

This section provides an overview on how the lack of economic incentives to protect water has caused industrial water pollution, illustrates some examples of present-day water pricing, and specifies some economic pricing incentives that can prevent or at least reduce water quality degradation due to effluent discharges.

Economic Techniques

The argument presented here is that, at root, water pollution is an economic problem, the result of a legacy of failing to recognize the value of water resources to industry for waste removal and to price these resources accordingly. Thus, a significant part of the solution lies in management initiatives based on a sound understanding of the economic characteristics of industrial water management, including both the financial and the allocative dimensions of the problem.

One well-entrenched and frequently pejorative viewpoint must be addressed at the outset, namely, that any economic steps in industrial pollution control will constitute "licenses to pollute." This claim is no more true for effluent charges (e.g., charges based on the volume and strength of effluents) than it is for any other administratively mandated control scheme. Public agencies will continue to be hamstrung in the industrial pollution control field if they continue to give credence to this myth.

Industrial Water Pollution

Throughout history, water has served not only as a raw material source for industry, but also as a dumping ground for waste residuals from the production process. One of the unique characteristics of water is its ability to cleanse wastewater flows of some pollutants (e.g., biodegradable solids) and to dilute others, often to insignificant levels. To a large extent, these biodegradation and dilution properties of water are the basis for using water bodies as waste-dumping grounds. This practice has been considered acceptable by society and its policy makers in cases where industry is widely dispersed and waste residuals are nontoxic.

As part of the economic growth phenomenon, population centres and their supporting industrial bases expanded in size and concentration. Also, technological change generated new products and particularly new chemical substances. The latter are not just nondegradable, but frequently toxic to many life forms, including humans (Muir and Sudar, 1987). Some results of economic growth, accordingly, have been the exceeding of available assimilative capacity and the dispersion of nondegradable and toxic materials into the ecosystem. This, in turn, has led to significant, often dangerous, environmental damages and a management problem that has persisted in spite of efforts by public agencies and a wide diversity of public interest groups.

Water pollution can be viewed as a problem of "externalities," which arise as industry uses environmental services as an integral, but unpaid-for, part of their production processes. The industrialist, seeking to maximize profits, has rationally chosen to use the unpriced water resource as a waste depository, as opposed to installing expensive pollution control or recycling equipment. The problem of environmental control is not primarily one of technology; we know how to control most wastes. Rather, it is a problem stemming from low and often nonexisting economic incentives to limit the discharge of waste materials. Pollution control costs, as shown earlier, are mere fractions of one percent of the value of industrial shipments, and as such constitute largely insignificant considerations in corporate balance sheets.

The traditional and, incidentally, still-current approach to pollution control is a classic case of grafting one of Schultze's (1977) "command and control" modules onto the economic system. Government agencies establish guidelines for the quality of industrial discharges or standards and regulations that must be met. Examples are the industrial regulations for pollution control under the Canadian Environmental Protection Act and similar regulations established in various provinces. The incorporation of "best practical technology" or "best available technology" frequently forms the basis of the standards and regulations, which, once established, constitute licenses to pollute. Further dimensions of this supply management approach are the negotiation of schedules for compliance with the regulations, protracted negotiations to minimize economic impacts, and frequent postponement of the need to comply. The efforts to place adequate controls on the discharge of meat packing wastes in the City of Winnipeg (Penman, 1974) is a classic example of the problems involved in supply management approaches. Hardin's paper (1968), "The Tragedy of the Commons," is a more general example of the consequences of supply management.

As noted above, the pivotal problem of industrial pollution is economic incentive, not technological knowledge. The absence of costs to the producer for waste discharge leads to minimal levels of waste treatment, or, more frequently, none at all. This, in turn, leads to the discharge of raw or inadequately treated wastes.

Table 13. Annual Water Charges ($\$/10^3 m^3$) for Manufacturing Use by Province

Province	Charge	Rate system	First block	Last block
Newfoundland	No			
Nova Scotia	Yes	V db	0.40	0.055
Prince Ed Island	No			
New Brunswick	No			
Quebec	No (Charges are only for instream use)			
Ontario	No			
Manitoba	Yes	V ib	2.00	1.00
Saskatchewan	Yes	V	12.16	2.43
Alberta	No (Water from provincially owned works $81.00/1000 m^3)			
British Columbia	Yes	V db	176.00	44.00
Territories	Yes	V db	22.00	2.20

Note : V=Water rates are charged by volume used.
V db=Water rates are charged by volume used, with the schedule following a declining block unit format.
V ib=Water rates are charged by volume used, with the schedule following an increasing block unit format.
Sources: Environment Canada (1986b) and Manitoba Gazette (1987).

Further, low costs for environmental services create no incentive at all for technological improvement.

Examples of Current Industrial Water Pricing

The ownership and control over water resources in Canada falls generally within the jurisdiction of the provinces. The federal government, however, has jurisdiction over the two territories and specific responsibilities in areas such as fisheries and international waters. Accordingly, many of the current water pricing arrangements in place for industry are provincially determined.

Water charges to industry vary greatly across the provinces. Six provinces levy no charges at all on industrial water withdrawals (Table 13). In the remaining four, charges to manufacturers reach up to about $176 per 1000 m^3, but normally decline because most price schedules follow declining block unit format. Manitoba is the only province that follows an increasing block unit format. Water rentals to power companies are based, in most cases, on the generating capacity or actual generation on a yearly basis (Environment Canada, 1986c).

Economic Incentives to Reduce Industrial Pollution

Water demand management offers both a new perspective and a new prescription for the industrial pollution problem. Economic research in this area demonstrates industrial water use is price responsive. De Rooy (1970, 1974) found water price to be significant in explaining the level of water demand by industrial plants. Renzetti (1987) recently confirmed these findings for Canadian industry.

These and other studies imply that as water prices rise, demand falls, largely through recycling and other process changes. This, in turn, suggests that one strategic approach to the incentive problem in industrial pollution is to begin to place prices on the waste amelioration characteristics of receiving waters.

Having stated the need to place prices on environmental services, there remains a wide variety of means for effecting this strategy. Kneese developed the case for placing effluent discharge fees on industrial discharges, concluding that

there is strong evidence that effluent and emissions charges, if properly implemented, would have advantages in efficiency, equity and effectiveness over the efforts to do the whole job by direct regulation which have characterized policy in most countries. Quite simply charge systems can be designed to induce responses which will cause environmental standards to be met at much lower cost than even a successfully implemented program of conventional standards. (Kneese, 1977, p. 253.)

Dales (1968) suggested a system of tradable effluent permits, based on the assimilative capacity of particular streams, to incorporate an economic dimension into industrial pollution control decisions. The price of the permits would be established through inter-firm bidding, with permit holders being allowed to continue discharging the specified pollutants, and those without permits being obligated to cease their polluting activities. In effect this system provides pollution abatement incentives for those who can clean up at relatively low cost, while the higher cost firms would be allowed to continue discharge of pollutants up to the limit of their permits. Ceilings placed on the availability of permits would ensure ambient water quality would be maintained. Periodic re-bidding for permits would allow for establishment of new or expanded operations. Working from principles of risk management, Giles (1986) suggested that even the imposition of minimal effluent charges would form significant industrial incentives for industrial pollution abatement. According to this approach, industries prefer to operate in an environment of policy stability. A public policy of minimal effluent fees (e.g., per unit of pollutant discharge) would establish a policy environment incorporating economic incentives for pollution abatement. Firms would take action even at minimal fee levels to ensure avoidance of higher fees in the future. Such a scheme would allow for adjustment to the new policies by keeping fees low over the initial period, say ten years.

The charging alternatives just outlined all focus on the discharge side of industrial operations. The common criticism of charges based on effluent strength and volume is the high amount of measurement data and number of records that must be kept. Although this criticism is basically ill-founded, for any effluent control scheme requires data, available evidence (e.g., Kollar and MacAuley, 1980) suggests that input pricing may achieve the same ends. In other words, raising the price of water will lead indirectly to decreases in waste discharge. This would occur, for example, because firms would find it profitable to recirculate spent wastewaters. Some treatment of these wastewater streams would be required prior to recirculation. This point will be discussed further in the next section. The point here is that higher water prices will decrease water demands. Higher water prices on the input side of plant operations could also lead to decreases in effluent discharge as firms find it profitable to treat waste streams and to recycle them.

The measures outlined above by no means exhaust the possibilities of economic action toward demand management. Tax incentives to encourage appropriate technology, such as accelerated capital cost allowances, can help overcome the barrier of high initial investment. These must be high enough to make demand management-related technologies economically attractive over the normal industrial write-off period of two to four years. Tax credits, direct deductions from tax, can be used for encouraging technological changes promoting water demand management.

Experience to date in Canada suggests that this type of instrument is most often made for "front-end" investments in research and encourages innovation. An alternative to tax credits is tax-exempt bonds for the adoption of water-saving equipment.

Structural and Operational Techniques

As shown in Table 11, water recirculation can form an important constituent of total industrial water use, effectively "stretching" available supplies to meet current and future demands. In discussing the concept of recirculation, it is important to keep economic factors in mind, even though these factors are not the focal point here. The decision to recirculate water is most often an economic one, not one to save water per se. As Bower (1966, p. 151) observed,

the criterion used by industry in evaluating possible investments in water utilization systems is, in general, the rate of return on the investment. This is particularly true of an existing plant where possible modifications are many. . . .Water saving in industrial operations is instituted not merely to save water, and it should be noted that suboptimization, i.e., minimizing total water utilization costs, does not always yield minimum total production costs.

In general, as concerns over water quality have increased and public standards for quality have been established, recirculation has accounted for an increasingly larger proportion of gross water use. For example, analysis of trends in the use rates for U.S. manufacturing industries from 1954 to 1973 demonstrates these rates have increased over time (Tate, 1979, pp. 70–72; Postel, 1985, p. 29). Further, Bower noted (1966, p. 162) that

a . . . major response to effluent controls is the adoption or the increase of water recirculation within the plant. It is obvious that as the quantity of water intake increases, the quantity of effluent and the waste disposal costs rise correspondingly. Thus, faced with effluent charges and/or the necessity of meeting specified effluent guidelines and/or limitations on the quantity of effluent, the most general reaction by industry is to curtail the intake of water in order to reduce waste disposal costs. By recirculation, the volume of water can be reduced substantially, which in turn reduces the size and cost of effluent treatment and handling facilities.

These observations show water recirculation technology, water costs, and waste treatment are closely linked. In general, the higher the costs of water supply and the more stringent the water effluent standards or charges, the greater will be the propensity for water recirculation to occur. Table 12 and related discussion show that water costs to industry form a minute portion of total production costs. The anticipated consequences of this fact for water recirculation would be static or even declining use rates over time, much in contrast to trends observed in the United States. These predictions are borne out in Table 14, where use rates have indeed remained static or decreased between 1972 and 1981. Only the thermal power sector showed any increase in the use rate, and this was due to the start-up of a new thermal power plant in the semiarid west.

Water recycling can lead to very substantial reduction in industrial water use. Table 15, which compares theoretically possible rates of recirculation with those rates recorded in Canada, provides an example of these potential water savings. Theoretically, water intake

Table 14. Industrial Use Rates for Canada by Selected Year

Sector	1972[1]	1976[1]	1981[2]
Mineral extraction	5.94	3.59	5.31
Manufacturing	2.34	2.31	2.10
Thermal power	1.00	1.00	1.10

[1] Tate (1984, p. 89).
[2] For 1981, see Table 11.

Table 15. Impact of Maximum Feasible Water Recycling on Industrial Water Intake for Selected Industries, 1981

Industry	Potential intake reduction through recirculation[1] (%)	Canadian recorded water intake, 1981[2] (MCM)	Potential water intake with maximum recycling (MCM)
Inorganic chemicals	90.1	1377	136
Meat packing	77.3	36	8
Hydraulic cement	78.3	20	4
Petroleum refining	81.0	563	107
Beet sugar refining	44.1	21	12
Total for selected industries		2017	267

Sources: [1]Kollar and MacAuley (1980).
[2]Environment Canada (1986a).

Table 16. Sociopolitical Tools for Encouraging Industrial Water Demand Management

A. Information and technology transfer

1. Demonstration programs
2. Case study profiles
3. Technology awareness programs
4. Targeted information programs
5. Environment audit programs
6. On-site training
7. Formal training
8. Environmental accounting programs

B. Industrial support

1. Waste exchanges and brokers
2. Environmental audit, consulting and service industry development
3. Register/data base of demand management and clean process technologies
4. Environmental technology warrantee program
5. Centres of technical and marketing excellence
6. Corporate environmental awards program

C. Regulation

1. Environmental targets
2. Environmental accounting
3. Environmental defense funds
4. Withdrawal and discharge permits
5. Government program procurement and support code

Source: Brooks and Peters (1988).

could be reduced by 87% in five selected industry groups upon adoption of maximum feasible recirculation. Further, Culp et al. (1979, in Postel, 1985, p. 29) showed the use rate for all manufacturing under projected conditions could reach 17.08. Postel (1985, p. 29) stated, in using the projected rates, that

the 1985 projected rates are likely to be overestimates since compliance with pollution control requirements has lagged. But by the year 2000, the recycling rates in both the primary metals and the paper industries are likely to rise to about 12, in chemicals to 28 and in petroleum to more than 30.

Using the rate for total manufacturing, the projected water intake of 58 900 MCM (Tate, 1985, p. 44) would decrease to 3448 MCM, a substantial decline over even the 1981 intake of 10 201 MCM.

It is emphasized, however, that these very high recirculation rates in the above table are theoretical possibilities, not predictions. As stated earlier by Bower, industry will only be interested in conserving water if there is a beneficial rate of return in doing so.

In addition to installing facilities to recirculate water, changing production processes themselves may reduce water demand. For example, the switch from open hearth to basic oxygen methods of steel making reduces water use by 42% in the conversion process itself and by about 10% in producing one tonne of steel from raw materials (Tate, 1971). In addition, broad trends in industrial technology are tending to lower water demands (Tate, 1984, 1986).

Sociopolitical Techniques

A wide variety of sociopolitical measures for water demand management can be applied in the industrial area. These are summarized in Table 16 under three main categories: information and technology transfer, industrial support, and regulation (Brooks and Peters, 1988). Awareness of new technologies in the environmental area is frequently the key to their successful adoption. Direct public financial support can promote this awareness. In return for this support, the recipient company could be requested to allow close monitoring of the technology and broad distribution of the results to other industries, including competitors. Industrial support programs may also increase the acceptability of environmental measures to industry. For example, waste exchanges could assist industries in locating markets for waste and recovered products. Additional measures of this type are listed in Table 16. Finally, direct regulation is the most traditional public response to environmental problems caused by industry. However, regulation is more likely to work in controlling water quality than in adopting water demand management measures.

PROBLEMS WITH DEMAND MANAGEMENT IN INDUSTRY

While demand management concepts offer some insights into the problems of industrial water use and some possible prescriptions for action, these concepts are not cure-alls. Even with a well-functioning demand management system, significant problems would remain.

One of the most serious of these remaining problems is that of toxic substances. In reacting to the demands of society, industry has generated serious environmental problems through its generation and deposition of toxic wastes (see Muir and Sudar, 1987, for a detailed discussion of these problems). Demand management concepts in the area of waste management are based upon the idea that the environment can assimilate certain quantities of waste, and, provided that this assimilative capacity is not exceeded, the deposition of waste is a legitimate use of water. Problems arise when assimilative capacities are exceeded, and in these situations, demand management instruments can be used to ration assimilative capacity among users. In the area of toxic waste discharges, however, demand management has little potential for effectiveness. Toxic substances, quite simply, must be banned from receiving waters. In such situations, strict regulation is likely to be the most effective solution.

Additional problems arise with demand management because it will increase the cost of industrial operation. Such cost rises could affect employment and international competitiveness. However, these problems are just as severe with the use of regulatory vehicles for control. In fact, demand management could ultimately be the cheapest means of waste control because, working through a decentralized incentive system, individual plants will be in the best position to choose actions for effective pollution control.

CONSEQUENCES OF WATER DEMAND MANAGEMENT FOR THE INDUSTRIAL SECTOR

Several benefits would result from increased levels of water recycling. Industry currently uses water in excess of theoretical requirements, as demonstrated in Table 15. This implies that discharge volumes are higher than necessary. The demands by industry on both municipal water utilities and ambient water resources would decrease substantially with increased levels of recycling. Although it is probably not possible to move completely to theoretical potentials, even moderate movement would generate substantial reductions in the pressure on Canada's water resources. An additional benefit would be significant savings in energy costs and increased by-product recovery.

The best documented studies of the value of water-efficient practices and processes are found in the United States, particularly in Massachusetts. The following examples (Special Legislative Commission on Water Supply, Commonwealth of Massachusetts, 1983, in Brooks and Peters, 1988) give an indication of the potential in commercial and industrial establishments.

- A Polaroid plant in Waltham, Massachusetts, began a program in 1980 which included employee awareness, mapping of pipes, metering, retrofitting, pressure reductions, spray nozzle conversions, timers, shutoffs, process changes and recycling of cooling waters. Water use has been reduced by about 50 percent, from 527 million gallons to 278 million gallons per year. Savings have included $3,113,740 a year in water and sewer costs, $1.8 million in capital savings resulting from a treatment plant capacity reduction, $50,000 a year in pre-treatment costs, and $195,000 a year in energy costs. The one-time program cost was $550,000; annual savings, not including the one-time capital plant saving of $1.8 million, are $545,000.

- The Gillette Company in South Boston, Massachusetts, began a water conservation program in 1973 and has since expanded the program to all of its plants worldwide. The Safety Razor Division at South Boston has reduced its water use by 70 percent, saving enough water to provide for 10,000 homes. Measures included installing cooling towers for plastic molding machines, recirculating cooling water, and reusing washing water. Total water use has declined from 730 million to 156 million gallons per year. The $1.025 million program cost has resulted in $771,000 annual savings in water and sewer charges.

- A Howard Johnson's frozen food processing facility in Brockton, Massachusetts, embarked upon a conservation program in 1970. Water use has been reduced from 63.8 million to 7.4 million gallons per year. Measures included a leak detection and repair program, converting to a 4-day/40-hour work week, installing an evaporative condenser system to provide cooling for a plant ammonia refrigeration compressor, installing a compressor water recirculation system, recirculating refrigerated water for process and comfort cooling, and enacting tighter controls on equipment operating time. The $30,000 cost resulted in $93,100 annual savings.

- A Digital semi-conductor plant in Hudson, Massachusetts, instituted water conservation in 1982. The drainage system in the product rinsing area was retrofitted for a water reclamation and reuse process. Conductivity meters signal valves to divert water, depending on its quality. Only lower quality water is diverted to the plant's wastewater treatment system. Annual savings of $341,000 have been achieved from a $20,000 investment. Annual savings include $22,750 in water fees, a saving increased to $91,000 by 1984 rate hikes; $22,750 in sewer charges; $61,000 in energy costs for pumping and water heating; and $97,142 in on-site chemical treatment costs.

- The Augat electronics equipment plant in Attleboro, Massachusetts, installed flow restrictors and temperature control valves, changed wet processes, and installed a custom-designed heat recovery chiller to eliminate the need for cooling water for a solvent recovery still. The total program cost was $28,000. Water use has decreased from 16.5 million to 2.6 million gallons a year, and the wastewater treatment plant now runs only every third workday. Total annual savings equal $36,000.

Agricultural Water Demand Management

BASIC FACTS

Water withdrawal for agriculture totalled 3125 MCM in 1981 (Table 17). In contrast to the data given in the previous two chapters for industrial and municipal water uses, which are the products of detailed survey work, agricultural water use data are estimates based upon areas under irrigation and livestock censuses. For the Prairie region, where the bulk of agricultural water use occurs, the volumes are somewhat more accurate, having been calculated in detail for 1978 by the Prairie Provinces Water Board (1982, Appendix 3), but even these are estimates. Further, agricultural water uses, especially irrigation, are highly dependent on climatic conditions, and therefore may vary widely from year to year.

Water use in this sector serves two main purposes: stock watering and irrigation. The latter dominates, accounting for 88% (2765 MCM) of water withdrawal in 1981. Irrigation is centred in Alberta and Saskatchewan, which rely on irrigation to overcome water deficits in this semiarid area. These provinces also account for the highest stock-watering use, although stock watering is more evenly dispersed throughout the country. Irrigation consumes 78% of water withdrawn, making agriculture the highest consumptive water user of all economic sectors. Also, 100% of the stock-watering volumes (360 MCM) are counted here as consumptive use.

AGRICULTURAL WATER DEMAND MANAGEMENT TECHNIQUES

As in other sectors, many means of managing water demands are possible. Most of the following management techniques outlined in this section apply only to irrigation because very little research has been done for livestock.

Economic Techniques

Traditional Water Pricing

Irrigators generally face water charges that substantially underestimate the cost of bringing water to the land. In Alberta, the cost of irrigation development is subsidized about 85% by the province. In addition to artificially low prices, irrigators pay water charges based on irrigated area, not on actual water volumes used. Consequently, there is little incentive for water demand management. Various studies (e.g., Acres International, 1984) have found that the efficiency of water use in irrigation (i.e., water reaching the crop divided by total water supplied) is only about 35%.

Current Water Pricing

British Columbia, Alberta, Saskatchewan, and the two territories are the only jurisdictions in Canada that have charging systems related to agricultural water use. One must exercise caution, however, in interpreting the precise meaning of such charges.

In British Columbia, the provincial government requires payment by private users and local authorities for withdrawals of raw water for irrigation or stock-watering purposes. In turn, a local water distributor can charge back the costs of water treatment and delivery services to agricultural and other customers in the service area.

In Saskatchewan and Alberta, raw water bears no charge when used for agricultural purposes. A service charge may be applied, however, wherever storage,

Table 17. Characteristics of Agricultural Water Use, 1981 (MCM)

Region	Intake	Recir-culation	Gross water use	Consump-tion	Discharge
British Columbia	545	0	545	304	241
Prairie provinces	2 338	0	2 338	1 892	446
Ontario	148	0	148	123	25
Quebec	82	0	82	81	1
Atlantic provinces	12	0	12	12	0
Total	3 125	0	3 125	2 412	713

Source: Tate (1985).

conveyance, and administrative costs are incurred in delivering the raw water to end users. In other words, a government agency or local water authority may levy charges based on the costs of providing a service, but such charges do not include a charge for the water itself.

The annual charges related to agricultural use vary substantially from province to province. In Saskatchewan, charges based on service costs are in the order of $5.00 per cubic decametre annually for private irrigators. Stock-watering charges are about $80.00 annually (Environment Canada, 1987b). In British Columbia and Alberta, irrigation charges are based on the number of hectares irrigated. In Alberta, charges range from no charge to $44.46 per hectare. In British Columbia, charges range from $39 per hectare to about $407 per hectare. In Alberta there is no charge for stock watering, and in British Columbia the charge is $20.00 per hectare annually.

Water Pricing to Reduce Water Use

Economic measures for water demand management again centre on more realistic pricing. First, according to Robinson and Anderson (1985), the mere step of metering water use would result in a 10% to 20% decrease in demand. The effect of water charges based on use are uncertain, but most studies show that the demand curve for irrigation water is "kinked," with a steep, rapidly falling (i.e., inelastic) portion at high water price levels and a much shallower (i.e., elastic) portion at lower price levels (Craddock, 1971; Andersen and Keith, 1981). According to Craddock, the kink occurs at the $12 per acre-foot (9.75/dam^3) level ($1971). Since irrigation water prices generally fall below this level, moderate price rises could induce relatively large decreases in irrigation water use. The implication here is that water used on marginally profitable, low-valued crops would no longer be feasible with even relatively small increases in water price. In summarizing their conclusions about the effects of water price increases on irrigation, Robinson and Anderson (1985) stated:

With adequate markets for higher-valued crops, . . . (price rises) might or might not actually "save" water. This would depend upon the consumptive water requirements of the new versus the old crop mix. But at the very least, there would be a net social gain, via lower implicit subsidies, and net returns to farmers with irrigation would climb.

Taxing fertilizer and using this revenue could provide an alternative source of income. This method could also be applied to pesticides. The money obtained could be earmarked for improving water quality downstream or assisting with water efficiency programs or purchasing water-saving equipment.

Structural and Operational Techniques

A wide diversity of structural and operational techniques are available for managing the demand for irrigation water. A few of the more important include:

- lining of irrigation canals,
- use of centre pivot and wheel roll application methods,
- drip irrigation for specialty crops, and
- improved scheduling of water applications.

Studies by the Nebraska Natural Resources Commission (1985) and Howe et al. (1970) provide fairly thorough reviews of potential water-saving irrigation methods. A Canadian perspective is contained in Robinson and Anderson (1985). Potential water savings from these improvements are variable and highly dependent upon local conditions. Robinson and Anderson (1985, p. 62) estimated that existing water supplies used in irrigation could serve twice the currently irrigated acreage (Table 18).

Table 18. Potential Improvements in Irrigation Water Use Efficiency

Area of improvement	Potential productivity gain
Dryland cultural practices	15% x 40 000 ha
Water delivery systems	
Off-farm	25% x 500 000 ha
On-farm	25% x 500 000 ha
Water scheduling	25% x 500 000 ha
Water pricing	Unknown
Water metering	15% x 500 000 ha

They also caution, however, that

higher water use efficiencies in agriculture will not likely release water for other uses. Indeed, just the opposite outcome would be expected and less water would actually reach downstream users. This would occur because, through increased water use efficiency, less return flow would reach downstream users.

In short, the socio-economic benefits of higher water delivery efficiencies are largely intra-sectoral. Efficient gains by existing irrigators might also moderate the demands for further irrigation development because existing water supplies will . . . irrigate more land (or the same land more intensively).

The material presented above shows there are many structural and operational ways in which water demand management could be implemented in the agricultural sector. The fact that water-conserving methods are not used is attributable to the low value placed on water, reinforced, in this case, by well-established public policies. Most references (e.g., Howe et al., 1970; Robinson and Anderson, 1985; Brooks and Peters, 1988) show that little action toward water conservation is likely to occur without substantial increases in water price.

Most of the water use efficiency improvements in agriculture have been instituted directly by provincial (and to some degree the federal—PFRA) governments. Demand management techniques have been used to realize efficiency gains through government-financed improvements in structural works and delivery efficiencies. The price or market system has not been used as the mechanism to improve efficiency. Examples of government intervention of this type include Alberta Environment's Headworks Rehabilitation and Alberta Agriculture's delivery system rehabilitation programs in southern Alberta; Saskatchewan Water's institution of piped irrigation water systems for the Luck Lake project to improve delivery efficiencies (Canada-Saskatchewan Irrigation Development Agreement under the ERDA); and PFRA's Southwest Saskatchewan irrigation infrastructure improvement program, also under the agreement. These programs will have (and have had) major impact in improving irrigation water use efficiencies.

Sociopolitical Techniques

In some of the preceding material, water prices have been shown to play a central role in water demand management. The absence of price considerations are, in fact, a notable reason for the underdevelopment of this dimension in Canadian water management. The development of irrigated agriculture illustrates another interesting and fundamental dimension of Canadian resource policy, namely, that important water uses can develop and flourish even though they appear to use scarce resources that, in strict economic terms, would be better allocated to other uses. Thus irrigation is a good example of the public policy aspects inherent in developing water demand management as a major water management strategy. Before outlining a few of the sociopolitical techniques of demand management in agriculture, a brief digression into the development of irrigation as a response to public policy will broaden the overall discussion.

Historical Overview of Public Policy for Irrigation

The southern part of the Canadian prairie region receives less than 380 mm of precipitation annually. The major portion of streamflow in the region originates with the spring freshet of rivers that rise in the Rocky Mountains. Early in Canadian history, the region was recognized as one where agriculture and economic development would be difficult. In the drive to unify the country, Canadian governments faced the added difficulty that "natural" geographic trading patterns were oriented north-south, suggesting that the region might form a northerly extension of the earlier developed western United States.

In a successful effort to overcome the influence of physical geography, early federal governments initiated and supported development of the Canadian Pacific Railway. The arrangements with the private C.P.R. company included extensive land transfers to the company, which then began to sponsor settlement into the region. Recognizing the need for strong communities and agricultural settlement of this large area, public and private agencies viewed the provision of water supplies as a top priority. Initially the federal government and later the provincial governments, notably Alberta, created large irrigation districts with dams to hold back much of the spring freshet, distribution canals, and related infrastructure.

Today, irrigated agriculture in the region is big business. Crops include both grains, which are also grown in nonirrigated areas, and specialty crops, which find markets in the urban areas. Irrigation provides two major benefits: protection from the vagaries of climate and significantly increased productivity. Thus irrigation has become a significant part of the regional economy, arising from a combination of political and economic conditions. The fact that this policy continues even today is demonstrated by a main plank in the recent election platform of the Saskatchewan provincial government ("Water on the Brain," Saskatoon Star Phoenix, June 1986).

This brief history of irrigation development in western Canada shows how public policies unrelated to water resources can have large impacts on water management. For irrigation, large public subsidies, often in excess of 90% of development costs, have created an industry based upon the use of high volumes of water in a semiarid area. This fact is of central importance in the region's water management and for demand management in particular, for it conditions the range of options that can be used to address the issues of high consumptive water use and competition for existing supplies by many different types of users.

Current Sociopolitical Techniques

Public education is probably the most valuable approach to developing demand management programs in the agricultural sector. The objective here would be to educate the farmers on the alternative forms of water-efficient irrigation systems technology as well as on the crops most adaptable to using less water. A number of approaches have been developed to improve management practices in the use of irrigation water (see, for example, International Garrison Diversion Study Board, 1975). These approaches, which can usually be offered through agricultural extension services, aim at determining the optimal pattern of application for irrigation water, given prevailing climatic conditions.

PROBLEMS WITH DEMAND MANAGEMENT IN AGRICULTURE

A variety of considerations stand in the way of establishing effective water demand management programs in agriculture. These include technical, economic, and political constraints. The examples given below illustrate these problems, but, of course, are not exhaustive in their coverage of issues.

On the technical front, much of the irrigation infrastructure in Canada is outdated. Many areas still utilize gravity and field flood methods of water application. The inefficiencies inherent in these methods can be overcome only with extensive rehabilitative efforts. In many instances, the costs involved are high and well beyond the means of the average farmer. In many cases, the impact of increased costs is compounded by the lack of large product markets. In some areas, irrigated land is being abandoned and new land is not being taken up due to the lack of economic benefits. Thus, without the adoption of new technologies, demand management will prove difficult.

A further technological issue relates to metering. In most cases, water delivered to the field is not measured, and prices are set based on irrigated area. Without a link between price and water volume, effective demand management is not possible.

Economically, the prices for irrigation water in Canada fail to recover water development costs, and thus come nowhere close to reflecting the value of the resources devoted to its supply. Without major reforms to this system, irrigation will remain as one of the most inefficient of water uses.

On the sociopolitical front, two factors spell difficulty for establishing viable agricultural water demand management programs. First, in dry areas, irrigation is often seen as a panacea for agricultural problems. Income stability could be achieved if only an assured source of water were available. This approach leads to an inexorable expansion of irrigated areas, even at the expense of competing water uses. Second, some public agencies, which often achieve significant powers, have developed with the primary focus of developing new irrigation areas. Although the claim is made that developments are in response to public pressures, these agencies are, in reality, advocates of irrigation expansion. In the face of the power exerted by these agencies, water demand management efforts can often be stalled.

CONSEQUENCES OF WATER DEMAND MANAGEMENT FOR THE AGRICULTURAL SECTOR

Expansion of irrigated areas in the West is probably inevitable, given the regional development objectives of governments. Water demand management principles are not in conflict with such expansions, in spite of the foregoing critique of past and current practices. In fact, if interpreted correctly, demand management will assist in such developments.

Effective demand management will stretch available water supplies to meet expanded demands. Also, developing new areas efficiently will allow available resources to cover as many projects as possible. Thus, a demand management approach to irrigation development will assure that water use will be controlled to meet demands effectively and to minimize wastage. In semi-arid areas, this will permit reallocation of extra supplies to other water uses.

Water Demand Management and Nonwithdrawal Uses

Water uses by withdrawal sectors are spatially discrete, with water use characteristics being relatively easy to measure. In contrast, nonwithdrawal uses, or instream use, are difficult to measure because of the absence of consistent measurement units. Examples of nonwithdrawal use include navigation, recreation (e.g., swimming, boating, fishing), hydroelectric generation, conservation for wildlife, and commercial fishing.

Nonwithdrawal uses take advantage of one or a number of characteristics of water as it occurs in the natural environment. Many of these uses, however, are affected by regulated altered flow (e.g., dams) as well as by the discharges of by-products from withdrawal uses (e.g., polluting substances). Thus, demand management, which tends toward increasing water conservation and sustainable development, is beneficial for many nonwithdrawal sector uses. This chapter focuses on two topics. The first illustrates the value of water to nonwithdrawal use. The second provides an example of how one major type of nonwithdrawal use, recreation, is measured in value as well as the effects of water demand management upon it.

VALUE OF WATER FOR NONWITHDRAWAL USES

Although it is generally underpriced, this does not mean that water has no value. Indeed, in a limited number of cases, as in the case of severe water shortage, water has a very high value. Even flood waters have value in renewing soil nutrients and washing away wastes.

Table 19. Selected Estimates of the Economic Value of Water, Canada, 1981

Use	Average net willingness to pay ($/1000 m^3)		Total willingness to pay ($ million)	
	Low	High	Low	High
Municipal	100	2430	288	6968
Irrigation	0	36	0	109
Thermal power	9	9	169	169
Industrial uses				
Paper	87	87	251	251
Chemical	76	76	217	217
Primary metals	16	43	44	118
Petroleum	19	19	10	10
Food and beverages	124	124	53	53
Subtotal			575	649
Total withdrawal uses			1 032	7 895
Hydroelectricity			4 226	6 553
Waste assimilation	1	4	645	2 272
Sports fishing	20	74	1 677	6 309
Seaway navigation			0	0
Freshwater fishery			0	0
Total instream			6 548	15 134
Grand total			7 580	23 029

Source: Based on Muller (1985, p. 92), with slight revision to correct arithmetic errors.

But we do not have to resort to extremes to show that substantial values attach to water, despite the fact that such values often prove hard to measure. Economists consider water as an input to production, and accordingly as part of a firm's production function. In theory, analysis of the production function will reveal the value of the input, in this case water, to the value of the firm's production. The problem with this approach when considering water arises as a result of water's cost-free nature. Thus, use of a production function approach to water valuation will consistently understate the value of water.

A second approach to water valuation is to assume that many productive enterprises, including all of the largest ones, would not be able to operate without water, and therefore that all production value is attributable to water. Such an approach, of course, is invalid since it acknowledges neither other factors of production (e.g., labour, capital) nor the substitution possibilities for lowering water demand.

Wollman (1962) and Young and Gray (1972) pioneered efforts to build an economic theory of water values. Based upon microeconomic and other considerations, they suggested that the value of water in any use is the value of the "next-best" alternative to that use. For example, the next-best alternative to new water intake for an industrial plant might be installation of a recirculation system. Accordingly, the value of water for intake at a specific site would be set at the cost of a recirculation system. A study of water values published in the *Canada Water Year Book, 1981-82* (Environment Canada, 1983) used this approach to generate an aggregate value of water in Canada between $10 billion and $20 billion in 1981. Gibbons (1986) and Muller (1985) presented studies based upon this approach also. For example, Muller (1985, p. 48) stated that

we interpret the value of water in a given use as the benefit users receive from being able to use water from the given resource rather than from the next best alternative source. In principle this alternative should be specified in the context of a specific project or policy which is being analyzed.

Muller proceeded to estimate the value of water in various economic sectors (Table 19), qualifying these estimates as follows:

A weakness of the following estimates is that they are not based on (specific project) . . . analysis. In general, the analysis we consider is the complete withdrawal of water from its current use. (Muller, 1985, p. 48.)

This table establishes that nonwithdrawal uses have considerable economic value. Yet, institutions are not equipped to use this information to reallocate available supplies to the higher valued users. Legal doctrines such as riparian rights or prior appropriation take precedence over economic considerations in current water management, resulting in inefficient water allocation among users as well as the failure of Canadians (i.e., the resources owners) to realize the maximum social benefit from the resource.

RECREATIONAL WATER USE

Many recreational activities are either totally or partially reliant upon water. The two most important characteristics of water for recreation purposes are high quality and flow stability. These two characteristics may affect recreation either directly, as in the case of body-contact sports (e.g., through poor quality), or indirectly, through impacts on fish or wildlife availability (e.g., through low flows or poor quality).

Given the wide variety of requirements of different uses, this relationship is complex, and the requirements for different recreation uses may, in fact, compete under certain circumstances. For example, increasing nutrients can enhance sport fisheries up to a point, but will reduce desirability for body-contact sports. At Lake Diefenbaker, for example, high levels of nutrients were good for sport fishing, but undesirable for beach-oriented recreation (R.D. Bjonback, 1989, Water Planning and Management Branch, Inland Waters Directorate, Regina, Saskatchewan, pers. com.).

Table 20. Selected Measures of Recreational Water Use

Use	Year	Measure	Measurement
Sport fishing	1980	User-days	85.3 million[1]
Swimming	1973	Number of provincial parks	3662
	1969	% of population participating	442
Canoeing	1972	% of population participating	102
Hunting	1971	Number of hunting permits	405 600[2]
Boating	1980	Number of households owning boats	1.2 million[1]

[1]Muller (1985, p. 81).
[2]Environment Canada (1975, pp. 157–159).

Measuring Recreational Water Use

The recreational activities of millions of Canadians focus on waterways for activities such as boating, swimming, fishing, and sightseeing. Since direct measurements of water values in these uses cannot be taken, measurement techniques such as fishing-days, boat or camping equipment ownership, areas of beach, and even distance must be used to gain a quantitative perspective on recreational water use. Table 20 illustrates a few such measures.

This table illustrates two major points. First, it is not possible to measure water use in recreation in common units among uses. This measurement problem has, perhaps, contributed to the relative lack of understanding and the past abuse of recreationally oriented water resources. Second, recreation is an exceedingly valuable water use, with many Canadians taking advantage of water-based recreational opportunities offered by the country's water resources (Environment Canada, 1975, pp. 157–159). Muller (see above, Table 19) places an annual value on sports fishing alone of between $1.6 billion and $6.3 billion.

Water Demand Management and Recreation

The impacts on the quantity and quality of the water for recreation often depend on the actions by the water withdrawal use sectors. The reverse situation, however, does not hold since recreation usually has little impact on water withdrawal activities. For this reason, water demand management for recreational use should be viewed in the context of effects. The issue here is not one of investigating techniques for demand management, but rather as one of examining how the impacts of demand management in other sectors affect recreational water use.

Accordingly, the main observation of this chapter can be stated fairly succinctly. If demand management can significantly reduce the demand for water by the withdrawal sectors, or even more importantly, lower pollution loadings through new policies such as more rational water pricing, recreational opportunities will be enhanced. It also follows from the demand management principles discussed throughout this paper that the recreational use should bear the full cost of providing the recreational opportunities.

International Experiences in Water Demand Management

Water demand management techniques of various types have been used in many countries with varying degrees of success. This chapter examines selected overseas experiences with demand management in the municipal, industrial, and agricultural sectors. This review is limited to the economically developed nations and is based on reports by the OECD (1987a, 1987b). Although some international research, particularly that from the United States, has been referred to in earlier chapters, this chapter takes a more in-depth view of experiences from other nations.

The overall conclusions drawn by the OECD support the position put forth in this paper that efficient water pricing is advantageous for water management. For example, the OECD (1987b, p. 16) stated that

water management authorities . . . should consider the use of economically efficient price mechanisms, in all water uses, based on the objective of marginal cost pricing, as part of the overall approach to water management.

Such mechanisms . . . should lead to more efficient use of the water resource.

. . . in the absence of metering (for domestic, industrial and agricultural uses), only a flat rate pricing system could be used which would act as a disincentive to efficient water use.

MUNICIPAL SECTOR

International studies show that water usage per capita varies substantially (Table 2). Much of this variation is accounted for by differences in domestic water use per capita, the averages of which vary between about 140 litres per capita per day (lpcd) in some of the northern European countries to highs of over 250 lpcd in North America and Australia. Variations in climatic conditions and living standards were put forth as the principal variables explaining these differences. As shown in Chapter 4, the price of water services also has a measurable influence on per capita water use as well.

Pricing structures for water across the economically developed nations show the same wide variations as they do for Canada. International studies compiled by the OECD (1987b) demonstrate the prevalence in several countries (e.g., the United Kingdom, Australia) of flat rate pricing and the same problems with these rate structures as found in Canada. Declining block rate structures are also common, with the OECD opposing their use on economic efficiency grounds. Constant unit charges are less common and are criticized for not reflecting marginal costs of system operation and for giving rise to uncertain revenue streams. In the latter regard, the OECD report (1987b, p. 42) stated that

the revenue of the (water) authority . . . is at its most uncertain in that virtually all of the costs 'appear' in the commodity charge. An unanticipated industrial recession or an unexpectedly wet summer could mean serious financial losses.

The OECD (1987b) report found that increasing block rates were becoming more common, at least in many developing countries. This finding is thought to be due to equity considerations as the rich in these countries use more water than the poorer citizens. Further, several developed countries (Belgium, Greece, Italy, Japan, Portugal, and Switzerland) are also using increasing block rates.

International experience also shows the importance of metering in developing efficient water pricing arrangements. The OECD found that metering was one of the most effective measures for water conservation. In all areas of the world, implementation of metering, combined with volume-based charging, showed significant reductions in the amount of water used. Some of the results are listed below (OECD, 1987b, p.111):

Gothenberg, Sweden 33%
Philadelphia, USA 45%
Moss City, Norway 41%
Toowoomba, Australia 41%
Copenhagen, Denmark 20%

On the basis of these internationally derived figures, combined with the data of Table 10, it appears that metering is effective in reducing municipal water use.

The economic viability of metering is more uncertain. Hanke (1982, in OECD, 1987b, p. 107) concluded that the benefits of metering outweighed the costs on the basis of his study in Perth, Australia. On the other hand, the U.K. Department of the Environment (OECD, 1987b, p.108) found that the metering decision was not economically viable, although the study acknowledged the need for further investigation. In a study for Environment Canada (CWWA, 1989), the Canadian Water and Wastewater Association found that the economic viability of metering depended upon local conditions and designed a benefit-cost framework for evaluating the metering decision. The literature reviewed in this report shows that metering generally had a benefit-cost ratio greater than one, indicating economic advantages. As noted, however, the result of benefit-cost analysis will vary among municipalities. Thus, metering passes the technical test of an effective water demand management measure. Its economic viability is less certain and assessments should be conducted at the local level.

International experience with dual water systems shows that such systems can be significant in water demand management. Substitution of nonpotable water can be undertaken through (1) a dual-supply piped system operated by a local water undertaking, (2) rainwater collected from roofs, and (3) recycled water within the home.

Examples of dual-supply systems serving domestic purposes are known in Hong Kong, Japan, Singapore, and California. Proposed developments such as in Tarif, Saudi Arabia, plan that two-thirds of the year 2020's demand of 185 000 m^3/day will be supplied by nonpotable water in a completely new dual system. All toilet flushing and garden watering, as well as public parks irrigation, street flushing, and fire fighting, will be supplied in this way.

With respect to rainwater collection for domestic purposes, the South West Water Authority of the United Kingdom has estimated that nonpotable household consumption was 100 lpcd and that a tank would have to store 10 600 litres in order to cover an average household's needs over a 40-day period without rainfall. Such a tank, weighing 12 tonnes when full, would have to be placed at ground level. A pump and separate plumbing system would be required to feed the toilet cistern and nonpotable taps. It was found that a capital cost of 168 million pounds would defer new conventional sources only until 1990. Despite the continuing benefits (in deferring the next alternative supply), the scheme was found to be uneconomic.

Residential recycling systems have been subject to experimentation, but it remains to be seen whether they are feasible in terms of cost as well as other problems such as possible health hazards. In two experiments conducted in the United States primarily concerned with conventional toilet cisterns, total in-house use fell by 22% and 26%. Even though these results indicate significant reductions in water demand, they require large capital outlays as well as accommodations for certain health hazards (Rump, 1978).

In the area of education, information, and public relations, the general consensus is that public education is an important dimension of municipal water demand management. In Japan, the financial motivation for water saving at home has been stressed, but it is recognized that the net financial advantages of adopting water-saving appliances may not necessarily always be large. This makes it more difficult to implement conservation measures, and public education programs can help bridge this gap. The most wide-ranging and expensive program in place to date is found in California, where conservation measures have been made necessary because of scarce water resources.

INDUSTRIAL SECTOR

Chapter 5 addressed two major issues of industrial water demand management: economic instruments for pollution control and the issue of technological change. The following brief discussion of international experiences is limited to considering these two issues.

As in Canada, the public strategy most frequently used internationally for pollution control is still regulation, supported by varying forms of financial incentives. All developed countries have established ambient and/or waste stream quality regulations. Often, part of the regulation process includes requiring the use of certain levels of technology in industrial abatement efforts. For example, Sweden requires the use of "best available technology" in new or altered industrial plants. The OECD (1987a, p. 40) concluded that "standards/permit systems will (likely) remain the senior partner in effluent control."

On the other hand, the OECD has conducted a substantial number of investigations of economic methods for effluent quality control. These studies found that, when used as adjuncts to effluent regulations and standards, effluent discharge fees or marketable discharge permits can be effective pollution abatement measures. For example, Bressers (1983, in OECD, 1984) used statistical analysis to study the relationships between charge levels, standards, and water quality improvement in the Netherlands. The study showed that there was a strong correlation between charge levels and the reduction of organic pollution. A substantial number of water board officials also ranked the effectiveness of charges as "very great" or "great."

The United States established a system of tradable discharge certificates in the air quality field in conjunction with conventional effluent standards in the mid-1970s. This system allows new waste discharges in an area only under permit, meaning that any new discharges must be offset by cutbacks at existing plants. Between 1976 and 1983, some 2000 offset transactions took place, establishing the viability of this marketlike instrument. The OECD researchers (1984, p. 9) observed that

since the economic incentives in the U.S. were developed after the physically oriented regulations were in place, any trade, since it is voluntary, has to have provided cost savings and profit for those making the transactions. The benefits are due to economic instruments alone. Moreover, air quality has increased in every offset transaction.

Studies in Germany (Erwingmann, 1984) found that a new effluent charge law was the main reason for pollution control investment in one-third of the cases reviewed. Also, some 20% of the interviewed municipalities had accelerated their pollution abatement plans because of the new effluent charges, while one-third of the municipalities had undertaken an upgrading of their facilities in response to the charges. What is more, these responses took place at very modest charge levels, estimated at under six dollars per capita annually.

According to the OECD (1984, p. 9), the revenue-raising dimension of effluent fees should not be overlooked. Even at quite low charge levels per unit, substantial revenues can be raised. In France, the estimated five-year revenue is $329 million, and in the Netherlands, $294 million. These amounts, if turned back into pollution control facilities, can lead to significant improvements in water quality.

The OECD studies also show that using economic incentives for pollution control is 10% to 60% cheaper than using physical-regulatory alternatives. The magnitude of the benefits depends on the ability to exploit efficient alternatives, the availability of trading options, and the stringency of the standards to be met. In the latter regard, savings decline sharply as the water quality standards increase. However, in view of the multi-billion-dollar costs involved, even modest savings of 25% are worth pursuing.

Thus, as concluded in Chapter 5, effluent charges, combined with publicly set regulations, can lead to substantial reductions in pollution loadings, reductions in enforcement costs, and increases in revenue generation, which can then be turned back into new abatement facilities. In the long run, they also offer incentives for technological change, in that the short-term efficiency gains are magnified because economic instruments encourage a faster pace of innovation designed to reduce costs or to encourage the conservation of environmental quality. Some technological change, however, can be mandated by public fiat. As noted earlier, in Sweden, new or upgraded industrial plants are required to incorporate "best available technology" for pollution control. Falkenmark (1977) attributes a halving of industrial water demand to this pollution control measure. In Japan, industrial waste discharge is regulated by the Water Pollution Control Act of 1971. This act imposed stringent quality regulations on industry disposing of effluent to municipal sewerage systems or directly to receiving waters. As a result, many factories introduced cascade and recycling systems (Tamai,1980, in OECD, 1987a). Gross industrial water use in Japan leveled off in 1974 and freshwater intake began to decline in the same year. In the succeeding 7 years, gross water use rose by only 15%, while freshwater intake fell by 15%.

With regard to industry, therefore, the principal conclusion accords well with one of the overall findings of this paper, namely, that economic instruments in industrial water management show substantial positive effects when combined with more traditional regulatory approaches.

AGRICULTURAL SECTOR

Irrigated agriculture is by far the largest user of water in a significant number of OECD member states, whether measured through withdrawals or consumptive use. In other countries (generally in northern and central Europe), irrigation is relatively unimportant overall. Water requirements for farm animals are generally a relatively small part of total agricultural use. Largely for this reason, less information is available for this sector than for the municipal and industrial sectors.

As in Canada, irrigation water has been heavily subsidized in all developed countries from the viewpoints of both the system development and annual operating and maintenance costs. A variety of charging systems is found within the industrial countries.

In Australia, most types of pricing schedules can be found, ranging from traditional flat rates to commodity charges on both a declining and an increasing block rate basis. At the very least, these charges are set to recover the overseeing authority's administration costs. Less frequently, they are set to recover some or all of the current operating and maintenance costs of the management and delivery system, in addition to administrative costs. Rarely have charges included resource depletion costs or capital costs. A rough rule of thumb in Australia has been that revenue from charges covers about one-third of the full resource cost (Department of Resources and Energy, 1983 , in OECD, 1987a).

In the United States, about 80% of the irrigation water provided by federal projects is subsidized from the public purse. Most of the contracts embodying these charges are long-standing and cannot be easily revised or renegotiated to increase charges. Water charges in both the publicly and the privately supplied sectors are based on irrigated area, not volume used. Thus, as in Canada, irrigated agriculture is highly subsidized, with the resultant water use inefficiencies.

Japan uses Land Improvements Associations (which are organizations of farmers) to administer and supervise irrigation projects. The central government subsidizes 55% to 60% of the capital costs, and the associations maintain and operate the systems. Associations collect dues from members in proportion to the areas irrigated, and there does not appear to be any volumetric charging (OECD, 1987b).

In conclusion, irrigation internationally still experiences heavy subsidization, which discourages efficient water management. In a number of countries, financial aids are used to induce water use efficiency in irrigation. In Spain, various financial incentives and loans cover 25% to 50% of the cost of appropriate infrastructure works in Valencia and the Canary Islands (OECD, 1987b), and in California, tax credits have been provided to encourage use of water-efficient irrigation equipment.

Toward a Water Demand Management Program for Canada

The Federal Water Policy (Environment Canada, 1987a) places considerable emphasis on water demand management as a major new direction for managing Canada's water resources. With its emphasis on realistic water pricing, public awareness, and science leadership, the policy has set the stage for significant revisions to traditional approaches to water management. The next major task is to fill in the details required to make a policy into a major program.

This chapter, based upon work done by Brooks and Peters (1987a) and Kreutzwiser and Feagan (1987) and augmented by the author's own research and experience, is a preliminary attempt to specify the components of an effective water demand management program. The aim of this program would be to develop water demand management to the stage where it is an equal partner with water quantity and quality in managing Canada's water resources. Major components of the strategy are highlighted in a general overview, followed by more specific strategies for the major water using groups. The final part of this chapter identifies the research and data needs to support water demand management.

This chapter attempts to be reasonably comprehensive in scope, as opposed to being completely pragmatic in the context of today's policy milieu. Most of the individual strategies have been tried and found successful in specific areas. In many cases, however, their more general applicability requires further investigation.

GENERAL COMPONENTS OF THE STRATEGY

General strategic components establish the background conditions and policy environment to encourage water demand management. Below is a brief description of the more important components of the strategy.

One of the main points to emerge from this paper is the need for **improved water pricing practices**. The term "water demand management" itself implies the centrality of pricing in influencing the use of water. Each of the water use-oriented chapters has stressed that pricing practices influence not only the volume of water demanded in an activity, but also the quantity of waste ultimately discharged. The conclusion to be drawn is that water-pricing practices that reflect the value of the resource are the necessary prerequisites to any serious attempt at building a water demand management strategy. If a move toward improved and realistic water pricing is taken, most of the remaining elements of the strategy will follow. If such a move is not taken, little can be done to bring the other elements of the strategy into play, simply because the required incentives will not exist. Thus, much of the entire strategy outlined here assumes a willingness to improve water-pricing practices to reflect a more accurate value of the resource, in ways outlined by Hirschleifer et al. (1960), Hanke (1978), McNeill (1988), and in Chapter 4 of this paper.

Any major field of resource management relies upon **comprehensive research and data collection programs.** From the material presented earlier, a number of research directions can be identified for development or strengthening. These increased efforts fall into three areas: analytical, technical, and socioeconomic research. Within each of these areas, several directions need to be explored, requiring cooperation by government, industry, and universities. A preliminary prospectus for this research effort will be presented.

Pricing information and support programs are necessary to facilitate the exchange of information in two main areas: the use and effectiveness of alternative pricing systems, and applied studies of demand management experiences in various sectors and situations. As shown throughout this paper, considerable information is available on the theory of water pricing, and there is a fair degree of agreement that the application of this theory will lead to water-pricing practices that reflect the value of the resource. Analysis of alternative pricing procedures will help in determining which ones are most suited to given situations. The focus here would be upon developing practical means to enable society to collect the economic rent from the resource, which is now accruing implicitly to self-supplied users. This procedure would be analogous to existing methods of collecting royalties from petroleum producers and stumpage fees from forestry companies.

Considerable controversy still surrounds the issue of economic incentives for pollution control. Many research results imply that discharge fees would be effective in reducing waste loadings. However, due to a series of relatively uninformed statements in the past by environmental managers and groups, the perception has emerged that effluent fees constitute licenses to pollute. Such licenses are viewed as unsatisfactory public policy responses. However, as noted in Chapter 5, the originators of these statements forget that any form of legal fiat, for example effluent standards, is in effect a license to pollute. The result of this particular controversy is that many managers completely dismiss the concept of effluent charges in pollution control. On the other hand, there is strong evidence that input pricing could achieve the same ends. The establishment of an effective system of incentives for pollution control exemplifies the type of subject that could be covered in a pricing information and support program. The problem of toxic effluents is one that could probably not be dealt with through the effluent charging methods suggested here, and should be dealt with through strengthened antidumping regulations.

Other required information would be case studies of Canadian utilities that have altered pricing systems toward demand management, including peak demand reduction. This would permit compilation of a range of situation-specific experiences to be used by municipalities or firms considering the employment of water demand management measures. In addition, surveys are required of pricing practices across the country to permit firms and utilities to place their own practices into a broader perspective. Studies of water charges to industry, power companies, and agriculture, such as done by Environment Canada (1986a, 1986b, 1986c), are necessary and should be continued and expanded upon in other sectors. Preliminary evidence indicates these types of studies result in provinces moving their water charges toward the high end of the national range as they become aware of experiences in other jurisdictions.

In the municipal area, work by Environment Canada staff for the Canadian Council of Resource and Environment Ministers (Tate, 1989) and by Fortin and Tate (1985) helps in making information available about water rate structures and retail water prices in Canadian municipalities. During the period of changeover to reformed water-pricing systems, support programs, including financial assistance to meet revenue shortfalls and to install universal metering, may be required.

As already noted, self-supplied water users may be licensed by individual provinces. Some provinces also license municipal water usage. In effect, license fees attempt to capture for society in general some of the economic rent that now accrues to private firms from having an assured source of water. To make licensing more effective, model water-licensing arrangements would be beneficial. Such model licenses would be based on the various provincial and federal laws, regulations, and other institutional measures. If adopted, they would lead to both revenue generation and more effective management. This task would begin by surveying existing water-licensing arrangements, both in Canada and elsewhere, and proceed to the development of idealized arrangements.

As noted in Chapter 2, the issue of equity in the face of rising water prices would also form a component of a pricing information and supply program. This component would focus on the distributional impacts and benefits of instituting pricing systems. One of the myths that needs to be addressed is that low-income groups are worse off with water pricing systems than they are with general funding and flat rates. The opposite is almost always the case, as owners of large suburban houses with lawns are usually subsidized significantly under flat rate pricing schemes. Such evidence on distributional impacts needs to be identified as part of the effort to promote the equity advantages of water pricing.

Movement towards increased water demand management offers a wide variety of opportunities for the development of new technologies. To promote these opportunities, a **venture capital program** could be established to provide low interest funding for the development of water-conserving products and practices. Such a program would help overcome the capital barriers between the research and development phase and the commercialization phase in the development of new techniques.

To achieve recognition of the importance of water demand management and conservation, efforts could also be directed to **promoting a recognized water conservation industry.** Many firms currently develop water-conserving products, but no recognition exists of this capability. The development of a new association of manufacturers, consultants, and contracting firms dealing with water-efficient technologies would provide a higher public profile for these efforts. Precedents for such an association can be found in the Conservation and Renewable Energy Industry Council, which aims at the promotion of energy conservation.

One main theme developed throughout this paper is the importance of **public education** in establishing water demand management as an integral approach to managing water resources. Currently, public education efforts are usually made during times of water supply crises. In Madison, Wisconsin, financial problems relating to the need for water system expansion to meet increasing peak-day water demands triggered a public awareness program that included movable displays, school talks and films, tips for lawn watering attached to outside taps, bus posters, billboard displays, radio and television commercials, and information brochures (Deibert, 1980). The program obviated the need for significant capital expenditures, thereby releasing public funds for other purposes.

Gilbert (1980, p. 46) suggested that awareness programs initiated during crisis periods may be beneficial over the long term as public support increases for legislation on conservation and reuse, improvements to water systems, and ground-water management. In a more formal sense, efforts by the National Survival Institute (1985) to develop public school curriculum materials on water conservation are aimed at initiating long-term changes in awareness and attitudes. At a more advanced level, one potentially important measure would be the introduction of courses or segments of courses on water-efficient design in engineering and architecture schools. This would promote changes in design approaches for the future.

MUNICIPAL COMPONENTS OF THE STRATEGY

Many actions can be taken by municipal officials to encourage water demand management. Some of these relate to improvements in the ways utilities are run, while others relate to direct intervention in the way water is used. Projects, information, techniques, and programs required to support water demand management are presented below.

The theory of effective water pricing needs to be interpreted for practical use. One essential step in this process is the preparation of a **comprehensive water rate manual** tailored for Canadian conditions. This would include sections on theory, water utility accounting, cost distribution to various classes of customers, rate-structuring techniques, and special adaptations to smaller utilities. These sections should be supported by one or more examples followed throughout the manual. The AWWA water rates manual (1983) provides a good starting point for developing a Canadian manual, with appropriate modifications to meet Canadian conditions and to incorporate a better theoretical base. The principal advantage of such a manual would be the gradual adoption of a common set of practices across Canada.

As shown in this paper, a wide variety of methods exists for controlling water demands. To facilitate diffusion of these methods, a **compendium of water demand management techniques** should be prepared and maintained. This compendium would contain all the information required to institute water demand management as an alternative strategy to supply management in municipalities, including models for analyzing and projecting water demands, a catalogue of water-efficient products and techniques, and selected programs for managing water demands. The catalogue of water-efficient technologies prepared by the Rocky Mountain Institute (Brooks and Peters, 1988, Appendix A) illustrates some types of materials required for such a compendium.

A **water demand management training program** for the managers and operators of municipal water utilities forms an integral part of a water demand management strategy. A training program would focus on sensitizing managers and operators to consider demand pattern alterations as part of their search for least-cost solutions to utility management and operation (including expansion). In other words, such a program would build an awareness of demand management alternatives. These concepts could be included in current training programs for water supply and waste treatment staff.

In addition to work at the conceptual level, many positive steps can be taken at the operational and standard-setting levels. These form a blend of structural, operational, and sociopolitical actions. **National product standards and information** are fundamental components in establishing a broadly based water demand management program, in a way analogous to programs in the energy field. The standards would consist of national protocols for measuring water use by fixtures and appliances under controlled conditions. The information component would concentrate on labeling, product catalogues, and other consumer-oriented product data. Establishment of this program element would fit best under the umbrella of an existing body, such as the Canadian Standards Association.

Building codes establish the standards within which new construction and building renovation take place. Since the water infrastructure of the building is an integral part of the construction process, **model building codes** could play an important role in managing future water demands. These codes would recommend ideal building and plumbing procedures to achieve water efficiency in homes, offices, and other buildings. The starting point for developing such models would be codes already in use in other countries and selection of those best suited to Canada. Some related federal programs already in place, such as the R-2000 home insulation program, could be modified to include water-efficient appliances. As mentioned earlier in this paper, Postel (1985, p. 45) showed that the average home-owner could save about $100 per year in energy costs through the use of water-efficient hot water appliances. This example demonstrates the close relationship between water and energy efficiency. The adoption of model building codes for new buildings financially supported by the federal or provincial governments presents an additional means of establishing water-efficient buildings.

Related to the establishment of model building codes is the design and application of **minimum water efficiency standards.** This would ensure the use of water-efficient appliances and fixtures in the future, much in the same manner as auto efficiency was mandated following the energy crises of the 1970s. Establishing such standards is likely a long-term undertaking, since they would require legal sanction and a strong commitment to enforcement. Also, federal-provincial agreements would be needed to put such a program in place.

To promote and effect a transition to water demand management entails certain costs to water users. Incentives such as **publicly funded financial assistance programs**, targeted to builders and developers, would encourage the installation of water-efficient fixtures and appliances. Assistance could take the form of low-interest grants or loans, or rebates for each piece of water-efficient equipment installed. This type of program has been tried with some success in the Regional Municipality of Waterloo, Ontario. An alternative to this type of program would be the provision of tax credits for construction projects incorporating water-efficient techniques. These types of financial assistance programs tend to be expensive and probably should not be initiated until less expensive alternatives are evaluated.

Water loss through leakage and other means is often quite high, resulting in excessive energy, chemical, and maintenance costs. Also, lack of knowledge or awareness of water use problems and the potential economic payoffs from conservation is a significant constraint to water management. One option for increasing awareness is the development of **systematic water audit programs**, particularly in commercial buildings. Audit programs measure the water use in buildings under controlled conditions, in effect accounting for water flows, including leakage and other forms of waste. The savings in water-heating costs alone would probably pay for the audits, and certainly would result in water demand reduction.

Finally, the education function is highly important in diffusing information on water demand management and conservation. This implies establishment of **information and technology transfer programs** aimed at building managers and landlords. The objective here would be to impart basic information to owners and managers of commercial buildings about water-efficient equipment and techniques.

INDUSTRIAL COMPONENTS OF THE STRATEGY

Many of the initiatives outlined for municipal water demand management, particularly those in the education and inventory areas, are also appropriate for industry. It is likely, however, that a much greater effort would be required for industry since this sector is composed of many diverse subcomponents, each requiring a somewhat specialized effort. Also, the largely private nature of industrial activities would mean more attention would have to be given to economic impacts, competition, international implications, and the like.

Some of the program and strategic elements outlined earlier for municipalities apply, sometimes with modifications, to industry. The following elements are thought to be more suitable to industry.

An **annual compendium of water-efficient products and practices** would contain information on the latest available industrial techniques for water demand management. Included here would also be documented case studies of water conservation measures applied to specific conditions. Several examples of such case studies were given in Chapter 5 of this paper. The inclusion of methods for simultaneously conserving water and energy would be especially important here.

To disseminate knowledge about water management techniques available to industry, a **water bus,** modeled on the vehicles successfully used in the energy field by the Department of Energy, Mines and Resources, should be considered. These vans or small buses would incorporate equipment to perform simple water audits and to make cost-effective calculations, and would travel to small- and medium-sized plants. They would compensate partially for the enhanced capability of larger operations to carry out their own studies. The vehicles could also demonstrate selected water-efficient equipment, but would not get involved in actual retrofits. Incorporating educational and technology transfer information, the bus personnel would be equipped to provide advice on additional information sources and retrofit financing.

Conversion to water demand management by established industries will involve costs for such things as new or altered equipment and changes in operating procedures. For this reason, and consistent with a similar initiative suggested for municipalities, **financial assistance programs** for projects related to demand reduction would provide incentives for industry to adopt demand management approaches. Assistance could take several alternative forms, such as low interest or guaranteed loans or accelerated capital cost allowances. This assistance would help firms adjust to higher water prices, particularly where changes in production processes are required to reduce water use or improve water effluent quality. Careful controls would have to be placed on such financial assistance. Where price increases were announced well in advance, no specific assistance should be given. But in some cases where existing plants would be unable to adjust to new pricing regimes on their own, financial assistance could be justified.

AGRICULTURAL COMPONENTS OF THE STRATEGY

Assuming more appropriate pricing is established for water use in the agricultural sector, two strategic components appear necessary.

Technology transfer is required to provide information on "best management practice" (see International Garrison Diversion Study Board, 1975) to optimize the application of water to irrigated land. It would also include training on how to use detailed weather information to avoid unnecessary irrigation. To facilitate the exchange of technology, existing extension services, farm journals, and broadcasting facilities would be used.

As in the case of the municipal and industrial sectors, a **financial assistance program** is an important strategy in this sector as well. The assistance would be oriented in two directions: for farmers to move out of irrigation and for adjustments to new water pricing or wastewater regulations.

DATA AND RESEARCH SUPPORT: A PRELIMINARY PROSPECTUS

Since water demand management is a relatively new field, many different dimensions offer opportunities for research and data collection. The converse is also true. The success of this approach is partially dependent upon the success of the knowledge-gathering infrastructure that coalesces around it. To some extent, as this paper has shown, research and data collection efforts are responsible in a major way for the current visibility of this field. It remains to systematize this knowledge and apply it to the practical problems of water management.

This section presents a preliminary prospectus for data collection and research studies in water demand management. It is based upon previous work by several persons and organizations, notably Brooks and Peters (1988), augmented by the discussions contained in this paper. As indicated in the title of this section, the prospectus outlined here is merely a first step in building an effective knowledge base to support water demand management.

Data Needs

As shown in previous sections, many sets of data on Canadian water uses, particularly in the municipal and industrial sectors, have been collected. In addition to providing basic inventory data on volumes of water withdrawn, consumed, and discharged, the data sets also provide information on end use and on the costs of water servicing. Both of these latter pieces of information are vital in the management process. With respect to end uses, it is desirable to be able to forecast a set of water uses responding to anticipated uses rather than to abstract economic projections of output, GNP, or other economic variables. In fact, the process of "backcasting," which is used in some studies of future energy demands, is based upon alternative views of desired future end uses of energy. Once these have been determined, the research problem then becomes the design of policy measures to achieve the desired ends. The advantage claimed for this method of probing the future is that the decision maker becomes an active force in the projection process rather than a passive observer of the outcomes of statistical operations. Economic information, the second element of the Canadian data, which moves beyond strict inventories of water use, is essential for determining the relationships between water use and the "price" of water. Average water cost (e.g., cost per cubic metre) can be used as a proxy measure of water price (de Rooy, 1974). Thus, with regard to two major withdrawal water uses, Canadian data are relatively adequate.

There are notable gaps, however, that remain to be filled. First, few data are available on agricultural water use in Canada. The Prairie Provinces Water Board issues five-year summaries of stock-watering, irrigation, and rural domestic uses for the Saskatchewan-Nelson basin based upon provincial data holdings. This covers much of the irrigation water use in Canada, but a much smaller part of the other two agricultural end uses. There is no consistent source of water use data for this sector in other areas. Second, there is a need for an agreed-upon set of water use categories and definitions. While there is consistency among the various sets of federal data, there must be a set of nationwide standards to achieve a common understanding among researchers and data users in Canada. Third, while end use data can be derived on an overall basis from survey results now available, these could be broken down further by processes in use and by product group. Availability of these data would enhance the water demand forecasting process (Sewell and Bower, 1968). Some difficulty arises here because questionnaires would have to become very much more detailed than those currently in use, and surveys would probably have to be tailored to specific industry groups. The additional costs required would be substantial. Finally, water use data for industries need to be tied to physical production, not to economic measures. This is required in order to enhance the demand forecasting process by allowing the analysis of product-specific future scenarios as opposed to those based on abstract economic measures.

Analytical Research Needs

The material outlined so far in this paper is based upon many pieces of analytical research, which, for the most part, have found little application to date. There is a need, therefore, to continue this type of research to increase knowledge about the characteristics of water demand.

A substantial number of basic measurements and calibrations are required for the basis of applying water demand management in given situations. These will serve as the standards for water demand management programs. The required measurements can be obtained by metering, monitoring, and using available data such as various Environment Canada water use surveys.

Several examples of such information can be given. For residences, daily per capita water use and waste loading data for a range of water-using fixtures and appliances should be determined. These measures would be the product of research on a cross section of housing stock across different regions. Water use audits, privately collected data, and monitoring would provide similar information for commercial and institutional buildings. Inventories by Wolff et al. (1966) and McCuen et al. (1975) illustrate the types of information required for the commercial and institutional sector. For many industrial groups, similar data would describe water intake, consumption, recirculation, and discharge patterns by type of plant, region, and end use. Where possible, such information should be in terms of physical product, not employment or output value. Establishing these types of standards might not be possible for some industrial groups in Canada because plants are few in number and widely variable in processes used. For irrigation water demand, region-specific water use coefficients by crop and soil type are also needed.

Much more work is required on the modeling of water demands in order to provide new insights into the variables determining the levels of water use. One area where research is required is in relating water use to technological change. Since technological change is one of the fundamental underlying determinants of economic progress, it inevitably helps to condition the level of water use. The author has made an initial analysis in this area (Tate, 1986), but much more work is required, both in extending the current work into the future and in finding new methods for analyzing the impact of technology on water use. One promising area is an approach using process engineering approaches (Kindler and Russell, 1984, ch. 3).

Modeling the interface between water use and water quality is a second area requiring analytical research. As shown by Demayo et al. (1988), water quality enhancement is a legitimate water demand that has been largely neglected in Canadian studies to date. The research problem here is to ensure that ambient water quality is suitable for current and future use. Relating quantity, quality, and use in a pragmatic analytical modeling framework is one of the frontiers of research in the water demand management field.

A third area of water demand modeling that requires work is to augment the current emphasis on strict volumetric forecasting to include the projection of end uses. The processes of "backcasting," which were outlined briefly above, merit research to apply them to the water demand field. The socioeconomic resource framework model developed by Statistics Canada (Gault et al., 1987; Hoffman et al., 1988) is currently being adapted as a primary means of conducting these types of analyses.

The prospect of atmospheric warming and climatic change holds significant implications for water demand, which in turn suggest a range of research activities. In many areas of Canada, notably the Prairies and the Great Lakes, water availability is projected to decrease. One research area is the determination of the magnitude of this decrease by spatial location. This will indicate the nature of prospective water shortages and will help determine the intensity of required demand management efforts or the need for supply augmentation. Related to this need is the examination of shifts in agricultural production areas. Comparing the modified to the existing agricultural areas will help to determine the need for new irrigation areas and the corresponding water demands. Finally, climatic warming will likely increase the water demands of all withdrawal uses as the demand curve shifts outward. Research is required in each sector to determine the likely shifts in water demand patterns.

Technical Research Needs

Technical research relates to the development of efficient equipment and processes. Reflecting on Schultze's outline of the role of price in inducing technological change given in Chapter 2, it seems clear that one of the largest impacts of effective demand management would be the technical advances ensuing from the adoption of such a strategy. Many possibilities exist for advancing what is still a relatively traditional state of water technology, and it is not possible here to enumerate or even envisage all of them. What follows is a brief discussion of some of these possibilities.

For some time now, commercial firms have been developing water-efficient fixtures and appliances for residential application. These developments have resulted in the availability of water-conserving equipment such as shower heads, toilets, faucets, and the like. Although further development will likely occur, the paramount need now is for demonstrations of this type of equipment. For other appliances, such as clothes washers and dishwashers, more research is needed to develop water-using efficiency to its full potential. For residential uses outside the home, water-saving equipment such as timers and soaker hoses need to be developed or adapted for Canadian conditions. In developing new equipment, it is essential that standards for efficiency measurements be developed, preferably through an existing body such as the Canadian Standards Association.

From the viewpoint of municipal water and wastewater system operations, a wide variety of research opportunities is apparent. B.E. Jank (1987, Wastewater Technology Centre, Environment Canada, pers. com.) has demonstrated that the flow-through capacity of waste treatment plants can be effectively doubled through computerization. This research finding has very significant implications for future plant design and the repair and upgrading of existing plants. The problem of water system leakage is a substantial factor in increasing water demands and, ultimately, operational costs. The problem has a variety of possible solutions, such as system replacement, pipe liners, and sonic leak detection. Technical research is required to define the available alternatives, evaluate them, and select the most advantageous ones. A third area of technical research that could be carried out under the demand management umbrella relates to the recovery of energy from waste treatment plant sludge. Pioneered at Canada's Wastewater Technology Centre, this process requires additional work to move it from the laboratory to commercial application. The more realistic water pricing regimes called for under a demand management strategy would provide the incentives for such research.

With respect to industrial water use, several technical areas of research are apparent. Many of these are related to water recirculation. For example, membrane separation has been shown as effective for in-plant cleaning of wastewaters at the laboratory scale. The research opportunity now is in adapting the process for large-scale applications and applying it commercially. Integrated waste treatment and process changes toward lowering the generation of waste residuals are other areas of research opportunity. For instance, work is needed on the design of more water-efficient tools and equipment. A third area of research would examine, at the commercial level, the feasibility of recirculating spent cooling water to other processes or activities (e.g., hydroponics, heating) requiring energy input. Some of this work has already begun, but a great deal more effort is required to make these techniques commercially viable.

Opportunities for technical research also exist in agriculture. Propelled by the possibility of climatic changes toward drier conditions, as well as by the need to rationalize the use of irrigation, the development of water-tolerant crops is one such opportunity. A second is the adaptation of new irrigation techniques to Canadian conditions. For example, the Nebraska Natural Resources Commission (1985) published an overview of irrigation containing an assessment of a wide variety of technical possibilities. A similar study should be done for Canada to ensure that the best available technology is available for use and receives adequate publicity.

Socioeconomic Research Needs

As demonstrated throughout this paper, water demand management is oriented to the socioeconomic dimension of water resources to a much larger degree than traditional supply management strategies. Because the socioeconomic side of the water field has been somewhat neglected in the past (Mitchell and McBean, 1985), many of the research opportunities in the water demand management field fall within the realm of the social sciences. The following discussion is indicative of these opportunities.

Three initiatives in socioeconomic research are general in nature in that they apply to all water uses. The first would develop public education programs designed to increase awareness of the salient characteristics of water use. Part of the problem in developing water demand management has been the lack of public concern about water other than during the occasional drought or flood period. For the most part, water management has been so effective and water so cheap that public apathy toward water resources is common. Public education programs would help to overcome this apathy. Second, research is required to determine the nature of attitudinal and professional resistance to measures aimed at controlling water demands. Municipal officials are often reluctant to raise or modify water rates or even to meter water use, despite good scientific evidence of the effectiveness of such measures. A precise understanding of these types of attitudes is essential for developing new demand management programs.

In the municipal sector, survey work needs to be continued to determine water rate-setting practices and comparative water rates across provinces and between municipalities. This type of survey work and the resultant analyses are in their infancy, and only two papers have been completed to date (Fortin and Tate, 1985; Tate, 1989), neither of which having received wide distribution. If water rate-setting practices are to be improved, a time series of such studies is required to draw the attention of decision makers. Two primary questions are most important: (1) what types of water rates are in current use, and (2) what are the resultant water prices to municipal water users. The research papers arising from these studies should receive the widest possible distribution, and, possibly through the dissemination of information brochures, be made available to the general public.

Following from the studies of water rates, the relationships between water use by end user class and the price of water should be studied. Such studies would indicate the relative effectiveness of varying price structures in controlling municipal water use. Also it is important that price elasticities be calculated over a wide range of water uses. Applications of such studies include the design of effective water rates, estimation of future water demands, and planning of infrastructure upgrading or expansion.

Once the demand relationships for municipal water are understood, important research relates to the setting of economically effective water rates. The water rates manual of AWWA is an example of such an effort, but this manual no longer reflects the best information on public utility rate-making and requires updating and adaptation to Canada. Full cost recovery, peak load pricing, and excessive use charges are important topics for discussion in such a manual.

In the industrial sector, several opportunities for socioeconomic research are also apparent. Recent work by Renzetti (1987) supports earlier research findings that industrial water use is price sensitive. Demand curves for industrial water can be calculated, with the implication that water price is an important policy variable influencing water use. Demand curves for water should be calculated for various industry groups and regions over a large range of water uses and over time. This will allow the calculation of price elasticities of water demand over a wide usage range. These calculations should be made every fifth year after each update of the federal industrial water use survey. The product of these studies will permit improved accuracy in future industrial water demand forecasting.

The water quality problems caused by industry need to be approached from a demand management perspective to provide some balance to the current standards-regulatory approach. Specifically, the feasibility of input pricing or some type of effluent charging must receive definitive study. The climate of skepticism about these policy instruments that pertains currently in most water management quarters needs to be challenged. Placing a realistic charge on the use of the environment as a waste repository is one key to future success in the pollution control sphere.

Water resources are publicly owned in Canada, and, in theory, the public should recover some of the economic rent that accrues from having these resources available. Governments collect rents from other publicly owned resources, such as petroleum, in the form of royalties and other taxes. In the water field, the nominal license fees charged by provinces are somewhat related to rent recovery. There is a need, however, to examine license fees in the context of recovering the rent inherent in water use. This could be a means not only of raising revenue for water projects, but also of rationalizing water demand.

As mentioned earlier, Giles (1986) suggested that industrialists are averse to risks, in that they prefer to operate in a predictable policy environment. On this basis, he suggested that the mere act of establishing mechanisms for charging effluent discharge fees at some future time period (e.g., 10 years hence) would motivate actions toward minimizing these fees. This hypothesis should be tested, for, if accepted, it suggests that minimal policy action would initiate environmentally beneficial behavior.

The nature of the links between water use and technological change were outlined in Chapter 4. From this it can be inferred that low water prices are partially responsible for the underdevelopment of technology in the water field. The interrelationships between water use, pricing policy, and technological change bear further in-depth analysis to improve the quality of water demand forecasts.

An Assessment of the State-of-the-Art of Water Demand Management in Canada

Water demand management is currently in its infancy in Canada. With a strong tradition of water supply manipulation to meet perceived "requirements," Canadian water managers have only recently begun to recognize that water use is actually a demand that can be influenced by pricing policies. This recognition has been propelled by the realization that water resources, even in a so-called water-rich country, are becoming increasingly scarce. More stringent limitations on public expenditures, concern about stretching available resources as far as possible, and reawakened interest in maintaining and enhancing environmental quality are some of the manifestations of this realization. Water demand management offers a series of useful tools and techniques for averting or meeting these concerns, and should be viewed as enhancing, not replacing, current water management approaches.

As the name implies, water demand management is strongly allied to socioeconomic characteristics of water use, particularly to sound water pricing practices. The view put forth in this paper is that realistic water pricing practices are the *sine qua non* of water demand management. Many actions can be taken to lower water demand without changing to any significant degree the nature of current social and economic activities. As past experience has shown, these actions will not occur without economic incentives, which result from pricing practices that reflect the value of the resource. In general, the use of realistic water pricing, based on full cost recovery and economic principles such as marginal cost pricing, is the best way to ensure that effective economic incentive systems are put in place.

This paper has outlined a wide variety of techniques for instituting water demand management in three major economic sectors: municipalities, industry, and agriculture. The economic techniques take advantage of the research finding that water demand varies inversely with price. Structural and operational techniques focus on modifying water-using equipment, adopting new equipment, or altering operating procedures. Sociopolitical techniques are oriented toward establishing the background conditions for the establishment of effective demand management. As noted above, however, the effect of any of these techniques is dependent upon establishing sound water pricing.

Water demand management is a broad set of management strategies that can affect both water quantity and water quality. The effects on quantity are inherent in the definition of the strategy given at the outset of this paper. However, water pollution problems are also viewed here as a basic demand problem, in that the capacity of the environment to absorb and degrade wastes (i.e., the demand) is exceeding the available supply of assimilative capacity. To bring these demands and supplies into rough equilibrium requires effective establishment of demand-oriented strategies.

To establish a comprehensive demand management strategy nationally is a complex undertaking. A large number of subcomponents of such a strategy were suggested, ranging from a revamping of current pricing arrangements to education programs to raise awareness. Some of these subcomponents are general in nature, applying to all sectors of the economy, while others are sector specific. A reasonably comprehensive supporting research program is an essential underpinning of a national demand management program. The suggested research program would encompass both the social and the physical sciences sides of water resource studies.

An effective demand management program would have many beneficial effects. By making socially beneficial reductions in water use or consumption, available water supplies will be used more efficiently, resulting in net social welfare gains. As a result, available resources will serve more and higher valued uses. On the downside, some water uses would become uneconomical and would cease. Available public capital could be stretched through water demand management to serve more uses in both the water and unrelated fields. One of the most important and yet unrecognized spin-offs would be accelerated technological change as entrepreneurs began to take advantage of revised incentive systems. In conclusion, demand management in Canada is an underdeveloped approach to water resource management. Current and emerging conditions are, however, combining to force more recognition for this set of management strategies. Demand management will be most useful when used in conjunction with supply-oriented approaches to broaden the range of alternatives available to water managers.

REFERENCES

Acres International. 1984. Water supply constraints to energy development. Phase III. Summary report. Inland Waters Directorate, Environment Canada.

Alberta Environment. 1977. A review of in-stream flow needs: Methodologies for fish and recommendations for instituting protective measures in Alberta. Planning Division, Edmonton, Alberta. Ms. copy.

American Water Works Association (AWWA). 1983. *Manual of water supply practices: Water rates.* AWWA M1. Denver, Colorado.

American Water Works Association (AWWA). 1986. Privatization: Trend of the future? J. Am. Water Works Assoc., 78(2): 33.

Andersen, J.C., and J.E. Keith. 1981. Assessing the agricultural demand for water. In *Selected works in water supply, water conservation and water quality planning,* ed. J.E. Crews and J. Tang, pp. 306-315. U.S. Army Corps of Engineers, Institute for Water Resources, Fort Belvoir, Virginia.

Barclay, D.S. 1984. Retrofitting apartment buildings to reduce costs and water demand. Can. Water Resour. J., 9(3): 45-47.

Barnett, H.J., and M.C. Morse. 1973. *Scarcity and growth: The economics of natural resources availability.* Baltimore: Johns Hopkins University Press.

Baumann, D.D., J.J. Boland, and J.H. Sims. 1980. The problem of defining water conservation. The Cornett Papers, University of Victoria, Victoria, British Columbia, pp. 125-134.

Bower, B.T. 1966. The economics of industrial water utilization. In *Water research,* ed. A.V. Kneese and S.C. Smith, pp. 143-173. Baltimore: Johns Hopkins University Press.

Brooks, D.B., and R. Peters. 1988. Water: The potential for demand management in Canada. Discussion Paper, Science Council of Canada, Ottawa.

Canadian Council of Resource and Environment Ministers. 1987. Report of the National Task Force on Environment and Economy. Ottawa.

Canadian Water and Wastewater Association (CWWA). 1989. Meters made easy. Inland Waters Directorate, Environment Canada, Ottawa.

Craddock, W.J. 1971. Linear programming models for determining irrigation demand for water. Can. J. Agric. Econ., 19(11): 84-92.

Dales, J.H. 1968. *Pollution, property and prices.* Toronto: University of Toronto Press.

Deibert, L.E. 1980. Fiscal planning and water conservation in Madison, Wis. In *Water conservation strategies,* AWWA Management Resource Book, pp. 12-15.

Demayo, A., D.M. Tate, and H. Vaughan. 1988. Water use analysis: Are water quality data needed? In Proceedings, AWWA Symposium on Water-Use Data for Water Resources Management, Tuscon, Arizona.

deRooy, J. 1970. The industrial demand for water resources: An economic analysis. Ann Arbor: University Microfilms.

deRooy, J. 1974. Price responsiveness of the industrial demand for water. Water Resour. Res., 10(3): 403-406.

Deschamps, J.D. 1986. Privatization of water systems in France. J. Am. Water Works Assoc., 78(2): 34-40.

Doctor, R.D. 1986. Private sector financing for water systems. J. Am. Water Works Assoc., 78(2): 47-48.

Earmme, S.Y. 1979. A water use projection model for the North Saskatchewan River basin, Alberta, 1980-85: An input-output approach. Ph.D. diss., University of Alberta, Edmonton.

Environment Canada. 1975. Canada water year book, 1975. Cat. No. En 36-425/1975. Ottawa.

Environment Canada. 1983. Canada water year book, 1981-1982, water and the economy. Cat. No. Em 36-425/1981E.

Environment Canada. 1986a. Canada water year book, 1985, water use edition. Cat. No. En 36-425/1985E. Ottawa.

Environment Canada. 1986b. Water charges to industry in Canada, 1985. Inland Waters Directorate, Ottawa. Int. rep.

Environment Canada. 1986c. Water charges to power companies, Canada, 1985. Inland Waters Directorate, Ottawa. Int. rep.

Environment Canada. 1987a. Federal water policy.

Environment Canada. 1987b. Water charges to agricultural users in Canada, 1986. Inland Waters Directorate, Ottawa. Int. rep.

Erwingmann, D. 1984. Pollution charges in the Federal Republic of Germany. Background paper for International Conference on Environment and Economics. Organisation for Economic Co-operation and Development, Paris.

Falkenmark, M. 1977. Reduced water demand—Result of Swedish anti-pollution programme. Ambio, 6, Part 1.

Federation of Canadian Municipalities (FCM). 1985. Municipal infrastructure in Canada: Physical condition and funding adequacy. Ottawa.

Flack, E.J. 1981. Residential water conservation. J. Water Resour. Plan. Manage. Div., ASCE, 107(1): 85-95.

Fortin, M., and D.M. Tate. 1985. Water rate setting practices in Canada. Inland Waters Directorate, Environment Canada, Ottawa. Unpub. draft.

Gault, F.D., K.H. Hamilton, R.B. Hoffman, and B.C. McInnis. 1987. The design approach to socio-economic modelling. Futures, 19(1): 3-26.

Gibbons, D.C. 1986. *The economic value of water.* Resources for the Future, Washington D.C.

Gilbert, J.B. 1980. The California drought—Out of disaster, better water management. In *Water conservation strategies,* AWWA Management Resource Book, pp. 44-46.

Giles, P.H. 1986. Supplementary measures project: Outline and preliminary report. Policy and Strategic Planning Branch, Environmental Protection, Environment Canada, Ottawa. Int. working paper.

Grima, A.P. 1972. *Residential demand for water: Alternative choices for management.* Toronto: University of Toronto Press.

Haney, P.E., and P.E. Hagar. 1985. Dual water system design. In AWWA Seminar proceedings—Dual water systems. No.20189. Conference of the American Water Works Association, June 23, 1985, Denver, Colorado.

Hanke, S.H. 1978. A method for integrating engineering and economic planning. J. Am. Water Works Assoc., 70(9): 487-491.

Hanke, S.H. 1983. Face to face (interview). J. Am. Water Works Assoc., 75(5): 20-30.

Hanke, S.H., and M. Fortin. 1985. The economics of municipal water supply: Applying the user pay principle. Inquiry on Federal Water Policy, Research Paper #21. Ottawa.

Hardin, G. 1968. The tragedy of the commons. Science, 162: 1243-1248.

Hennigar, G.W. 1984. Water leakage control and sonic detection. Can. Water Resour. J., 9(3): 52-57.

Hess, P.J. 1986. Ground-water use in Canada, 1981. NHRI Paper No. 28/IWD Tech. Bull. No. 140, National Hydrology Research Institute, Inland Waters Directorate, Environment Canada, Ottawa.

Hirschleifer, J., J.C. deHaven, and J.W. Milliman. 1960. *Water supply: Economics, technology and policy.* Chicago: University of Chicago Press.

Hoffman, R.B., B.C. McInnis, and J. Robinson. 1988. Design for an integrated framework for water use and water quality analysis. Waterloo Simulation Research Facility, University of Waterloo. Unpub. ms. available from Inland Waters Directorate, Ottawa.

Howe, C.W. 1979. *Natural resources economics: Issues, analysis and policy.* New York: John Wiley and Sons.

Howe, C.W., C.S. Russell, and R.A. Young. 1970. *Future water demands: The impacts of technological change, public policies and changes in market conditions on the water use patterns of selected sectors of the United States economy. 1970-1990.* Resources for the the Future, Washington, D.C.

International Garrison Diversion Study Board. 1975. Report of the International Garrison Diversion Study Board, International Joint Commission, Ottawa.

International Union for Conservation of Nature and Natural Resources (IUCN). 1980. World conservation strategy. Gland, Switzerland.

Kellow, R.L. 1970. A study of water use in single dwelling residences in the city of Calgary, Alberta. Master's thesis, Department of Economics and Rural Sociology, University of Alberta, Edmonton.

Kindler, J., and C.S. Russell. 1984. *Modeling water demands.* Toronto: Academic Press.

Kitchen, H.M. 1975. A statistical estimation of a demand function for residential water. Soc. Sci. Ser. No. 11, Water Planning and Management Branch, Inland Waters Directorate, Environment Canada, Ottawa.

Kneese, A.B. 1977. *Economics and the environment.* Markham, Ontario: Penguin Books.

Kollar, K.L., and P. MacAuley. 1980. Water requirements for industrial development. J. Am. Water Works Assoc., 72 (1): 2-9.

Kreutzwiser, R., and R. Feagan. 1987. Utilization of water demand management strategies among southern Ontario municipalities. Department of Geography, University of Guelph, Guelph, Ontario.

Kuhn, T. 1970. *The structure of scientific revolutions.* Chicago: University of Chicago Press.

Loudon, R.M. 1986. Municipal experiences in pricing and water conservation. A paper delivered at the Canadian Public Works Conference and Equipment Show, May 11-14, 1986, Ottawa.

MacLaren, J.W. 1987. Magnitude of the problem of the rehabilitation of municipal water distribution systems in Ontario. Unpub. ms.

Manitoba Gazette. 1987. Licence fees. 116, 16, p. 854.

McCuen, R.H., R.C. Sutherland, and J.R. Kim. 1975. Forecasting urban water use: Commercial establishments. J. Am. Water Works Assoc., 67(5): 239-244.

McMillan, T. 1987a. The federal government and municipal infrastructure. Notes for an address to the First Canadian Conference on Urban Infrastructure, Royal York Hotel, Toronto, Ontario. February 5, 1987.

McMillan, T. 1987b. A realistic price for Canada's water. Notes for an address to l'Association québécoise des techniques de l'eau, Palais des Congrès, Montreal, Quebec.

McNeill, R. 1988. Economic theory of water pricing. Staff paper. Pacific and Yukon Region, Inland Waters Directorate, Environment Canada, Vancouver, British Columbia.

Millerd, F.W. 1984. The role of pricing in managing the demand for water. Can. Water Resour. J., 9(3): 7-16.

Mitchell, B., and E. McBean. 1985. Water resources research in Canada: Issues and opportunities. Inquiry on Federal Water Policy, Research Paper #16. Ottawa.

Muir, T., and A. Sudar. 1987 . Toxic chemicals in the Great Lakes basin ecosystem, some observations. Ontario Region, Environment Canada, Burlington, Ontario.

Muller, R.A. 1985. The socioeconomic value of water in Canada. Inquiry on Federal Water Policy, Research Paper #5. Ottawa.

National Survival Institute. 1985. Social studies—Water conservation unit, grade 9. Calgary, Alberta.

Nebraska Natural Resources Commission. 1985. Water use efficiency. State Water Planning and Review Process, Lincoln, Nebraska.

Organisation for Economic Co-operation and Development (OECD). 1984. Economic instruments: Review and outlook. OECD Environment Committee, Group of Economic Experts, ENV/ECO/CI/83.9, Paris.

Organisation for Economic Co-operation and Development. 1987a. Improved water demand management state of the art. OECD Environment Committee, Group on Natural Resource Management, ENV/NRM/87.2, Paris.

Organisation for Economic Co-operation and Development. 1987b. Pricing of water services. Paris.

Pearse, P.H., F. Bertrand, and J.W. MacLaren. 1985. Currents of change: Final report, Inquiry on Federal Water Policy. Cat. No. En 37-71/1985-1E, Ottawa.

Penman, A. 1974. The experience with the effluent charge scheme of the city of Winnipeg. Environment Canada, Ottawa. Unpub. ms.

Postel, S. 1985. Conserving water: The untapped alternative. Paper 67, Worldwatch Institute, Washington, D.C.

Prairie Provinces Water Board (PPWB). 1982. Prairie provinces water demand study: Historical and current water uses in the Saskatchewan-Nelson basin. Regina, Saskatchewan.

Renzetti, S. 1987. The economic aspects of industrial water use. Inland Waters Directorate, Environment Canada, Ottawa. Unpub. ms.

Robinson, J.E. 1980. Demand modification as a supply alternative: A case study of the Regional Municipality of Waterloo, Ontario, Canada. Department of Environmental Studies, University of Waterloo, Waterloo, Ontario. Unpub. ms.

Robinson, J.E., and M. Anderson. 1985. The role of water demand management in a federal water policy. Inquiry on Federal Water Policy, Research Paper #20. Ottawa.

Rump, M.E. 1978. Potential water economy measures in dwellings: Their feasibility and economics. Paper CP 65/78, Building Research Establishment, Watford, U.K.

Schultze, C.W. 1977. *The public use of private interest.* The Godkin Lectures. Cambridge, Mass.: Harvard University Press.

Sewell, W.R.D., and B.T. Bower. 1968. Forecasting the demands for water. Policy and Planning Branch, Department of Energy, Mines and Resources, Ottawa.

Sewell, W.R.D., and L. Roueche. 1974. The potential impact of peak load pricing on urban water demands: Victoria, British Columbia, a case study. In *Priorities in water management, Victoria, B.C.*, ed. F.M. Leversedge, University of Victoria, Western Geographical Series, Vol. 8, pp. 141-161.

Sherwood, D.E. 1986. Water-related resources in the Kettle-Granby river basin. Pacific and Yukon Region, Environment Canada, Vancouver.

Solow, R.M. 1957. Technical change in the aggregate production function. Rev. Econ. Stat., 39: 312-320.

Statistics Canada. 1985. Canada year book. Ottawa.

Tate, D.M. 1971. Water requirement of the iron and steel industry in the Canadian Great Lakes basin. Discussion paper 71-2, Policy and Planning Branch, Department of Energy, Mines and Resources, Ottawa.

Tate, D.M. 1977. Manufacturing water use survey—A summary of results. Soc. Sci. Ser. No. 17, Water Planning and Management Branch, Inland Waters Directorate, Fisheries and Environment Canada, Ottawa.

Tate, D.M. 1979. Consumptive water use in the Canadian section of the Great Lakes basin, 1975-2035. Environment Canada, Inland Waters Directorate for The International Great Lakes Diversions and Consumptive Uses Working Committee, Ottawa.

Tate, D.M. 1983. Water use in the Canadian manufacturing industry, 1976. Soc. Sci. Ser. No. 18, Water Planning and Management Branch, Inland Waters Directorate, Environment Canada, Ottawa.

Tate, D.M. 1984. Industrial water use and structural change in Canada and its regions: 1966-1976. Ph.D. diss., University of Ottawa, Ottawa.

Tate, D.M. 1985. Alternative forecasts of Canadian water use, 1985-2011. Inquiry on Federal Water Policy, Research Paper #17. Ottawa.

Tate, D.M. 1986. Structural change implications for industrial water use. Water Resour. Res., 22(11): 1526-1530.
Tate, D.M. 1987. Current and projected water uses in Canada, 1981-2011. In Canadian Aquatic Resources, Bulletin of Fisheries and Aquatic Sciences 215, ed. M. Healy and R. Wallace, Fisheries and Oceans Canada, Ottawa, pp. 43-69.
Tate, D.M. 1988. Industrial water use and structural change. In Proceedings, AWWA Symposium on Water-Use Data for Water Resources Management, Tuscon, Arizona.
Tate, D.M. 1989. Municipal water rates in Canada, 1986—Current practices and prices. Soc. Sci. Ser. No. 21, Water Planning and Management Branch, Inland Waters Directorate, Environment Canada, Ottawa.
Tate, D.M., and D.M. Lacelle. 1978. Municipal water use in Canada. Can. Water Resour. J., 3(2): 61-78.
Tate, D.M., and D.M. Lacelle. 1987. Municipal water use in Canada, 1983. Soc. Sci. Ser. No. 20, Water Planning and Management Branch, Inland Waters/Lands Directorate, Environment Canada, Ottawa.
Tate, D.M., and D.N. Scharf. 1985. Water use in Canadian industry, 1981. Soc. Sci. Ser. No. 19, Water Planning and Management Branch, Inland Waters Directorate, Environment Canada, Ottawa.
Thomas, J.F.J. 1959. Nelson River drainage basin in Canada, 1953-56. Industrial Water Resources of Canada, Water Survey No. 10, Department of Mines and Technical Surveys, Ottawa.
Wade Miller Associates. 1987. The nation's public works: Report on water supply. Categories of Public Works Series, National Council on Public Works Improvement, Washington, D.C.
Westerhoff, G.P. 1986. An engineer's view of privatization: The Chandler experience. J. Am. Water Works Assoc., 78(2): 41-46.
White, G.F. 1961. The choices of use in resource management. Nat. Resour. J., 1(1): 23-40.
Wolff, J.B., F.P. Linaweaver, Jr., and J.C. Geyer. 1966. Water use in selected commercial and institutional establishments in the Baltimore metropolitan area. Report on the Commercial Water Use Research Project. Department of Environmental Engineering Science, The Johns Hopkins University.
Wollman, N. 1962. *The value of water alternative uses.* Albuquerque: University of New Mexico Press.
World Commission on Environment and Development. 1987. *Our common future.* New York: Oxford University Press.
Young, R.A., and S.L. Gray. 1972. Economic value of water: Concepts and empirical estimates. NTIS, #PB 210356, Springfield, Virginia.