Inquiry on Federal Water Policy
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THE ROLE OF WATER DEMAND MANAGEMENT IN A FEDERAL WATER POLICY

by

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THE INQUIRY ON FEDERAL WATER POLICY

The Inquiry on Federal Water Policy was appointed by the federal Minister of the Environment in January of 1984 under the authority of the Canada Water Act. The members were Peter H. Pearse, chairman; Françoise Bertrand, member; and James W. MacLaren, member. The Inquiry was required by its terms of reference to review matters of water policy and management within federal jurisdiction and to make recommendations.

This document is one of a series of research papers commissioned by the Inquiry to advance its investigation. The views and conclusions expressed in the research papers are those of the authors. Copies of research papers and information on the series may be obtained by writing to the Enquiry Centre, Environment Canada, Ottawa, Ontario K1A 0H3.

Frank Quinn
Director of Research

Abstract

This paper presents an overview of water demand management, its importance, and how it should be integrated with supply management for water and wastewater systems. Demand management measures in agriculture include dryland cultural practices, improved water delivery systems (both off-farm and on-farm), water scheduling, and water metering; each of these could provide productivity gains of 15 to 25 percent, allowing a doubling of irrigated production with existing supplies.

In the industrial sector, recycling processes can reduce water use per unit of output by up to 97 percent for individual firms, and perhaps up to 75 percent in industries such as pulp and paper. Municipal water use can be reduced by 13 to 50 percent for each of: improving distribution system maintenance, metering, rate structure modification, and use of insulated and heat-traced services in northern communities. Long term reduction of over 25 percent can be achieved in new residential development by ensuring new structures include more water-efficient fixtures and appliances.

Despite institutional problems, the federal government can assist through improved coordination among departments, re-focussing supply-oriented technical assistance, additional research and extension education, support for public information services including interest groups, tax incentives, programs and actions to facilitate use of more water-efficient fixtures, and support of provincial initiatives related to demand management.

Résumé

Ce rapport présente un aperçu de l'importance de la gestion de la demande en eau et de la façon dont celle-ci pourrait être intégrée à la gestion des approvisionnements pour les systèmes de distribution et les systèmes de traitement des eaux usées. Les mesures de gestion de la demande en agriculture comprennent l'utilisation de techniques de type cultures non irriguées, l'amélioration des systèmes de distribution (tant sur les fermes qu'à l'extérieur de celles-ci) le calcul des quantités d'eau requises et le comptage de l'eau. Chacune de ces mesures pourrait apporter des gains de productivité de l'ordre de 15 à 25%, ce qui permettrait de doubler la production des terres irriguées sans augmenter les approvisionnements actuels.

Au niveau du secteur industriel, les méthodes de recyclage peuvent réduire la quantité d'eau utilisée d'un facteur pouvant atteindre 97% pour les petites entreprises et peut-être 75% pour des secteurs tel les pâtes et papiers. L'utilisation d'eau au niveau municipal peut être réduite de 13 à 50% par chacune des méthodes suivantes: amélioration de l'entretien du système de distribution, comptage de l'eau, modification des tarifs et utilisation de réseaux thermiquement isolés dans les communautés nordiques. Une réduction à long terme de 25% peut être atteinte dans les nouveaux projets résidentiels par l'utilisation de fixtures et d'appareils ménagers utilisant moins d'eau que leurs prédecesseurs.

Malgré les problèmes institutionnels, le gouvernement fédéral peut apporter sa contribution par l'amélioration de la coordination interministérielle, par la réorientation de l'aide technique relié aux approvisionnements, par la mise en place de programmes de recherche et d'éducation supplémentaires, par le support à l'information du public y compris les groupes d'intérêt public, par la mise en place de stimulants fiscaux, par l'établissement de programmes et actions afin de faciliter l'utilisation de fixtures plus performantes et par le support d'initiatives provinciales reliées à la gestion de la demande.

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J. E. R.

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I INTRODUCTION

1.1 Objective:

The general objective of this paper is to describe existing and potential applications of demand management to municipal, industrial, and agricultural water uses, and to recommend means and advantages of incorporating them more widely into Canadian water management practices.

More specifically, the objectives of this report are to briefly:

1. Describe the range of demand management measures which have been or could be applied in Canada to reduce the rate of growth in water use, including measures for recycling, reclamation, recovery and reduction at source.
2. Assess the socioeconomic, environmental, and legal implications of such measures.
3. Indicate the advantages of and obstacles to integrating demand and supply-oriented water management.
4. Recommend appropriate means by which the federal government can encourage greater application of water demand management in Canada, taking into account its jurisdictional limitations.

1.2 What is Water Demand Management?

1.2.1 Supply Management

Water demand management may be more easily understood by first reviewing supply management. Traditionally, much attention in water policy has focussed on managing the supply of water and of wastewater treatment. This attention has included both the quantity and quality of supply.

When a concern has arisen about supply, the conventional approach has been to develop population projections, to convert these to water or wastewater treatment demand projections using current usage rates and trends, to calculate water supply or wastewater treatment capacity deficits given the existing supply and distribution system, and then to devise alternative projects to meet those deficits. The focus on supply results from a policy (implicit or explicit) of meeting all user requirements without question. Because of this focus on supply, devising alternative policies which could affect demand is not usually considered because supplies can rarely be increased by policy.

In other words, in water supply management, the focus is on flows in the water supply, treatment, and distribution subsystems with the input being water from renewable (or possibly non-renewable) sources and the main output being water for the use subsystem, i.e. to meet water demand (Figure 1.1). In the supply management approach to wastewater treatment, the focus is on the wastewater collection and treatment subsystems with a primary input being wastewater from the use subsystem and the output is discharge into receiving waters.

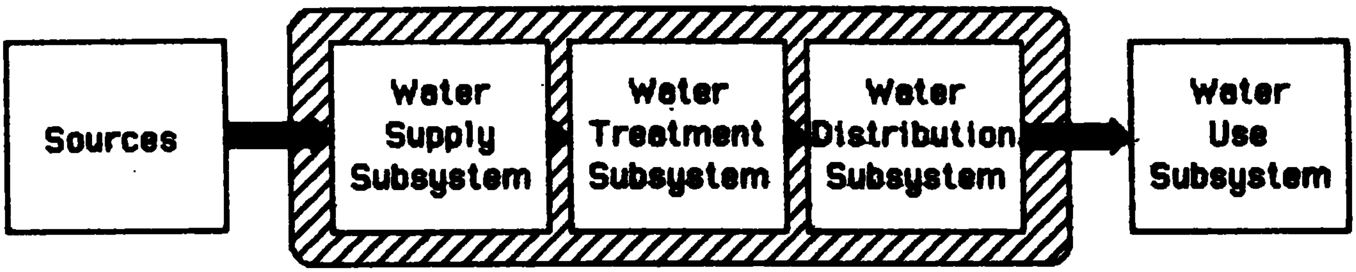
Supply management thus tends to regard demands as given and supply as subject to increase, to be project and not policy oriented and to focus on water supply and wastewater treatment as distinct management areas.

1.2.2 Demand Management

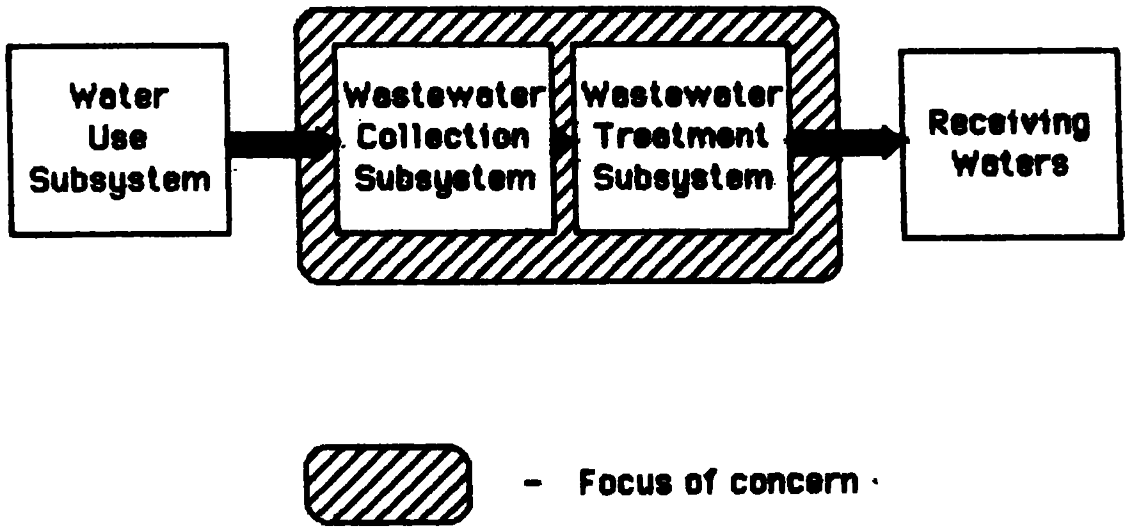
In demand management, a principal objective is to reduce water use, where water use is seen in the broadest sense applying to all subsystems. Demands are not regarded as given; rather, supply can be considered fixed and demand subject to

Figure 1.1: Supply Management System

(a) Water



(b) Wastewater Treatment



decrease. Demand management also may apply to water supply or to wastewater treatment.

In the system described above, water demand management would focus on decreasing flow in the water distribution and use subsystems, and a demand management approach to wastewater treatment would have a similar focus on the use and wastewater collection subsystems (Figure 1.2).

Managing water demand, however, requires development of policies (explicit or implicit) on appropriate use of the water system. (Supply management also requires such policies but these are often implicit.) Even an apparently straightforward policy of cost recovery can have significantly different results depending on what costs are recovered and from whom. Griffith (1984) illustrates application of a policy of recovering costs of providing for peak demands from users contributing to those peak demands; the system requirements with such a policy appeared reduced by about 12.5 percent over the previous policy of averaging peak demand costs into overall water rates. Augmenting supply by an equivalent amount would have been much more costly.

1.3 Why Consider Water Demand Management?

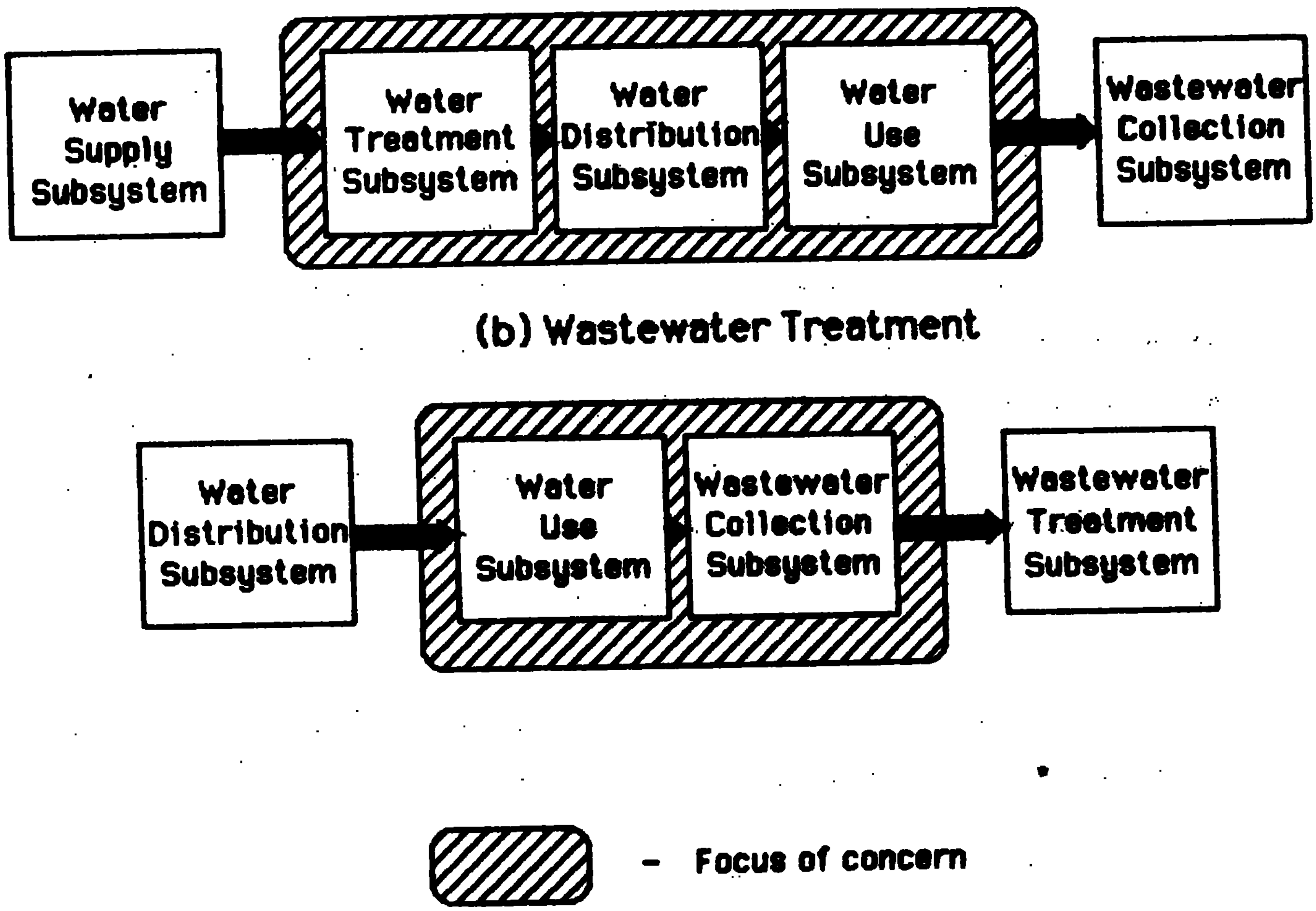
1.3.1 Inavailability of Short Term Supply

Managing water demand has traditionally been used primarily to meet critical water shortages (Viessman and Welty, 1984 p. 233). Most such crises have been a result of a severe drought which had strained the supply system to the point that all requirements (including emergency reserves) could not be filled.

Figure 1.2: Demand Management System

(a) Water

(b) Wastewater Treatment



While some people view demand management and crisis management interchangeably, there are many factors other than crises which favour water demand management: these in most cases are of a longer term nature.

1.3.2 Inavailability of Longer Term Supply

(a) Physical Quantity

On a per capital runoff basis, Canada has the most water wealth of any nation, with over 100,000 m^3/person and over 13 times the world average (Postel, 1984, pp. 9-10). However, by the year 2000 at least some river basins in the Prairies may be unable to meet dry-year demands. Even the Great Lakes basin is not secure. An investigatory board of the International Joint Commission has predicted that Great Lakes levels may be lowered by 12 to 23 centimetres over 40 years as a result of increasing consumption.

(b) Physical Quality

The quality of available additional supplies may also be of concern. Stretching existing supplies may be particularly desirable in such cases.

(c) Increased Preservation of Other Uses

In recent years, there has been greater recognition of the value of and the need to protect in-stream uses of water--not just plant and fish growth, or dilution and purification, but also aesthetics, and to protect aquifer levels. At the same time, concern for preservation of other uses of reservoir sites has intensified.

(d) Political and Institutional

Problems related to social, political and institutional questions appear to have increased, especially where interbasin transfers of water are involved.

1.3.3 Cost

Because demand management has been considered less frequently, the total costs, both economic and environmental, may be less in many cases to manage demand than to augment supply, e.g. recovering costs of providing for peak demands mentioned in section 1.2.2.

A significant portion of cost savings may arise from deferral or scaling down of capacity expansions of plants, and from energy and chemical costs related to pumping and treating water. El Paso, Texas, found that besides reducing strain on aquifers, conservation (pricing and education efforts) is expected to meet 15-17 percent of long-term water needs, and has been doing so for an average cost of 135 dollars per 1000 cubic meters--8 percent less than the average cost of existing water supplies (Postel, 1984, p. 46).

1.3.4 Predicted Declines in Population Growth Rates

Another reason to consider demand management is that recent Canadian population projections indicate an increase until the turn of the century only, and after that period of time it could even begin to decline unless immigration levels are significantly increased (Statistics Canada, 1984). The implication of this is that while some municipalities will experience continued growth, others will grow slowly and then decline. Some must be expected not to grow at all. Such statistics raise questions about the longer term desirability of many water facility capacity additions which may be proposed, at least in the absence of a national population policy.

1.3.5 Public Attitudes

Public attitudes appear generally very favourable toward water conservation measures. In a survey of 1383 households in both humid and semiarid regions, 86 percent perceived the need to conserve as moderately important or very important (Baumann et al., 1984). Even on the use of reclaimed water, except for uses related to direct ingestion, six studies have shown opposition to 25 uses of reclaimed wastewater to be consistently less than 40 percent; if indirect ingestion uses (e.g. swimming) are removed, opposition is less than 25 percent (Bruvold. 1985, p. 133).

1.4 **How should Demand Management be Integrated?**

1.4.1 Integrating Supply and Demand Management

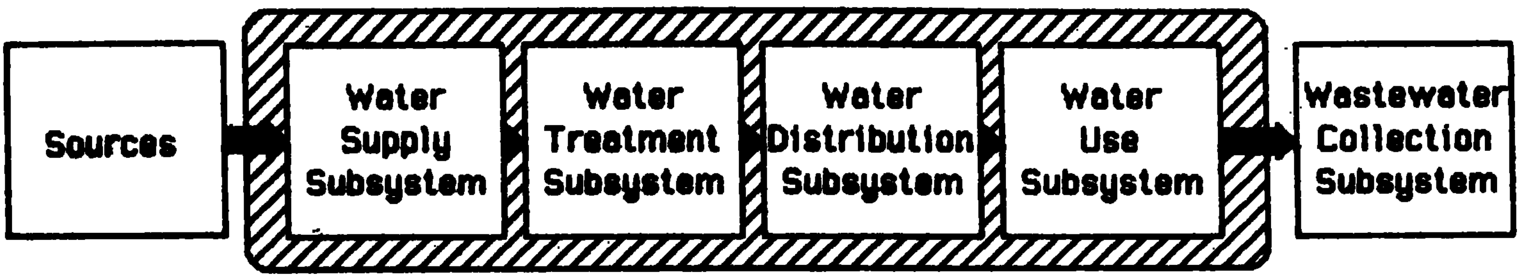
If the goal is efficient water system management, neither supply management (section 1.2.1) nor demand management (section 1.2.2) alone are satisfactory. While there is some overlap, each considers a different set of subsystems as of primary importance. While supply management often emphasizes additional large-scale capital projects, demand management options are often either many smaller scale changes or policy modification. A better approach to water system management is to integrate supply and demand management. This is illustrated in Figure 1.3 for water and for wastewater treatment systems.

1.4.2 Integrating Water and Wastewater System Management

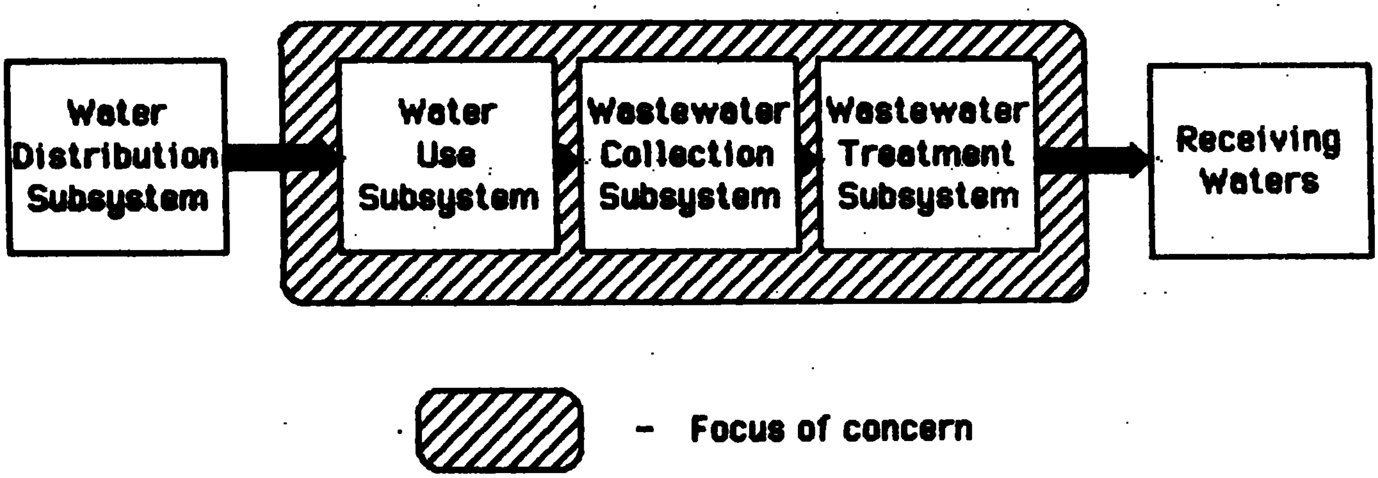
It can also be noticed from the discussions of demand management, and from Figure 1.3, that consideration of managing demand has another implication. Once the use system's demand for water and generation of wastewater are not treated as given,

Figure 1.3: Integrated Demand and Supply Management System

(a) Water



(b) Wastewater Treatment



the clear separation of water supply and wastewater treatment as management areas no longer exists. Measures affecting the use system will have effects on both areas.

To avoid problems of suboptimality in a water/wastewater system, it can be seen that the entire system must be managed together. Figure 1.4 is illustrative of an agricultural or municipal system. It consists of at least six subsystems: water supply, water treatment, water distribution, water use, wastewater collection, and wastewater treatment. In such a system, water from various sources enters the supply subsystem and leaves from others including the wastewater treatment subsystem. From the latter it is discharged to receiving waters.

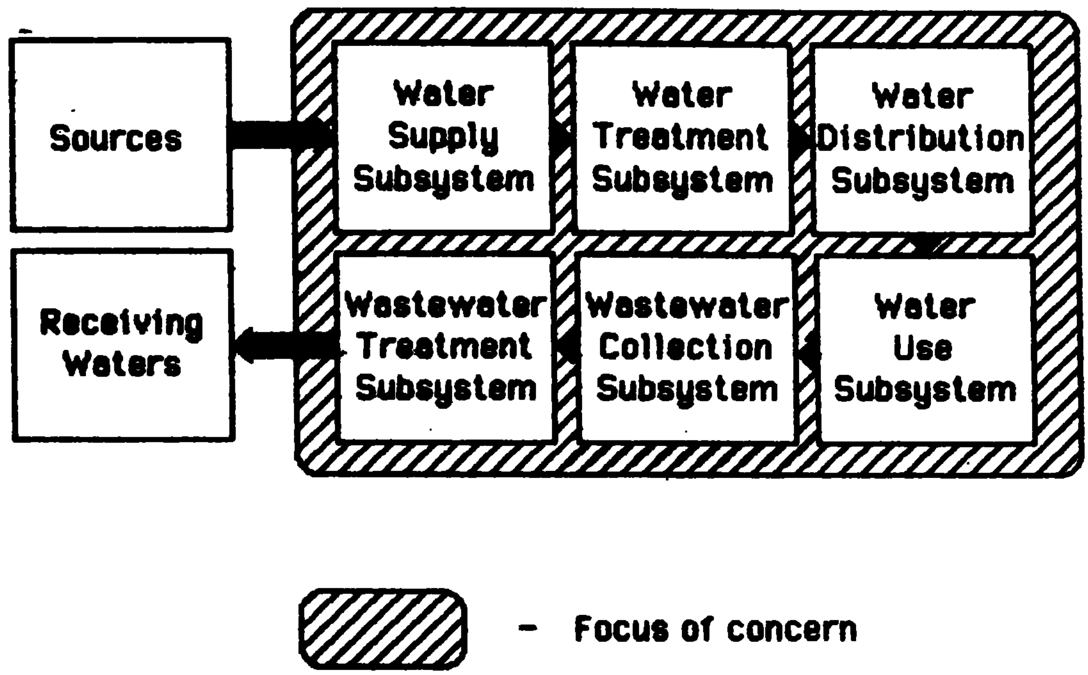
As an example of improved optimality, a measure which reduces water demand may not just avoid augmenting supply, but may defer wastewater treatment expansion as well (Howard-Ferreira and Robinson, 1980c).

In summary, demand and supply management should be integrated to avoid suboptimality, and this leads naturally to integration of water and wastewater system management as well. Integrating demand management in this way should not be seen as anti-development, but rather as focussing on rational water use, including socially beneficial reductions in consumption, and putting scarce resources to more economic use (Tate, 1984, p. 6).

1.4.3 In What Sectors is Integration Important?

Managing water demand is often associated with the residential sector, primarily due to disproportionate amounts of effort and publicity in that area. However, a review of the reasons for considering demand management (section 1.3), and of how it should be integrated in water system management (sections 1.4.1 and 1.4.2), reveals

Figure 1.4: Integrated Water-Wastewater System



that two of the fundamental objectives served are (a) increased availability of water, and (b) improved economic efficiency or system optimality. These objectives are important in all sectors.

II EXISTING AND POTENTIAL DEMAND MANAGEMENT MEASURES: AGRICULTURE

The focus of this section is on identifying demand management measures which are currently in use or which could be used to reduce the rate of growth of water use in the agricultural sector. Both dryland and irrigation agriculture are considered.

2.1 Dryland

The agricultural community in Canada is taking a growing interest in dryland soil moisture management. This interest is particularly apparent in the direction of dryland cultural practices and in the increased emphasis on wetland management on agricultural lands, e.g. slough consolidation and supplemental irrigation.

The on-going changes in dryland cultural practices that will make more effective use of available moisture include the following:

- reduced summerfallow
- snow management to trap additional water for crops
- greater use of drought resistant crop varieties
- better farm management (eg: timing of operations)

(Canada Grains Council, 1982; dar Wall Consultants, 1983).

These changes will obviously not increase the overall availability of water for dryland agriculture. They will, however, make better use of the water that is available.

Drainage, again, does not affect the total water supply. Rather, the purpose of drainage is to redistribute water. The water may be channelled away from areas of excess to be used elsewhere.

2.2 Irrigation

Demand management measures are on-going in irrigation agriculture. The following takes many examples from irrigation in Alberta because of its prime importance as an irrigating province.

2.2.1 Water Rights

Controls are already in place to limit the amount of land that can be irrigated. Agricultural lands are given irrigability classifications which effectively limit the extent of irrigation development and, hence, water use. In Alberta, private irrigators must obtain approval from Alberta Environment to divert water. These diversions are inspected every three to five years after the license has been granted in order to ensure that the water is being used according to the conditions set out in the license (Environment Council of Alberta (ECA), 1979).

However, because the number of hectares of potentially irrigable land greatly exceeds current development levels on the Prairies (by, say five times), water rights, as presently constituted, generally only serve to allocate water to agriculture at one point in time.

2.2.2 System Technologies/Design

Irrigation system design is obviously a major factor in water management. A brief description of common conveyance systems follows:

Open channel systems can be lined or unlined. Unlined canals are very inefficient with seepage losses often ranging from one-quarter to one-third of the total water diverted (Jensen, 1980).

Lining ditches is an effective way to prevent erosion, control rodent damage and reduce seepage losses at a reasonable cost. Concrete is probably the most commonly used material although asphaltic materials, membranes, chemical sealants and impermeable earth materials are also used.

The most efficient (and most costly) water conveyance system is pipe. Its main advantages are that water losses are negligible as are maintenance costs, and, if buried, a pipeline can take the most direct route from water source to outlet.

In Alberta, most canal rehabilitation is done using concrete lining although some pipe has recently been installed.

System configuration or layout is also important in a water management context. Assuming an open channel system, water losses due to evaporation, operational spills and the like can be significant (see Figure 2.1). Irrigation systems which follow field or quarter section lines, as opposed to the contours of the land, result in improved field work efficiencies, better weed control and more efficient water use.

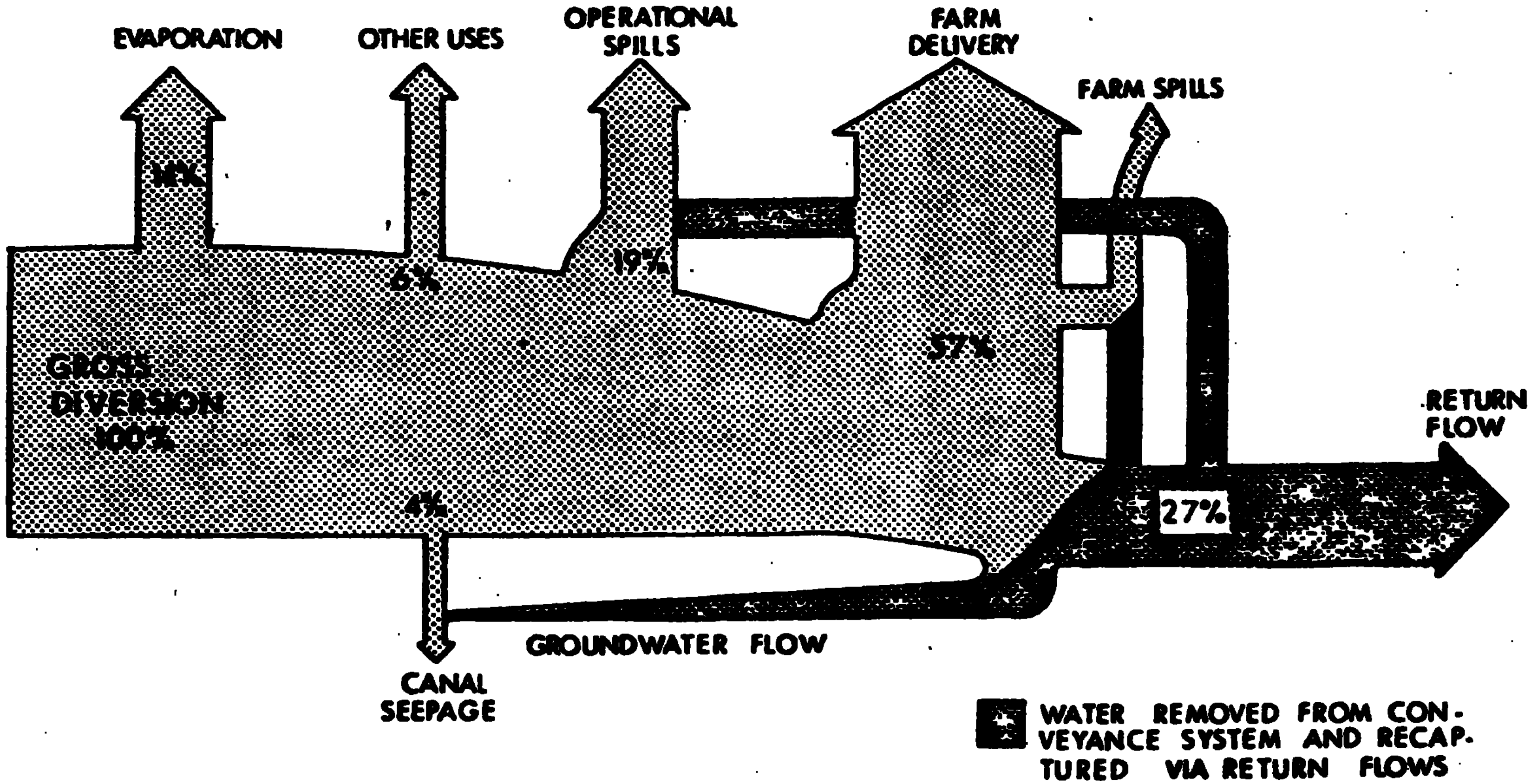
The "bottom line" in the whole question of delivery system design is irrigation efficiency levels. Estimates vary (Alberta Environment, 1982; ECA, 1979), but irrespective of source, it is clear that improving irrigation efficiency levels would play an important part in restricting the rate of growth of water use in agriculture.

And this is slowly happening. Millions of dollars per annum are now being spent on irrigation rehabilitation on the Prairies. These expenditures translate into higher irrigation productivity levels because more water is now reaching the farm gate.

2.2.3 On-Farm Technologies

Water use can also be controlled to some extent by the on-farm method of application. Flood irrigation for example, can be a low cost system but water may be nonuniformly distributed and erosion can be a problem. Wheel roll and center pivot systems (including low pressure sprinklers) offer greater control of water use but only by absorbing higher capital and/or labor costs. Drip irrigation is potentially the most

Figure 2.1
WATER USE IN IRRIGATION



NOTE: PERCENTAGE DISTRIBUTIONS BASED ON STUDY OF EASTERN IRRIGATION DISTRICT.

Source: Alberta Environment (1984) Summary Report, South Saskatchewan River Basin Planning Program Planning Division, Calgary water efficient system because a relatively small area is wetted, thereby reducing evaporative losses and runoff (Jensen, 1980). However, problems of clogging and the fact that drip systems have no advantage over conventional systems for many crops (e.g., forages, cereals) suggests that drip irrigation is unlikely to completely replace other irrigation methods, despite its efficiency advantages.

Other on-farm technologies which could serve well to reduce water use include the selection of crop varieties that are more resistant to dry conditions and improved control of phreatophytes (water-loving weeds) by means of herbicides.

2.2.4 Scheduling

Improved water management is also possible by irrigation scheduling; both system and on-farm. The benefits of scheduling at the District level are substantial and include:

- more efficient use of water conveyance and distribution systems;
- reduced diversion and pumping requirements;
- reduced probability of system shutdown due to water shortages (ECA, 1979).

With scheduling, more water is available for irrigation. Design criteria for the system can be reduced because water is distributed more efficiently. Further, by matching water supplies to farm demand less water is spilled and salinity problems can be reduced.

On the farm, the scheduling of irrigation water to correspond to farm demand will result in yield and quality improvements. In addition, there is a reduced requirement for drainage and subsequent disposal of saline water.

2.2.5 Pricing

The price presently charged for water for irrigation across Canada is generally tied to the cost of various irrigation services, not the water itself.

For example, in Alberta the basic cost of water to both Irrigation Districts and non-District irrigators is the cost of obtaining a license from Alberta to divert water. These costs ostensibly represent the cost of processing a license application, and are dependent upon the annual quantity of water diverted as indicated following:

1 - 100 acre feet	- $1 for each 10 acre foot increment
101 - 1,000 acre feet	- an additional $5 for each 100 acre foot increment
1,001 - 10,000 acre feet	- an additional $5 for each 1,000 acre foot increment
10,001 - 20,000 acre feet	- an additional $10 for each 1,000 acre foot increment
20,000 acre feet - up	- an additional $5 for each 1,000 acre foot increment

In turn, Irrigation Districts generally finance their own operations by charging individual irrigators for water. Again, the charge is for the service, not the water itself. Individual Districts have a variety of methods of charging for water but each District has a basic levy charge which is based upon assessed irrigable area within the District (Table 2.1). Assessed irrigable area is that area suitable for irrigation to which the irrigation district has provided water service. The individual irrigators are charged the annual levy whether they irrigate or not. Districts also have a variety of other methods of charging for water including "final water agreements", "special water agreements", "terminable water agreements", and "pumping agreements". Outstanding rehabilitation requirements, however, suggest that the farm levies have been insufficient to cover required system maintenance.

The rehabilitation of existing irrigation works (in Alberta) is funded in the following way: The upgrading of the reservoir, division and headworks system is almost entirely the responsibility of the provincial government. Upgrading of the water distribution system is a cost-shared program with 86 percent funded from government sources and 14 percent from farmers' contributions (Underwood McLellan, 1984). The 14 percent share, while seemingly small, commits farmers financially to the process of improving water use efficiency through existing system improvements.

2.2.6 Metering

As noted above, each Irrigation District generally has a basic levy charge which is based upon assessed irrigable area within the District. The charge effectively guarantees the irrigator at the farm gate 1.5 acre-feet per acre of water throughout the irrigation season (Environment Canada (EC), 1977). This guaranteed gross diversion is the extent to which water use is now metered. More efficient water use would result if the levied price was based on the quantity of water actually used rather than a fixed volume (ECA, 1979).

2.2.7 Public Information

Finally, a good example of the type of public information program which can be very useful from a water demand management perspective is the South Saskatchewan River Basin Planning Program. The purpose of the SSRBPP was to develop criteria to evaluate various possible water use alternatives using a multiple use, multiple objective approach. The real value in the SSRBPP study (and others like it) is that it clearly identifies the water use options available (e.g. irrigation versus recreation versus industry) and the tradeoffs that are required once a certain water use option is selected.

Table 2 1

ALBERTA AND B.C. - AGRICULTURE IRRIGATION DISTRICT WATER RATES PER HECTARE

(18" gross diversion)

Year	Alberta													B.C.
	St. Mary River	McGrath	Raymond	Taber	Western	Eastern	Bow River	Mountain View	Leavitt	Aetna	United	Lethbridge Northern	Ross Creek	S.E. Kelowna
1940	2.47	3.09	1.11	2.22	1.23	3.95	3.71	0.74	---	---	1.24	3.09	---	36.08
1960	3.34[a] 4.94	6.18	2.47	6.18	[illegible]	5.93	4.94	1.23	n/a	---	2.10	4.94	2.47	52.51
1970	5.68[a] 8.16	6.18	3.09	7.41	[illegible]	6.67	7.41	1.48	3.09	2.47	3.09	7.41	2.47	56.98
1980	20.26	12.36	14.21	18.53	12.36	12.36	12.36	4.94	9.27	4.33	6.80	19.77	6.18	123.55
1984[b]	29.64[d] (12.00)	14.82 (6.00)	16.06 (6.50)	27.17 (11.00)	16.67 (6.75)	17.29 (7.00)	24.70 (10.00)	12.84 (5.20)	19.76[c] (8.00)	14.82 (6.00)	8.03 (3.25)	30.88 (12.50)	7.41 (3.00)	n/a

[a] SMRID-W and SMRID-E respectively.

[b] Per acre rates indicated in brackets.

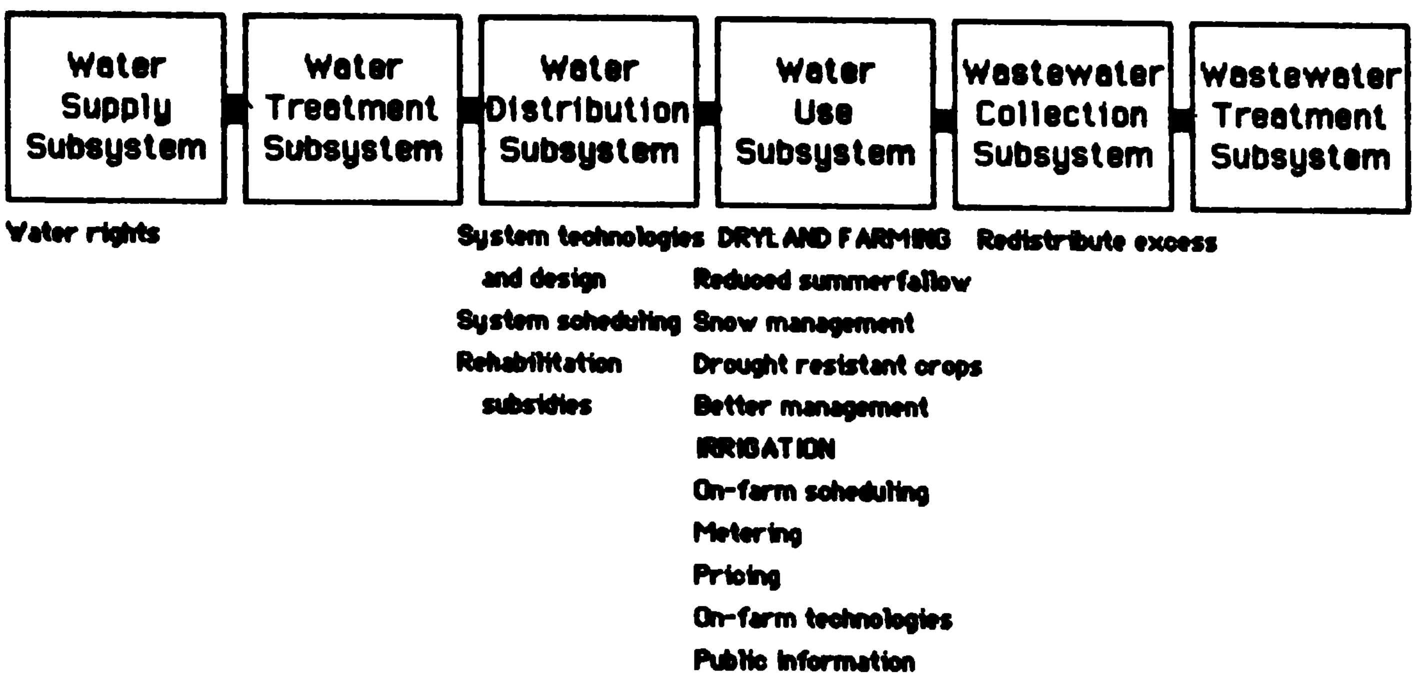
[c] Plus a $4.94/ha annual levy for farmers with a pipeline.

[d] Plus a $43.47/ha annual levy for farmers with a pressure pipe system.

2.3 Summary of Agricultural Measures

The measures discussed above are summarized in Figure 2.2. The principal component of the water system on which the measure is targetted is noted. The implications of some of the apparent options and opportunities are addressed in Section IV.

Figure 2.2: Summary of Agricultural Measures



III EXISTING AND POTENTIAL DEMAND MANAGEMENT MEASURES: MUNICIPAL AND INDUSTRIAL

The focus of this section is on identifying measures which are currently in use or which could be used to manage municipal and industrial demand for water and for wastewater treatment. These will be discussed taking each part of the water system in turn.

3.1 Water Supply and Treatment Subsystem

3.1.1 Direct Regulation of Source Withdrawals

Managing source withdrawals can occur through regulation of access. One example from western Canada is the use of rights to water withdrawals. Another example in a riparian province, Ontario, is that the Ministry of the Environment requires an approval for supplying more than five homes or a permit for withdrawing more than 50,000 litres/day of groundwater.

However, such regulations can only work well for supplies which are documented. While much measurement of water supply has been done, mapping of groundwater systems has been generally overlooked. Such mapping would greatly improve management capability.

3.1.2 Matching Water Quality and Use

Estimates of demand for water are based for most uses on a presupposition about water quality. There is no need to use potable water for all water purposes. This principle is recognized for households in many areas in the United Kingdom; a storage tank is required in the roof space to feed non-potable supplies such as toilets, hot water cistern, etc. to reduce the effects of peaking on the distribution network

(Jamieson and Million, 1980). Brackish water or saltwater is beginning to be used for cooling of power plants in Finland, Sweden, the United Kingdom, and the United States (Postel, 1984, p. 46). South African water policy specifically calls upon all users to "make use of the minimum quantity of water of the lowest acceptable quality for any process" (Postel, 1984, p. 46). Such an approach in Canada could reduce the demand on existing water systems by transferring some uses, which currently use high quality water, to non-potable supplies.

3.1.3 Public Cost Information

While most municipal water supply systems, including those which are metered, charge on an average cost basis, the system itself must be constructed to meet maximum-day and peak-hour demands, not just average demands. Maximum-day demands from 1.5 to 3.5 times average-day demand, and peak-hour demands from 2.0 to 7.0 times average-day demand, are quite common (Fair and Geyer, 1971). Therefore, the capital and operating costs involved in providing for peak demands are much higher than for average-day demands. Because charging currently is done on an average-cost basis, the cost of providing for maximum-day demands is often not estimated and less often public knowledge. Information about such peaking costs and also of incremental average-day demand costs, if provided to the public and to policy-makers, could assist in improving decisions about use.

3.2 **Distribution Subsystem**

3.2.1 Proper Installation, Leak Detection, and Maintenance

In areas where freezing and soil movement is a problem, careful installation of distribution lines is necessary. Leakage losses from the distribution system, while inevitable, can be minimized through a routine maintenance and leak detection program (Hennigar, 1984; Kroushl, 1984). A California study found that almost 99 percent of underground leaks in urban water supplies could be economically detected and recovered using existing technology (State of California, 1984, p. 31). This contrasts rather sharply with findings of the Prairie Provinces Water Demand Study that in some municipalities, over 40 percent of total water pumpage could not be accounted for by flows received by the various customer groups (Tate, 1984, pp. 5-6).

3.2.2 Regulation of Water Pressure in New Development

Operating water pressures in a municipal system are generally between 345 and 834 kilopascals (50 to 120 psi) with an objective of 140 kpa (20 psi) under fire flow conditions. Reducing high main pressures would lower consumption for flow dependent uses, as water flow rate from a fixture at a fixed setting is related to the square root of the pressure drop. Principal flow dependent uses at fixed settings include system leakage, certain types of equipment e.g. residential dishwashers, and some outside uses.

However, substantial reduction of main pressure in existing areas may not be practical because of the implication of reduced fire flow. In new development, an attempt to limit water pressure to 345 to 420 kpa (50 to 60 psi) would reduce both leakage and use somewhat. The HUD studies suggest the reduction in residential use for a drop of 205 to 275 kpa (30 to 40 psi) would be about 6 percent (U.S. Dept. of Housing and Urban Development (USHUD), 1984).

3.3 Water Use Subsystem

3.3.1 Metering of Use

While many studies of metering have been conducted, few have separated commercial, industrial and residential users within one city or district over the same time period. The HUD study, however, attempted to determine the effect of metering on residential water use by comparing water use in similar homes in the same area of Denver having had metering or flat rates for some time (USHUD, 1984). Winter water use showed little difference, but summer metered consumption was reduced significantly even though annual water costs were similar for both classes. Metered outside water use over a three-year period was reduced by 20 percent.

In addition, outside water use in both metered and flat rate homes was linearly related to the monthly net evapotranspiration (water requirement in addition to rainfall) of the vegetation.

3.3.2 Water Rate Structures Better Reflecting Costs

Water rate structures are a very important component of demand management. Such structures are possibly the most important influence by a supplier on industrial water demand. It is difficult to convince many water users that water use is important or that new water supplies are costly when their water bills confirm the exact opposite. Effective rate structures, however, presuppose installation of water meters (section 3.3.1).

Grima (1984) showed that water rates in Ontario in the recent past have not been related well to costs of providing supply. Nevertheless, a rate structure should closely reflect the costs of construction, operation and maintenance of the entire system, including peaking costs and the costs of wastewater collection and treatment.

This was done, except for reflecting peak demand costs directly, in the Regional Municipality of Durham. A 33 percent reduction in demand per customer and hence in water supply capacity requirements was observed (Loudon, 1984).

However, the factor not reflected directly in the Durham rate structure, peak demand, is perhaps the most important factor affecting costs. Such demands determine plant sizing and additions, and also are responsible for large electrical power demands and costs. Costs of providing for peak demands have traditionally just been averaged in with other costs by customer class. This results in inequity, both by not informing those contributing to the peak of the real costs of their use, and by charging those not contributing to the peak demand.

Recently, however, a number of utilities in the U.S. have modified rate structures to improve equity and, at the same time, to charge a better approximation of the real costs of providing for peak demands. One of those found to significantly improve equity is referred to as an excess-use charge, incurred by water users greatly exceeding their winter base consumption during peak demand months. Use of such a charge in Fairfax County, Virginia, was estimated to reduce maximum-day water demand by about 12.5 percent from 1.6 times average-day to 1.4 (Griffith, 1984).

3.3.3 Constructing New Structures to be More Water-Efficient

(a) Installation of Low-Flush Toilets

While common toilets use about 21 l. per flush, major North American manufacturers do market models requiring 13.25 l. or less. A recent extensive study showed that households equipped with such low-flush toilets consumed about 30.3 l/capita/day less than those with standard toilets (USHUD, 1984, pp. 4-5, 4-6). This represents a 36 percent reduction in consumption.

A typical West German toilet requires much less water than even our so-called conserving ones, only 9 litres per flush, or a 57 percent decrease in consumption over conventional North American models (World Environment Report, 1984a). Nine litre toilets have also been legislated for many years in the United Kingdom (Jamieson and Million, 1980).

(b) Installation of Low-Flow Showerheads

The HUD sample of typical non-conserving showerheads (maximum measured flow greater than 11.4 l/min.) had an in-use average flow rate of 12.9 l/min. This was much higher than for a mixed set of low-flow showerheads which averaged 44 percent less, with some specific models reducing consumption by 62 percent.

(c) Installation of Minimal-Water-Use Toilets and Showers

New products have been developed using advanced technologies which reduce water consumption significantly more than those discussed above. There is a good potential for development of such products which cut water demand substantially and are acceptable to users. This is especially so for toilet technology; showering is partially a volume dependent activity, and very low flow rates cause user dissatisfaction. Currently, however, advanced technology fixtures are much more costly and complex than conventional ones.

(e) Installation of Combinations of Water-Efficient Equipment

In many areas in the U.S., plumbing regulations require installation of water-efficient equipment in new homes. A recent HUD study compared water use in homes containing 13.25 l/flush toilets, 11.4 l/min. showerheads, and low flow (10.4 l/min.) faucets, with a matched control group in the same vicinity. The HUD study recommends the expected water savings they have documented--49 l/capita/day and 62 l/capita/day for single and multi family dwellings respectively--be adopted as predicted values for the effect of installation of low-flush toilets and low-flow showerheads on per capita residential water use.

3.3.4 Retrofitting of Existing Buildings

(a) Reducing Functional Consumption

Modification or retrofitting of water fixtures to reduce water consumption has been attempted in many municipalities, especially in the United States. The effects of such programs have not been well documented, and most evaluations which do exist are of one specific municipality. After the Regional Municipality of Waterloo, the HUD study was the second, and largest scale attempt to document effects of retrofitting and relate these to the context and to the implementation program.

There are two primary factors to be considered: the effect of retrofitting on resource consumption, and the installation/retention rates of the devices.

(i) Resource Consumption

Utility programs to retrofit toilets with displacement bags or bottles, and showers with flow restrictors are estimated to reduce water consumption by 15 to 25 l/capita/day and energy consumption/capita by 420 to 630 MJ (11.4 to 17m^3) annually for gas water heaters (HUD, 1984, p. 6-5). Greater reductions should result either from use in toilets of dams or of devices to close the flapper valve prematurely (about 4.5 l/capita/day more for dams) or from use on showers of replacement showerheads. The savings noted are those estimated from retrofit devices alone; controls were used for extraneous factors and an allowance was made for other components, e.g. leak detection tablets, conservation information, of some programs.

(ii) Installation/Retention Rates

The installation and retention rates of the devices are also important in assessing a retrofit program. There are many factors which determine the extent to which installation of retrofit devices takes place. Some of these include:

(1) the perceived importance of the program in extending existing water supplies or wastewater treatment capacity,

(2) whether installation was voluntary or mandatory,

(3) how the program was promoted and the devices distributed,

(4) whether installation was conducted by utility or trained personnel or by the owner, and

(5) if by the owner, the ease of correct installation.

Retention rates are related to all of the above as well as to:

(6) satisfaction with device performance.

(7) failure rates of each device, and

(8) the rate of purchase of replacement fixtures.

It appears that installation rates in residential buildings can range all the way up to about 80 percent in single family buildings and 100 percent in multiple dwellings (including motels) for a mandatory program with utility installation (HUD, 1984, p. 6-6). There is no evidence that a voluntary program can achieve greater than a 60 percent installation rate with 50 percent a more realistic maximum under non-drought conditions.

For any one device, it might be expected that retention rates would be constant. Only two studied utilities, North Marin County and North Tahoe California, used an identical device and evaluated retention rates. Surveys concluded that the 11.4 l/min Nolan celcon shower restrictor had a five-year retention rate over 80 percent in each case. Different toilet devices had 5-year retention rates in houses ranging from 59 percent (dams-North Tahoe) to about 77 percent (2 bottles each 0.95 l., 1 bag 2.7 l.).

(b) Reducing Leakage

Retrofitting of apartment buildings has also been studied in the Washington D.C. area. Toilet leakage appears to be a major problem; even in some new buildings, the rate averaged 178 l/day/unit, or 91 l/day/toilet. (In a separate study of single family homes, 17 percent of non-conserving toilets were found to be leaking. This percentage might be even higher when low-flush toilets are used or in apartment buildings).

Replacing ballcocks and flapper valves is the best method for correction of toilet leakage. This measure alone was found to reduce residential consumption by up to 178 l/day/unit or 89 l/capita/day, or by over 40 percent.

3.3.5 Regulation of Water Pressure

Although the saving was lower than previous estimates, a reduction of 205 to 275 kpa (30 to 40 psi) would reduce residential leakage and use about 6 percent, according to the HUD studies (see section 3.2.2 above). This reduction could be accomplished by use of pressure regulating valves in buildings in high pressure areas. Such a measure could be implemented most easily for new developments in high distribution pressure areas where the distribution pressure cannot be reduced; existing low rise developments could also install pressure regulating valves. These valves, by regulating water pressure, can reduce wear on water fixtures and thus maintenance costs as well.

3.3.6 Use of Insulated and Heat-Traced Services

The use of "bleeders" (continuously flowing lines) to prevent line freezing results in major losses for water utilities in northern communities and increases demands on wastewater treatment plants. Ontario Ministry of the Environment reviews have found bleeders responsible for up to 50 percent of winter potable water consumption. The proper solution is use of insulated and heat-traced services (Robinson et al, 1984).

3.3.7 Recycling of Wastewater

Recycling means use by the same household, business, or plant two or more times in a coordinated planned manner, sometimes with partial treatment between uses (Viessman and Welty, 1984, p. 241). The lowering of energy costs for pumping, water heating, and wastewater treatment may be more significant than the reduction in water cost by recycling.

(a) Residential

By collecting blackwater (toilet water waste) and gray water (other wastewater) separately, the graywater in principle can be reused before being used finally for lawn irrigation or being disposed of via the sanitary sewer system. Such re-use raises many serious concerns about the effects on the health of humans and landscapes (Farallones Institute, 1979, pp. 97-109).

(b) Industrial

Significant advances have been made in the recycling capabilities of cooling tower recirculation systems: the average recycle rate for cooling water in 1972 was 4.1, but by 1978 this had risen to 7.1 with some companies claiming 27:1 (Viessman and Welty, 1984, p. 237). Thermal power plants can reduce their requirements by 98 percent or more by using recycled water in cooling towers rather than the typical once-through cooling methods (Postel, 1984, p. 42). A Canadian vinyl fabric manufacturer, by installing a cooling tower recirculation system, reduced total water consumption over 90 percent while increasing production by 60 percent (Krueger, 1984).

Other industrial recycling practices include treating some or all process wastewater for re-use as other process make-up water e.g. cooling towers, recirculation systems with discharge a low percentage of flow, and cascading effluent from one process as input for another with or without intermediate treatment (Viessman and Welty, 1984, p. 244). A Canadian heat exchanger manufacturer reduced water consumption by one-third, with a payback period of less than one year for the system modification (Paul, 1984).

The degree of recycling can affect water use tremendously. Manufacturing a ton of steel may take as much as 200,000 litres or as little as 5,000, and a ton of paper may take 350,000 litres or only 60,000. Moreover, recycling the materials themselves can also greatly cut industrial water use and wastewater discharges. Manufacturing a ton of aluminum from scrap rather than virgin ore, for instance, can reduce the volume of water discharged by 97 percent (Postel, 1984, p. 42).

On a national level, adoption of recycling technologies can have a major impact on water use. Israel's adoption of what amounts to a "best available technology" standard for industrial water use efficiency has reduced water use per unit value of industrial production by 70 percent over the last two decades. Sweden's industrial water use, primarily for pulp and paper, quintupled between 1930 and the mid-sixties; however, strict environmental protection requirements for the industry brought widespread adoption of recycling technologies, which, despite a doubling of production, cut its total water use by half--a fourfold increase in water efficiency (Postel, 1984, pp. 42-43). The United States is expected to more than double pulp and paper production between 1981 and 2000, while reducing total water usage about 4 percent; use of developing technologies could reduce water usage another 28 percent (Wyvill, Adams, and Valentine, 1985). The exact potential for such technologies in Canada is not known; however, when other countries are reducing water use per unit of output by 75 percent in resource-based industries such as pulp and paper, and Canada is not a known leader in recycling efforts, there must be much room for increased water use efficiency.

3.3.8 Education

Education about water conservation and management is seen as desirable both by the public and by water experts (DeYoung and Robinson, 1984). In addition, many initiatives in this area have been taken.

Water system management materials suitable for Canadian school system environmental studies programs have been developed by the American Water Works Association (Bock, 1984). A water use index is currently published in the local daily newspaper by the Regional Municipality of Waterloo during summer months (Pawley, 1984). A number of utilities insert with water bills pamphlets on water use and on suggestions for conservation. Other education activities also exist. However, there is little documented evidence of the effects on water demand of such programs by themselves.

Part of the reason for this is that most education activities are undertaken as part of another specific project. In such cases it may be better to regard education programs not as measures which directly affect demand, but rather as both necessary public relations activities and integral components of other specific management measures.

3.4 Wastewater Collection Subsystem

3.4.1 Reducing Infiltration

Wastewater collection and treatment systems are also designed to meet maximum day and/or peak hour demands. A major problem in meeting these demands is caused by extraneous flow. Extraneous flow may result from infiltration of defects by groundwater, or from inflow of surface and/or stormwater into the system.

Wastewater system expansions may be reduced through proper design, construction and routine preventive maintenance. Specific actions which can be taken include avoidance of areas of high water table for development, regular sewer inspection, and sewer relining or replacement (Benninger, 1984a; St. Onge, 1984).

3.4.2 Reducing Inflow from New Development

While it may be assumed that new development will have separate storm and wastewater systems, other measures deal specifically with connections of foundation drains, sump pumps or roof gutters to the wastewater collection system. Effective action consists not just of prohibiting such connections, but also of enforcing the prohibition. One measure which can be used where gravity connections to storm sewers are not practical is to require sump pumps draining weeping tile to be installed in all new residential construction, as has been done in Waterloo, Ontario; this reduces any temptation to make illegal connections to the sanitary sewer. Although enacted for a different purpose - drier basements, the policy of Cambridge, Ontario, to provide storm sewer connections to new residential development and to require sump pump pits should have a similar effect.

New development in some communities is specifically designed to facilitate retention and percolation of stormwater, reducing the load on storm sewers and streams. Such practices help manage the demand for stormwater facilities.

3.4.3 Reducing Inflow from Existing Development

The other part of the problem is correcting existing connections, which were almost a standard practice for many years. Even in areas where they were technically illegal, they were regarded often as minor sins especially if committed when the building inspector was not present. Now, while legislation such as the Ontario Municipal Act gives them authority, municipalities have been reluctant to force homeowners to correct inflow problems caused by improper connections. Fort Erie, Ontario, however, has done so and gave property owners a choice of correction arrangements: dealing with a government-tendered contractor at a fixed price, negotiating with a contractor of their own choice, or having the city order the work done and billed through city taxes (Robinson et al, 1984).

3.5 Wastewater Treatment Subsystem

3.5.1 Costs

As effluent volumes and levels of treatment increase, wastewater treatment costs rise rapidly. Reduction of wastewater flows can reduce treatment costs significantly in three ways. Reducing the peak volume of effluent water processed can defer the capital costs of expanding existing facilities; in most plants, lower flow rates provide for increased efficiency of plant processes due to higher concentration of waste, and lower operating costs or improved effluent quality; and lower flows also reduce untreated water overflows if or when the plant is overloaded. In the latter cases, the reduced costs are environmental rather than financial. Public cost information could assist.

3.6 Wastewater Re-use

Re-use refers to use by someone other than the original user, especially in an uncoordinated and random way (Viessman and Welty, 1984, p. 240). The water may be re-used without treatment where lower quality is acceptable, or may be reclaimed (treated for re-use) for the same or for a different purpose.

3.6.1 Direct Re-Use

For direct re-use, the wastewater is usually treated and then piped directly into a supply system.

The supply system could be one for potable water. The City of Denver has planned for direct potable re-use by the end of this century, has completed pilot studies, and is currently testing effectiveness and safety of a 1mgd demonstration plant and conducting studies on public attitudes and on appropriate methods of conducting a public education campaign (Lauer, Rogers and Ray, 1985; Lohman and Milliken, 1985). South African engineers estimate the cost of treating raw sewage to a quality suitable for drinking to be competitive with another surface source (World Environment Report, 1984b).

Reclaimed municipal water may also be appropriate for non-potable uses. One of the principal benefits of non-potable re-use is the preservation of higher quality water for potable consumption. Such domestic non-potable re-use effectively requires a dual distribution system for potable and non-potable water.

Re-use as cooling water and as boiler feed water are two principal industrial applications of reclaimed wastewater. For example, a nuclear power plant built in the desert outside Phoenix, Arizona, will draw on nearby communities' treated wastewater, which the plant will re-use 15 times (Postel, 1984, p. 42).

Re-use of municipal wastewater for irrigation has been endorsed by the Environment Council of Alberta to reduce deterioration of river water quality (ECA, 1979, pp. 66-67). Additional benefits include savings in energy, treatment costs, groundwater supply augmentation, and nutrient utilization, but some level of treatment of the wastewater may be necessary because of public health concerns. In 1981, Israel was already re-using 30 percent of municipal wastewater, mostly for irrigation, and by the turn of the century, projects re-using 80 percent (Postel, 1984, p. 47).

Studies in Alberta have shown irrigation from a sewage lagoon has had no marked effect on soil chemistry and no identifiable impact on groundwater (Alberta Environment, 1978). Feasibility studies are being conducted on piping treated sewage from Calgary to irrigate 100,000 acres in southern Alberta (Thompson, 1984).

Stormwater collected separately from wastewater can also be reclaimed for non-potable uses with appropriate physical treatment depending on the required quality; uses range from high quality steam boiler feedstock to industrial cooling to lawn irrigation, fire protection and landscape ponds (Viessman and Welty, 1984, p. 250-252).

3.6.2 Indirect Re-Use

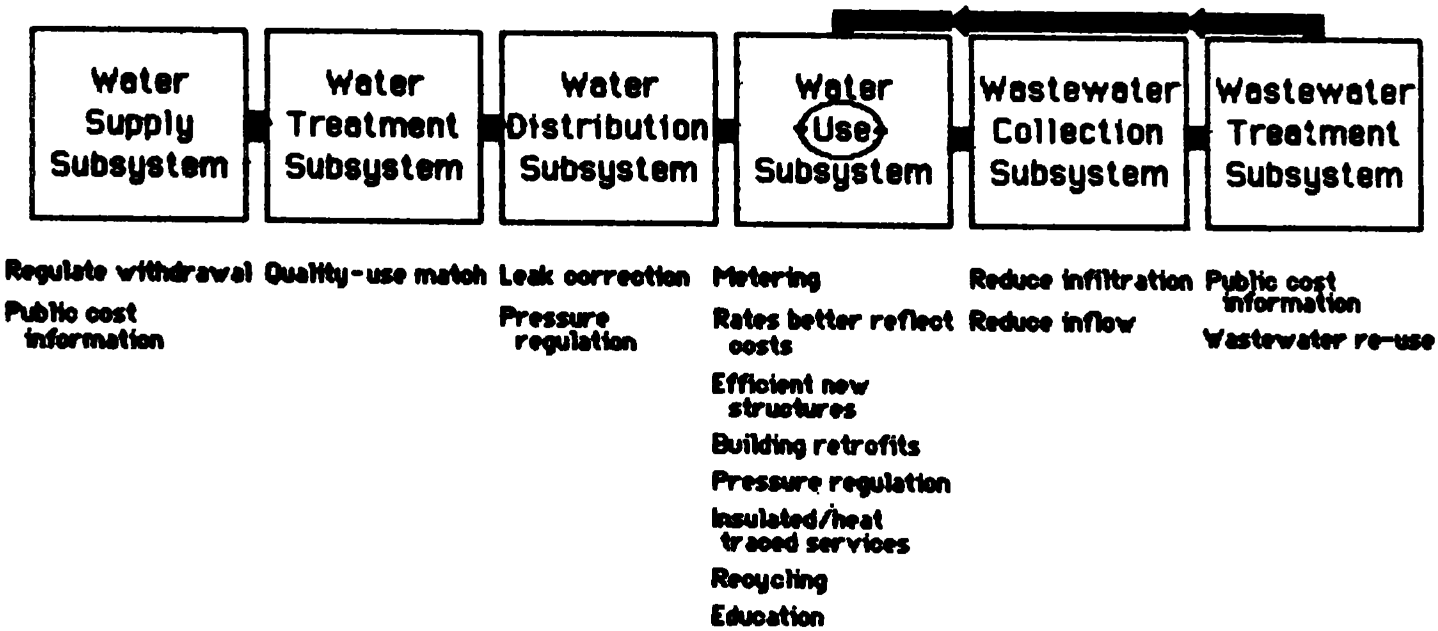
With indirect re-use, one or more stages, e.g. discharge or mixing with another water supply, are inserted between treatment and re-use. A common and accepted example of indirect re-use is that of water users with intakes downstream of a wastewater treatment plant discharge outfall.

Another example is the artificial recharge of groundwater aquifers with reclaimed water for storage, dilution, and later withdrawal and re-use. However, this form of re-use for drinking water is subject to the same concern as direct re-use: what chemical constituents are acceptable in potable water and in what concentration? High quality reclaimed water is already being stored in aquifers in California, but quality standards for potability have not yet been accepted (Viessman and Welty, 1984, p. 243).

3.7 Summary of Municipal/Industrial Measures

The measures discussed above are summarized in Figure 3.1.

Figure 3.1: Summary of Municipal/ Industrial Measures



IV WATER SYSTEM EFFICIENCIES: IMPACTS & IMPLICATIONS

4.1 Introduction

The potential importance of additional water use efficiencies in Canadian agriculture must be emphasized because

1. agriculture is the largest single consumer of water in Canada, particularly on the Prairies, and
2. the potential for major improvements in water use efficiencies in agriculture is still immense.

Further implications beyond those discussed above are provided for two other longer term approaches to managing industrial and municipal demand: matching water quality and use, and constructing new structures to be more water-efficient.

A summary of potential water use efficiency improvement potentials is provided at the end of the chapter.

4.2 Efficiency Measures: Agriculture

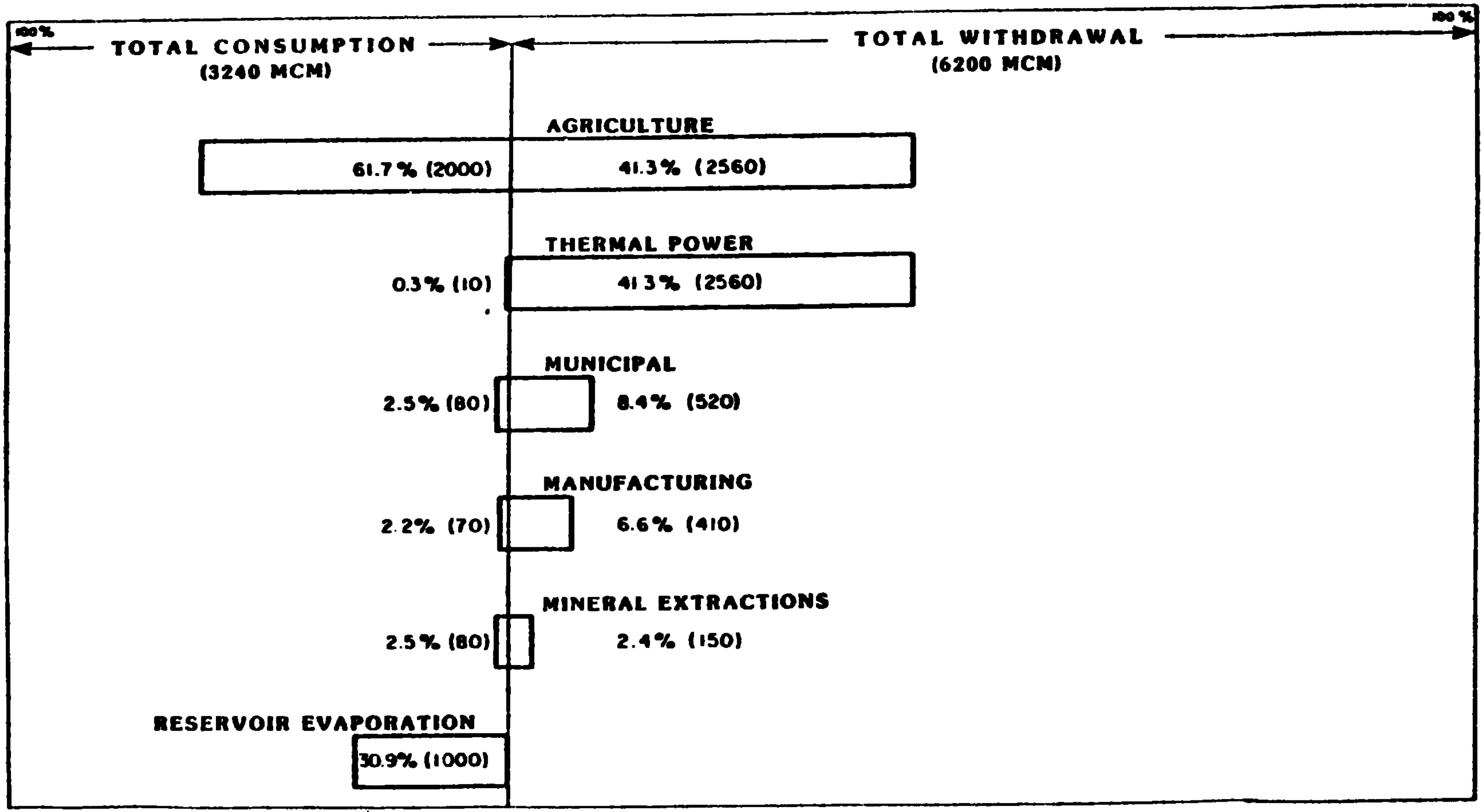
The dominant role of agriculture in both the withdrawal and consumption of water in Canada is illustrated in Figure 4.1 and accompanying Table 4.1.

The principal implications of increased water use efficiencies in agriculture are considered with respect to the following: (1) dryland cultural practices, (2) water rights, (3) delivery systems, both on-farm and off-farm, (4) scheduling, and (5) pricing and metering.

FIGURE 4.1

WITHDRAWAL AND CONSUMPTIVE USES IN THE PRAIRIE REGION, 1981

(million cubic metres)



Source: Environment Canada, Submission to the Inquiry on Federal Water Policy, Regina, 1984.

4.2.1 Dryland Cultural Practices

Many on-going changes in dryland cultural practices are having an obscure but very real impact on water use and, hence, groundwater levels and streamflows. These changes include shifting cropping patterns, tillage practices, harvesting technology, fertilizer practices, weed control practices, and crop genetics. The projected qualitative impact of these measures on water use during the next 15 years is indicated in accompanying Table 4.2.

Shifting cropping patterns, particularly away from summerfallow, are, however, very dependent upon relative prices and marketing opportunities[1] (Ed Braun, Pedocan, and Marv Anderson (Ed Braun et al), 1984).

The role of water management in dryland agriculture is particularly important because its impact could be so pervasive: very, very modest improvements in dryland water use efficiencies on almost 40 million hectares of cropland and 155,000 farms on the Prairies would, in addition, reduce on-going soil degradation on the Prairies yet still increase its drought-proofing capability (Ed Braun et al, 1984). (Compare Table 4.3 with Table 4.4)

Facilitating changes in dryland cultural practices might be a particularly attractive water demand management strategy because the public cost of these water-saving technologies is relatively low. The public research expenditure required to develop drought-tolerant crops is an obvious exception.

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[1] In this context, there is still the age-old controversy over the "bias" in the Canadian Wheat Board market delivery system which, to some extent, still considers summerfallow a crop in its quota acreage calculations.

TABLE 4.1

WITHDRAWL AND CONSUMPTIVE USE OF WATER, CANADA, WESTERN CANADA, PRAIRIES, AND BRITISH COLUMBIA, 1980

(millions of litres per day)

Withdrawal	Canada	Share of Total Use (%)	Western Canada	Share of Total Use (%)	Prairies	Share of Total Use (%)	B.C.	Share of Total Use (%)
Municipal & rural domestic	12,410	11.1	2,815	10.9	1,739	10.6	1,076	11.5
Manufacturing	38,156	34.2	6,502	25.3	860	5.3	5,642	60.3
Mining	4,443	4.0	2,616	10.2	2,339	14.3	277	3.0
Agriculture	8,296	7.4	7,446	28.9	5,878	35.9	1,568	16.8
Thermal	48,400	43.3	6,344	24.7	5,557	33.9	787	8.4
TOTAL	111,705	100.0	25,723	100.0	16,373	100.0	9,350	100.0
Consumption								
Municipal & rural domestic	2,075	22.5	752	13.8	470	11.5	282	20.7
Manufacturing	1,567	17.0	381	7.0	154	3.8	227	16.7
Mining	792	8.6	574	10.6	465	11.4	109	8.0
Agriculture	4,409	47.9	3,678	67.7	2,941	72.2	737	54.2
Thermal	364	4.0	48	0.9	42	1.0	6	0.4
TOTAL	9,207	100.0	5,433	100.0	4,072	100.0	1,361	100.0

Source: Environment Canada. *Canada Water Year Book 1981-1982*.

And, finally, one important side-effect of these anticipated changes in dryland agriculture is that they should also reduce the public pressure for more irrigation on the Prairies. Under this scenario, irrigation, ceterus paribus, would effectively become a relatively less profitable on-farm intensification option.

4.2.2 Water Rights

Water rights are the fundamental non-market regulatory mechanism presently utilized to allocate water, both between sectors and within the agricultural sector.

In Alberta at least, water rights give irrigation farmers a quasi-legal right to 1.5 acre-feet of water per acre, irrespective of how efficiently it is used. It is analogous to a non-transferable production quota. It cannot be bought, sold, or traded. It cannot be disassociated from the "assessed" irrigable acreage in question. As such, there are no built-in incentives to encourage water use adjustments (or efficiencies) over time.

Perhaps the single most effective policy change required to facilitate more efficient water use in agriculture would involve making all water "quotas" terminable and/or transferable between farmers (land parcels), subject to District approval.

The nature and extent of the efficiencies which could be secured by this institutional change are, however, unknown. An analysis of efficiency differences between transferable and non-transferable quotas in, say, the dairy industry would be instructive.

A more extreme change would challenge historic riparian law whereby water rights are allocated (in practice, for perpetuity) successively to those who put water to a "beneficial use". For example, to reestablish public "ownership" over socially

TABLE 4.2

SUMMARY OF PROJECTED DRYLAND CULTURAL PRACTICES AND IMPLICATIONS FOR WATER USE ON THE PRAIRIES, 1985 - 2000

Item	Brown and Dark Brown Soil Zones		Black and Other Soil Zones	
	Summary Description	Impact on Water Use	Summary Description	Impact on Water Use
Cropping Patterns	Minor increase in crop rotation length; increased special and pulse crop production	Positive impact from the aspect of diversification and stability of summerfallow crop yields	Significant increases in crop rotation length; increased special and pulse crop production	Diversification will mitigate drought; decrease in summerfallow could accentuate drought in Thin Black soil zone
Tillage	Decreased tillage; substitution of chemicals for weed control; more combined operations at seeding	Positive effect when coupled with innovative harvesting and snow trapping techniques	Decreased tillage; substitution of chemicals for weed control; more combined operations at seeding	Positive effect
Harvesting	Increased standing stubble height; improved distribution of straw and chaff; increased grain drying; decreased burning	Positive effect when coupled with reduced tillage; reduced risk of crop loss due to grain drying	Increased standing stubble; improved straw management; decreased burning	Positive effect
Fertilizer Practices	Major increases in cropped area treated; minor increases in rates; increased banding at expense of broadcast incorporation methods	Positive impact; increased drought tolerance of crops	Major increases in cropped area treated; minor increases in rates; increased banding at expense of broadcast incorporation methods	Positive impact; particularly in Thin Black
Weed Control Practices	Minor increases in herbicide coverage and areas treated with more than one chemical	Positive impact on productivity; decreased competition during critical dry period	Minor increases in herbicide coverage and areas treated with more than one chemical	Positive impact on productivity; decreased competition during critical dry period
Crop Genetics	Minor increases in drought tolerance of recommended crop varieties	Positive impact	Minor increases in drought tolerance of recommended crop varieties	Minor impact in Thin Black; no impact in Other zones

Source: Adapted from darWall Consultants (1983) Historic Trends, Drought and Cultural Practices Study Element No. 8, Saskatchewan Drought Studies, Regina.

questionable water diversions for any purpose (at the expense of other uses), legal recourse to the "public trust" doctrine might be desirable:

> "Dating back to Roman times, (this doctrine) asserts that governments hold certain rights in trust for the public and can take action to protect them from private interests. Its application has potentially sweeping effects since even existing water permits or rights could be revoked in order to prevent violation of the public trust." (Postel, 1984)

Water rights are a provincial responsibility. Nevertheless, federal initiatives could at least encourage study of the social, economic, environmental, and legal ramifications of changes to existing water rights legislation in Canada.

4.2.3 Water Delivery Systems

Delivery systems must be considered at two levels: off-farm (District) systems, and on-farm irrigation systems. The efficiency of each can be measured by looking at **water conveyance efficiencies** and **farm water application efficiencies** respectively.

Regarding existing off-farm water conveyance efficiencies, Table 4.5 is suggestive. An average conveyance efficiency of 60 percent is characteristic of irrigation on the Prairies. Yet a good quality open conveyance system should result in an 80 percent efficiency level; virtually 100 percent for pipe. Eight-100 percent conveyance efficiency levels would, by definition, deliver 20-40 percent more water to the farm gate.

The socio-economic payoff to efficiency improvements of this magnitude is relatively high. Moreover, the relative socioeconomic benefit-cost (B/C) ratio for irrigation rehabilitation is generally better than the corresponding B/C ratio for new projects.

TABLE 4.3

CANADIAN AND PRAIRIE AGRICULTURE, 1981

	Canada	*Prairies*
Total number of farms	318,361	154,816
Number of farms with sales of $2500 or more	271,604	142,023
Number of farms: wheat[1]	55,780	54,579
Number of farms: small grains[1]	52,086	35,188
Improved Area (million hectares)		
Under crops	31.0	24.6
Summer fallow	9.7	9.5
Pasture	4.4	2.9
Total[2]	46.1	37.7
Improved area per farm (hectares)	144.9	243.6
Cropped Area (million hectares)		
Wheat	12.4	12.1
Barley	5.5	5.0
Other grains[3]	3.7	1.9
Total grains	21.6	19.1
Rapeseed	1.4	1.4
Other oilseeds[4]	1.0	0.7
Total Oilseeds	2.4	2.1

Notes: [1] Farms with sales of $2,500 or more, by major product sold.
[2] Including other improved land uses.
[3] Oats, mixed grains, corn, rye, buckwheat.
[4] Flaxseed, soybeans, sunflowers, mustard seed.

Source: Statistics Canada, *1981 Census of Canada*.

Some empirical evidence for the South Saskatchewan River Basin (Oldman River), each developed using an identical methodology, is illustrative: (Marv Anderson, 1983a)

Rehabilitation:	ID No. 1......B/C = 2.2	
	ID No. 2......B/C = 1.9	
New Development	Option 1...B/C = 1.2	
	Option 2...B/C = 1.3	
	Option 3...B/C = 1.4	

More recently public hearings re-affirmed that:

> There was complete agreement... that rehabilitation of existing conveyance structures and facilities was the highest priority in the development of irrigation in southern Alberta [because of] the additional water that would be available if transmission losses were reduced and [because of] the reduction in seepage and the consequent reduction in salinization. (ECA, 1979)

This ignores distributional questions.

With respect to environmental impacts, our tentative conclusion would be similar. The net impact should be more positive for rehabilitation than for new irrigation development on more marginal lands.

Again, however, the jurisdictional ramifications do not make this choice so obvious. Provincial and federal cost sharing agreements in both Alberta and Saskatchewan, at least, are generally more favourable for major irrigation structures (such as new reservoirs and main canals) than for Irrigation District rehabilitation. From a socioeconomic and environmental perspective, this is perverse.

At the farm level, water application efficiencies are heavily dependent upon both the method of irrigation and on the way the irrigation system is managed.

Surface irrigation systems of the border and contour ditch type were the earliest

TABLE 4.4

IRRIGATION IN CANADA, 1971 and 1981

Province/Region	No. of Farms*			Irrigation Farms as % of Total Farms	Irrigated Area (ha.)			Irrigated Area as % of Total Improved Land
	1971	1981	% Change		1971	1981	% Change	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Newfoundland	8	n.a.	-	1.2	50	n.a.	-	0.5
P.E.I.	17	n.a.	-	0.5	219	n.a.	-	0.1
Nova Scotia	160	n.a.	-	3.2	755	n.a.	-	0.4
New Brunswick	138	n.a.	-	3.4	1,267	n.a.	-	0.2
MARITIMES	323	-	-	2.5	2,291	-	-	0.4
QUEBEC	2,418	n.a.	-	5.0	37,609	n.a.	-	1.6
ONTARIO	3,880	n.a.	-	4.7	40,272	n.a.	-	0.9
Manitoba	151	283	87%	1.0**	2,968	6,935	134%	0.1**
Saskatchewan	918	1,277	39%	1.9**	31,372	55,913	78%	0.3**
Alberta	3,678	4,159	13%	7.2**	217,539	393,969	81%	3.1**
PRAIRIES	4,747	5,919	25%	3.8**	251,879	456,817	81%	1.2**
B. C.	5,794	6,706	16%	33.5**	89,468	100,475	12%	10.6**
C A N A D A	17,162	n.a.	-	5.4***	421,519	n.a.	-	0.9***

* Number of farms with at least some irrigation.
** In 1981. All based on farm numbers and farmland areas in 1981.
*** In 1971. Based on farm numbers and farmland areas in 1981.

Source: Statistics Canada, Census of Agriculture, 1971 and 1981.

to be used. As the irrigated area increased and greater efficiency was required, border dyke and furrow systems came into use. Sprinkler irrigation has become increasingly popular over the past 20 years with the major shift to these systems occuring in the period 1960-64. Now about two-thirds of Prairie irrigation is irrigated by sprinkler systems (about one-half of which is center pivots) and one-third is irrigated by surface systems. Sprinkler irrigation is used mainly for the irrigation of intensive crops such as sugar beets, green peas, potatoes, and some cereal grains. Surface irrigation is more typical for pasture, forage crops, and cereals.

The resulting on-farm efficiency rates are presently about 50 percent (Table 4.5). A further shift to sprinkler (and drip) systems would result in still higher on-farm water application efficiency levels.

But most irrigation experts agree that the actual efficiency of water use obtained in the field depends as much on the way the irrigation system is managed as on the type used. Although drip irrigation may be inherently more efficient by design, the wide average range of efficiency for each system—40-80 percent for gravity flow, 75-85 percent for a center pivot sprinkler, and 60-92 percent for a drip system—shows that management is a key determinant. Farmers using conventional gravity-flow systems, for example, can cut their water demands by 30 percent by capturing and recycling the water that would otherwise run off the field. Some U.S. jurisdictions now require these tailwater reuse systems while many U.S. farmers who pump water from aquifers find that a tailwater reuse system is less expensive than pumping additional well water (Postel, 1984).

In Canada, with a low cost (to the farmer) supply of surface water assured at the farm gate, the economics are different; the economic incentives to use water more

TABLE 4.5

ESTIMATED IRRIGATION EFFICIENCIES FOR SELECTED IRRIGATION DISTRICTS IN ALBERTA, 1978

District	Delivery Efficiency*	Farm Efficiency**	Irrigation Efficiency***
	....	percent	....
SMRID West	53	50	27
SMRID East	77	50	39
LNID	60	44	26
TID	72	58	42
RID	45	40	18
MID	45	40	18
UID	40	35	14
Aetna, Mountain View, & Leavitt Districts	40	35	14
OLDMAN RIVER BASIN (average)	64	49	31

* The ratio (or percent) of the volume of water delivered at the farm headgate, by an open or closed conveyance system, to the volume of water delivered to the conveyance system at the supply source(s). Also termed "water conveyance efficiency".

** The ratio (or percent) of the volume of irrigation water transpired by plants plus that evaporated from the soil plus that necessary to maintain a favourable salt content in the soil solution, to the volume delivered. Also termed "water application efficiency".

*** The ratio (or percent) of the volume of water that is beneficially stored in the root zone to the volume of water initially diverted or stored for irrigation. It is the mathematical product of the water application efficiency, the water conveyance efficiency, and (if applicable) the reservoir storage efficiency.

Source: Stanley/SLN Consulting, Oldman River Basin Irrigation Studies, Summary Report, Alberta Environment, Edmonton, 1978, pp. 4-5.

efficiently on the farm are less pronounced.

The net result is that about one-half of the water diverted for irrigation is presently lost to agriculture. It is withdrawn but not consumed (Table 4.1).

This, however, may overstate on-going "losses". If we recognize that return flows to natural systems are not real "losses" and further calculate that return flows account for 15 to 20 percent of the traditional "efficiency" loss, then estimated efficiency levels are somewhat higher, say 60 percent (Table 4.6).

This logic can be questioned. But what is irrefutable is 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 potential downstream users.

In short, the socio-economic benefits of higher water delivery efficiencies are largely intra-sectoral. Efficiency gains by existing irrigators might also moderate the demands for further irrigation development because existing water supplies will subsequently irrigate more land (or the same land more intensively). On the other hand, greater irrigation efficiencies will increase the profitability of irrigation vis-a-vis dryland and this, in turn, would tend to increase the demand for more water for additional irrigation development on existing drylands.[1]

---

[1] The development process in Israel is illustrative. Through the widespread adoption of sprinkler and drip systems and excellent management, the average volume of water applied per hectare declined by nearly 20 percent between 1967 and 1981, allowing the nation's irrigated area to expand 39 percent while irrigation water withdrawals rose by only 13 percent. (Postel, 1984)

TABLE 4.6

DISTRICT IRRIGATION WATER EFFICIENCIES IN THE ALBERTA PORTION OF THE SASKATCHEWAN-NELSON BASIN (%)

Year	Overall Diversion Efficiency $\frac{Wcu - Pr}{Dg}$	Effective Efficiency $\frac{Wcu - Pr}{Dg - Fr}$
1951	33.10	122.54
1956	55.41	80.78
1961	42.83	61.56
1966	39.72	85.44
1971	44.29	59.62
1976	47.35	62.60
1977	45.81	58.67
1978	32.05	46.84

Overall diversion efficiency = $\frac{Wcu - Pr}{Dg}$

Effective efficiency = $\frac{Wcu - Pr}{Dg - Fr}$

where Wcu = crop consumptive use values

Pr = precipitation from May 1 to September 30

Dg = gross water diversion to the District

Fr = return flow from the District

Source: Alberta Environment (1982) Prairie Provinces Water Board, Water Demand Study, Agricultural Water Uses--Alberta Planning Division, Edmonton

4.2.4 Water Scheduling

Like water delivery systems, water scheduling has both an off-farm and on-farm component.

The objective of improved scheduling is to adjust water withdrawals considering actual weather conditions, evapotranspiration rates, soil moisture, and crop water requirements.

Most Irrigation Districts in Canada have managers and "ditch riders" to regulate flows through the system. For major systems, proper scheduling is a complex and increasingly sophisticated process. When it takes, say, a week for water to go from the main turnout to the last farmer at the other end (like the large St. Mary Irrigation District in S. Alberta), proper scheduling becomes especially critical.

Proper scheduling has two payoffs: (1) it results in water savings, and (2) irrigating precisely when it is required (before the crop is under stress) increases crop yields substantially. Proper scheduling can reduce water needs by 20-30 percent yet increase yields by a similar percentage (Postel, 1984).

Both system and on-farm scheduling can be improved further by using computerized water balance models, computerized models to estimate crop water requirements, and telephone "hotlines". In Canada, however, this level of sophistication is still in its infancy.

4.2.5 Pricing and Metering

Perhaps no other water-related topic has received so much attention by resource economists. An extensive literature review was completed by Marv Anderson and

Associates (1978b).

Yet what most of these studies establish is a price elasticity of demand for irrigation water; not the expected socioeconomic benefits and costs of actually increasing the real price of water to manage this resource more effectively. Economists in general seem to simply assume that this socio-economic payoff would be considerable. This, however, is not readily apparent--perhaps, in part, because so few irrigation authorities have actually experimented with price adjustments to try to regulate demands.

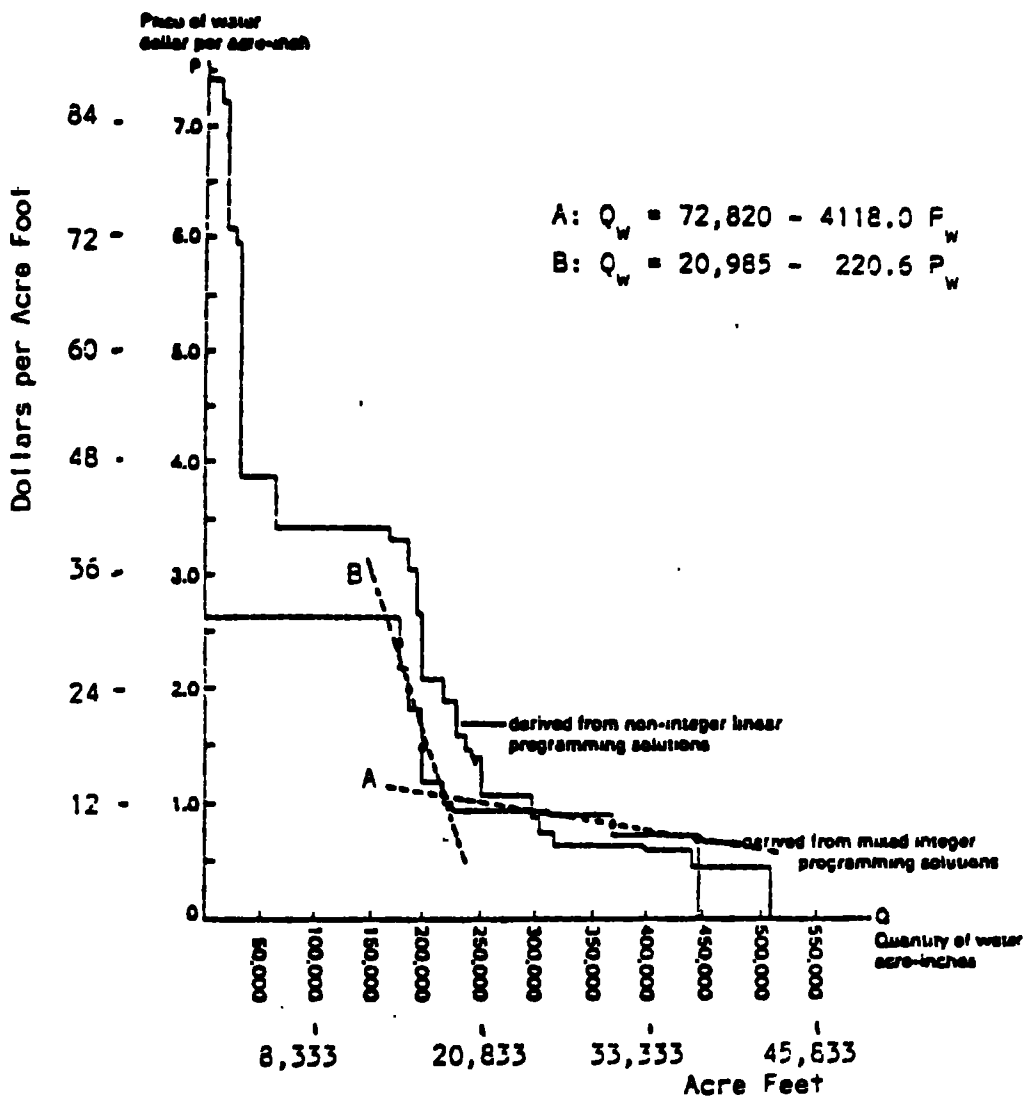
Price rigidities may, in fact, be almost imperative, ceterus paribus, because of the structure of the agricultural industry itself. In agriculture, there is a strong tendency for the residual "profits" from various factors of production to be quickly capitalized into the value of the land (PFRA, 1984b). If, in fact, this is true, then water prices may really only be flexible with respect to new irrigation.

Nevertheless, the potential for using an effective price to allocate limited supplies of water to irrigation is still very appealing because even modest water price increases (i.e. lower implicit subsidies) would have a very major impact on how water is used particularly on the Prairies. In part, this is because there is a pronounced "kink" in the demand curve for irrigation water in Western Canada, as illustrated in accompanying Figure 4.2 (i.e. Section A is much "flatter" than Section B). The reason for this "kink" can be traced to the use of water on marginally profitable low-value crops which would no longer be profitable to irrigate with even very modest water price increases (Marv Anderson, 1978b).

With adequate markets for higher-valued crops (so cropping patterns would change), this might/might not actually "save" water. This would depend upon the

Figure 4.2

"STEPPED" AGGREGATE DEMAND CURVE FOR IRRIGATION WATER (MANITOBA FARMS)



Source: W. J. Craddock (1971) "Linear Programming Models for Determining Irrigation Demand for Water", Canadian Journal of Agricultural Economics Vol. 19, November.

consumptive water requirements of the new versus 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.

A more politically palatable policy might simply involve water metering and effective water quotas, given a flat rate (and inflexible) price structure. There is at least some evidence to suggest that water metering alone might result in water savings of 10 or 20 percent. At this juncture, however, even the effective metering of irrigation water in Canada is not widespread.

Augmenting water prices and/or metering would also stimulate further improvements to water delivery systems which, in turn, would reduce seepage and salinity accumulations along existing canals. But too little water could also limit the on-farm opportunity to flush excess salts from the soil (which, of course, can also reduce the quality of return flows). The net environmental impact is obscure.

Perhaps a major reason that an effective water pricing policy is not used to regulate irrigation water demand is jurisdictional. At least in Alberta, Irrigation Districts are largely self-governing bodies, somewhat similar to municipalities or counties. Water rates are, in effect, self-imposed taxes. Here again, it might be argued that the price of a provincial-national resource should not be unilaterally determined by potential regional users of the resource in question.

4.3 Efficiency Measures: Municipal/Industrial

4.3.1 Matching Quality and Use

One reason that recognizing the concept of matching quality and use is important is because potability may be getting more difficult to assure, making such supplies more precious. While water treatment to compensate for bacteriological problems has been quite well developed, treatment for trace toxics which are now becoming detectable has not. Perhaps of most import is that the detectability of, and the recent concern about, such toxics is likely to continue to lead both knowledge about their effects and ability to remove them (Robinson et al, 1984). One longer term implication of the trace toxic problem for demand management is that treating all municipally supplied water for potability could become much more costly, resulting in severe price increases which would affect demand.

The only alternatives are variations on the theme of matching quality and use:

a) consideration of separate provision of waters of different quality for different purposes; and/or

b) encouragement of point-of-use treatment or use of other sources, e.g. bottled water for those especially concerned about unknown effects of trace contaminants.

Any of these would have significant impacts on the water use system, including equity and safety (Robinson et al., 1984).

Another implication of our inability to routinely treat toxics is that the quality-demand relationship should be more clearly understood for residential/commercial and for industrial water users in each area. This is a prerequisite for development of emergency procedures for catastrophes, e.g., accident or sabotage rendering part or all of the supply non-potable. While some water supply systems have plans at some level for dealing with drought or unexpected low quantity, almost none have procedures for sudden problems with quality. While now rare, plans for both should be developed as water supplies are vulnerable; disasters would require the ultimate in management of demand.

Matching quality and use will become more important in Canada, and will not come about just through use of non-potable supply sources. It is also happening through industrial recycling and through re-use of wastewater and stormwater, discussed above in sections 3.3.7 and 3.6.

4.3.2 Constructing New Structures to be More Water-Efficient

While the discussion in section 3.3.3 showed that technology exists to reduce domestic consumption, such water-efficient fixtures are readily available in Canada (Anderson, 1984). Also, the cost increases for low use over conventional fixtures are small, in the range of $8-20 in 1980, and the cost savings through lower water consumption more than justify their use in specific regions (Howard-Ferreira and Robinson, 1980a). The question that remains is the method which should be used to maximize their installation where desirable.

(a) Regulation

The most common approach in such a case is that of regulation. It has been used quite successfully in many cities in the United States.

For a number of years discussions have been held with Ontario government staff and associated agencies re the implementation of regulations that would encourage the use of water efficient plumbing fixtures because the province has regulatory jurisdiction. In 1977, almost all major municipalities requested that the Ontario Water Resources Act Regulation 647 (plumbing regulations) be amended to accommodate needs of local municipalities desiring water efficiency. Such an amendment would provide at minimum for an alternate set of regulations which could apply to specific areas where water use was a significant concern.

However, the Province did not act at that time on the rationale that such a move might spur a revision back to the pre-1952 era when each municipality had its own plumbing code. One specific concern was that uniform provincial regulations improved efficiency in the building industry by facilitating mobility of trades. Another was that the existing regulations were developed for health and safety objectives only, not for economic or other objectives, and thus any such change would require a new philosophical base for them.

Since then, discussions have also been held with the Canadian Standards Association (CSA) and three large domestic toilet manufacturers. A request was made that the manufacturers post the flush volume of their products on the CSA certification sticker in a similar fashion to that used to indicate the energy consumption of appliances. This approach was rejected initially as the manufacturers were concerned that flush volume not become a basis for customer purchase decisions. At subsequent meetings, however, it was agreed that those water closets advertised as being "water-efficient" would be tested by the Certification Division of CSA as to whether they met a "water conservation standard". An amendment to the CSA B-45 series of standards provides for certification of water closets as "conservation type" providing they do not use more than 13.25 litres per flush. This is a mid-range limit which many current water closets could reach (CSA, 1984).

However, although Canadian standards for "conservation type" or water-efficient toilets now exist, there is as yet no legal means provided by the provincial government, or available to local or regional municipalities, to require their installation in any region (Howard-Ferreira and Robinson, 1980a). In the absence of such means, there is no straight-forward approach in areas where such fixtures should be used for water-efficiency or economic reasons.

(b) Incentive Program

The Regional Municipality of Waterloo in 1981 approved funding for a program providing a $75.00 rebate for each newly constructed dwelling in which water-efficient fixtures were installed. The dwelling had to be supplied by public water distribution and wastewater collection facilities. Implementation did not begin until late 1984 after development of detailed procedures and a catalogue for identification of qualifying water-efficient fixtures.

While such a program may be considered desirable in that it retains a voluntary complexion, it could not have been implemented without the goodwill and substantial cooperation among the politicians and staff of the several local municipalities and of the Regional Municipality of Waterloo. Such goodwill and cooperation may not be present in all regions where action is desirable.

The effect of the program in changing the mix of fixtures installed remains to be seen.

4.4 Summary of Water Use Efficiency Improvement Potential

In the absence of market or non-market constraints to improved water use efficiencies, the potential productivity gains in the agricultural sector are enormous:

Dryland Cultural Practices	15% X 40 M hectares
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.

Note, in particular, that this would essentially double irrigated production, given existing water supplies.

Thus:

1. Water demand management policies which focus on improving water use efficiencies in agriculture would, almost by definition, translate into more efficient, more profitable farming operations in Canada.
2. Further, it would allow for considerable irrigation expansion (or intensification) with existing water supplies.
3. In addition, this should moderate the **short-run** demands for water for irrigation.
4. At the same time, water "savings" to accommodate other potential water users are not envisioned.

The anticipated effects of demand management measures on municipal and industrial use are summarized in Table 4.7.

Table 4.7 Summary of Water Use Efficiency Potentials: Municipal and Industrial Measures

(Based on Experiential Data)

Measure	Change	Percent (Max)	References
A. Short-Term Measures			
1. Leak detection and maintenance	Reduce line losses	(40)	Tate, 1984
2. Metering	Reduce residential total use (small municipalities)	(13-20)	Loudon, 1984
	Reduce residential outdoor use	20	USHUD, 1984
3. Rate structure modification			
a)user pay policy, including sewer surcharge	Reduce total use	33	Loudon, 1984
b)user pay policy, adding excess use charge	Reduce maximum day demand	12.5	Griffith, 1984
4. Retrofitting	Reduce residential use where installed		
a)Toilet + shower devices 75% retention	(N.B. also energy savings)	5.5-8.8	USHUD, 1984
b)Stop toilet leaks		(42)	USHUD, 1984
c)Shower + faucet device, stop toilet leaks	(N.B. also energy savings)	(65)	USHUD, 1984
5. Regulation of water pressure	Reduce residential use, high pressure areas (> 625 kpa)	6	USHUD, 1984
6. Insulated/heat traced services	Reduce use, northern communities	(50)	Robinson et al., 1984
7. Recycling	Reduce use/unit output		
a)individual firms		(94-97)	Postel, 1984; Krueger, 1984
b)nationally		(75)	Postel, 1984
B. Longer Term Measures			
1. Pressure regulation	Reduce use, new residential/ commercial development, high pressure areas	(6)	USHUD, 1984
2. Water-efficient new structures	Reduce use, new residential development		
a)Low flush toilets			
i)North American [A] (13.25 l./flush)		14	USHUD, 1984
ii)European (9 l./flush)		21	
b)Low-flow showerheads [B] (11.4 l./min.)	(N.B. also energy savings)	13	USHUD, 1984
c)Low-flow faucets		0.88	AWWA, 1981
d)Low flush toilets [A] + low-flow showerheads [B]	(N.B. also energy savings)		
i)single family		23	USHUD, 1984
ii)multiple family		29	USHUD, 1984
3. Water-efficient appliances	Reduce residential use at rate of turnover + new installations		
a)Clotheswashers		3.0	USHUD, 1984
b)Dishwashers		1.8	USHUD, 1984

V. OBSTACLES AND OPPORTUNITIES

5.1 Obstacles

The principal obstacles to developing a more broadly-based water demand management strategy generally have a social-political dimension.

1. The fundamental constraint is that greater efficiencies (as employed in the proceeding) are only one of many objectives in the policy-making process. In fact, in the politics of water the active political players are not really interested in relative total social costs and benefits. What is important to them is the distribution of costs and benefits of a particular policy option:

> ...from the perspective of interests in the project area,...it does not matter if national economic benefits are less than costs. Interests in the project area focus upon the benefits that are heaped on their locality and ignore the costs which are distributed to a diffuse national [or provincial] public (Martin, 1982, p. 130).

In other words, in this context regional or sectoral **equity** considerations take precedence over **efficiency** considerations. They are preoccupied with the longer-term distribution of wealth. Physical possession of water supplies is the ultimate prize: "Possession is nine-tenths of the law." And then quickly establishing artificially high use-levels (via built-in inefficiencies and perverse pricing) effectively acts as a hedge against even higher potential water requirements in the future: "Use it or lose it."

2. Related to (1) is the fact that agricultural communities (including public and private "support services") with potential access to irrigation have a fundamental "water-is-different" philosophy. Water is believed to give rise to a Midas Touch, creating wealth and guaranteeing a prosperous future wherever it is present in ample

quantities:

> "...there are a number of opportunities across the Prairies for expanded development of water supplies...The process of removing these constraints can contribute to economic activity and employment within the Prairie region and throughout Canada. The infrastructure installed by a policy of water development can create opportunities for future generations of Canadians" (PFRA, 1984b)

And this is undoubtedly true in a site specific or regional context, even though there is little or no evidence to support the proposition that increased water supplies augment **overall** economic growth and development (Cicchetti et al., 1975; Cox et al., 1971; Fullerton et al., 1975; Kelso et al., 1973; Rivkin-Carson, 1973). The similar assumption that continued economic growth would require increased energy consumption has already been proved false since 1973.

Once again the issue here is the structure of development and, hence, ultimately, the distribution of wealth and power.

3. Historically, water has been an inexpensive commodity and even the marginal cost of new supply has been quite low; supply augmentation seemed the obvious answer.

For the manufacturing industries that use a great deal of water—primary metals, chemicals, food products, pulp and paper and petroleum—the cost of water is rarely more than 3 percent of total manufacturing expenses. Incentives to use water more efficiently have come either from strict water allocations or stringent pollution control requirements (Postel, 1984, pp. 42-43).

4. While a supply management approach tends to lead to decisions favouring system expansion, bias toward such decisions have a deeper base than the management approach. Occasionally, a large visible facility, even if more costly, may be

preferred by politicians over improving management, which may be less visible. Such a facility has the added advantage of the capability of being used to honour a politician (Tate, 1984).

Additionally, payment for implementation of many demand management measures would be allocated to a water manager's operating budget which is often pressured by politicians in an attempt to reduce rates and taxes in the short term. Projects which can be capitalized may be more readily approved.

Provincial subsidies are frequently available for capital projects while programs to reduce the need for such projects must all be funded locally. This provides additional incentive for decision-makers to favour a system expansion.

A number of demand management measures require metering of use as a basic prerequisite. However, most regulators, e.g. provincial governments, have not exercised their authority to require installation of water meters in municipalities.

5. The institutional separation of functional responsibilities for the various subsystems can make integrated management almost impossible without a high degree or cooperation. And this level of cooperation generally has not been forthcoming yet.

It is in this context that we can briefly address how the federal government might encourage greater application of water demand management in Canada.

5.2 Federal Initiatives

The list of federal initiatives which might be proposed in the above context is almost endless. We will briefly discuss seven practical policies or policy changes which would, in our professional judgement, greatly enhance water-use efficiencies in Canada.

These include the following:

1. In-house institutional reform
2. Re-focus technical support services
3. Research-Extension/Education
4. Revision of cost-sharing programs
5. Improved public information services
6. Income tax incentives
7. Reducing residential use: water-efficient fixtures, and
8. Inter-governmental support

5.2.1 In-House Institutional Reform

The Inland Waters Directorate of Environment Canada, (IWD), has responsibility for water management in five main areas: water data and monitoring, international relations, ambient water quality measurement, water planning, and research (EC, 1977).

While it is recognized that other agencies are involved, the IWD is the principal national water planning agency in Canada. Their role should therefore be expanded in line with section 5.2.5 following.

Closer coordination of water-related activities between Energy, Mines and Resources, Environment Canada, Indian and Northern Affairs, and Agriculture Canada is also highly desirable (Agriculture Canada, 1984). From a national perspective, resource use must be examined in a global context, especially land and water. This is particularly apparent when one considers current inter-related soil degradation issues (Ed Braun et al., 1984; Senate of Canada, 1984).

The important point here is that the federal government already has the power (i.e., potential policy instruments) to alter the long-term structure of industrial/agricultural production throughout Canada. This applies to both production (e.g., grain quota and grain stabilization programs) and resource use (e.g., fuel taxes).

By affecting the long-term economic structure of the economy, the demand (consumption) for water will also be affected because industrial/agricultural water demands are, in effect, a derived demand. In the longer-term, this represents sufficient leverage to greatly affect total water consumption requirements, even in the absence of direct controls over the water resource per se.

5.2.2 Re-Focus Technical Support Service

Federal technical support services have generally been characterized by a very pronounced bias in favour of engineering services. This is best exemplified by Prairie Farm Rehabilitation Administration (PFRA) expenditure patterns where Soil and Water Conservation Technical Services are still in their infancy (Table 5.1 and Figure 5.1).

In addition, PFRA essentially volunteers its engineering services to provincial governments on the Prairies for the purpose of investigating the technical feasibility of newly proposed water supply schemes in the Province(s) in question. The underlying wisdom of this rather indiscriminate policy might also be re-examined. (Also see section 5.2.5 following.)

5.2.3 Research and Extension-Education

It has been documented well in agriculture that the socioeconomic payoff to research is relatively high, often much higher than the return to other investments (Table 5.2). Some isolated success stories indicate even higher annual returns to research are possible. For example, canola research in Canada during 1960-1975 reportedly yielded a 95-110 percent return per annum (Nagy and Furtan, 1977). At least two dozen other studies on the return to agricultural research (which all document relatively high payoffs) have been catalogued (Evenson, 1979).

TABLE 5.1

PFRA EXPENDITURES AND REVENUE, BY ACTIVITY

	1980-81	1981-82	1982-83
Expenditures			
Headquarters Analysis, Planning and Program Development	$ 1 760 548	$ 1 747 026	$ 1 624 072
Headquarters Administrative Services	2 024 511	2 778 254	3 259 214
Engineering Technical Services	6 686 521	7 531 597	8 647 043
Soil and Water Conservation Technical Services	—	329 060	594 415
Construction Service Operations	709 342	849 512	890 853
Water Development Program Administration	2 453 260	2 921 826	3 413 291
On-Farm Water Development	4 238 247	5 783 356	4 904 613
Small Community and Group Water Development	—	111 418	619 216
Community Pasture Administration and Operations	7 427 723	7 839 147	8 908 640
Community Pasture Improvement and Development	2 226 953	1 572 414	1 488 212
Tree Distribution	2 000 071	1 812 048	2 325 691
Demonstration Farm	147 259	180 759	544 509
Agricultural Service Centres	2 359 976	2 382 797	1 076 782
Water Development and Drought Proofing:			
Manitoba Agreement	173 277	1 589 411	914 882
Saskatchewan Agreement	924 902	1 715 301	3 007 394
Southwest Saskatchewan Irrigation Projects	1 040 293	1 198 241	1 532 749
Alberta Irrigation Rehabilitation	717 239	178 720	60 868
South Saskatchewan River Project	191 235	320 054	367 149
Community Water Projects Program	24 083	35 949	10 233
Assiniboine River Diking	237 611	74 043	35 217
Herd Maintenance Assistance Program Administration	1 057 860	230 249	—
Herd Maintenance Assistance Contributions	42 887 046	2 093 436	—
Emergency Water Supply Program	311 744	490 275	—
	$79 599 701[2]	$43 764 893	$44 225 043
Revenue			
Community Pasture Operations	$ 5 967 088	$ 6 912 965	$ 8 448 147
Southwest Saskatchewan Irrigation Projects	225 311	197 356	215 919
General Revenue	3 393 914	3 320 725	2 792 251
	$ 9 586 313	$10 431 046	$11 456 317

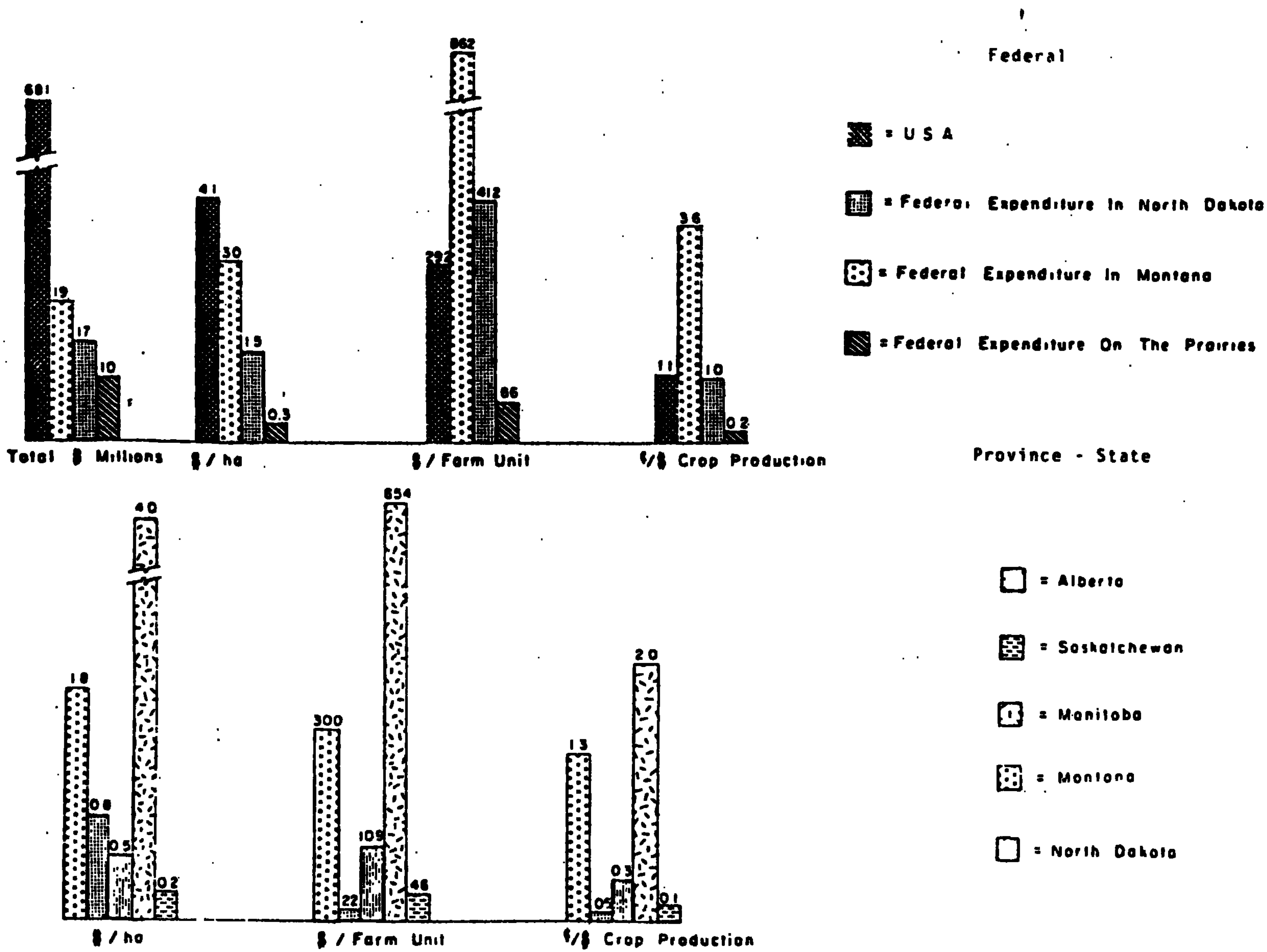
[1] Includes operational expenditures, capital expenditures and contributions

[2] Does not include write-off of working capital advance $513 739 in fiscal 1980-81

Source: PFRA (1984) Annual Report, 1982-83 Agriculture Canada, Ottawa. Appendix 1, p. 18.

FIGURE 5.1

COMPARATIVE FEDERAL, PROVINCIAL AND STATE EXPENDITURES
ON SOIL AND WATER CONSERVATION 1979



Despite its evident value, very little research has been conducted in Canada on water demand management. A major factor contributing to this is that the federal research budget available for such work is low and has been effectively declining

Table 5.2

ESTIMATED RETURNS FROM INVESTMENT IN ALL

AGRICULTURAL RESEARCH IN THE UNITED STATES

Investigator	Year	Period	Annual Return (%)
Peterson and Fitzharris	1977	1937-1942	50
		1947-1952	51
		1957-1962	49
		1957-1972	34
Griliches	1964	1949-1959	35-40
Evenson	1968	1949-1959	47
Lu and Cline	1977	1938-1948	30

Source: R. E. Evenson et al. (1979) "Economic Benefits from Research: An Example from Agriculture", **Science** Vol. 205, No. 4411, Sept. 14.

annually. For example, the total budget for the Inland Waters Directorate's Water Resources Research Support program, only a fraction of which can be allocated for demand management research, has held constant at $250,000 since the late 1970's. In addition, the work of the Inland Waters Directorate's two research institutes has not addressed this area of research.

Clearly, more funds are needed to stimulate research in this area, even if they only are used to match research expenditures on demand management by lower levels of government.

Such research should investigate not just the effects on reducing water use, but also the broader questions of **all** beneficial and adverse effects.

In the municipal and industrial sectors, research on the effects of policy changes and of technological modifications in the Canadian context are needed. The potential for recyling technologies in Canadian industry needs to be examined and documented to assist in policy development. Further research is also needed on practical re-use possibilities for wastewater and for collected stormwater. One basis for federal involvement in such research is the potential for reduction of pollution of the Great Lakes.

One area of demand management needing particular attention is the development of Canadian research and experience on rate structure alternatives better reflecting costs of supply and on how to successfully implement such rate changes (i.e. the practice as well as the theory). Dissemination of this information, and information on metering, is required not just to water managers, but also to decision-makers and especially to the general public who have had little or no experience with significant real changes in the cost of water (DeYoung and Robinson, 1984).

In agriculture, funding both for research and for extension-education with a well-defined focus on water conservation is required. This long-term program would key on some of the more prominent on-farm water-saving technologies, some of which are still in their infancy, including:

—improved irrigation scheduling
—improved irrigation technologies for Canada
—minimum tillage
—use of stubble mulches
—improved snow management
—drought-resistant crop varieties (cereals and forages).

Each research component would ideally have its extension-education counterpart. This would generally be done in cooperation with provincial extension services, similar to an on-going salinity control project in south-eastern Alberta. In the longer-run, this would greatly enhance on-farm water-use efficiency levels.

5.2.4 Revise Program Structure

This initiative would re-examine all land and water related program expenditure priorities, expenditures which generally relate to existing costsharing agreements with the respective provinces.

The historical provincial bias in favour of water supply augmentation and status quo expansion (versus demand management and expansion with structural change) is expected and widely acknowledged. (See, for example, accompanying Table 5.3) The objective here would be to re-direct some of these funds towards viable water demand management alternatives.

5.2.5 Provide Additional Support to Public Information Services

As already discussed in the preceding, the socio-political system almost makes financial-technical support for broadly-based public interest groups obligatory. This is required to counter the inherent advantages held by special interest groups. This might also involve more actively supporting provincial or inter-provincial river basin studies, particularly comprehensive planning studies such as the on-going SSRBPP.

5.2.6 Tax Incentives

In this context, numerous income tax incentives could be devised. For example, a tax credit could be offered for improving on-farm distribution systems (e.g., lining on-farm ditches) or, perhaps, for planting drought tolerant crop varieties.

Another use of tax credits might involve encouraging the multiple use of existing water supplies, e.g., farmer tax credits for slough consolidation to support waterfowl

TABLE 5.3

WATER MANAGEMENT EXPENDITURES IN SASKATCHEWAN, 1935-1980

Program/Program Category	Expenditures[b] $M 1980	Program Ranking
1. Water Augmentation		
South Saskatchewan River Irrigation Project	433	3
Individual & Neighbor Stockwater Dams, Dugouts, & Other Source Development	141	5
Southwest Saskatchewan Irrigation Projects	131	6
Farm Water & Sewage	88	8
Individual & Neighbor Farm Wells	24	15
Individual & Neighbor Irrigation Projects	16	18
Irrigation Development for Organized Groups	13	19
Sub-Total	$ 846 (33.0%)	
2. Water Conservation		
Saskatchewan Research Council	18	16
Tree Planting & Shelterbelt Program	17	17
Sub-Total	$ 35 (1.4%)	
3. Modification of Demand	nil	
4. Modification of Intra-Sectoral Characteristics		
PFRA Community Pastures	105	7
Municipal Water Assistance Boards	67	9
Association Pastures	54	10
Provincial Pastures	52	11
Ducks Unlimited	41	12
Agricultural Service Centers	41	13
Community Capital Fund	12	20
Sub-Total	$ 372 (14.5%)	
5. Spread/Share Losses & Costs		
Debt Adjustment	540	1
Prairie Farm Assistance Act	467	2
Crop Insurance	279	4
Herd Maintenance Assistance Program	26	14
Sub-Total	$1,312 (51.1%)	

[a]Based on the top twenty programs and tabulated expenditures ($ real) during 1935-80.

[b]Program category shares indicated in brackets.

Source: Marv Anderson & Associates Ltd. (1983) Catalogue of Drought Programs Study Element 15A, Saskatchewan Drought Studies, Regina, March.

habitat and hunting, or farmer tax credits to encourage the supplemental irrigation of highlands with excess water from neighboring lowlands.

5.2.7 Reducing Residential Use: Water-Efficient Fixtures

(a) Establishment of a "WATERGUIDE" Program

Such a program would be modelled on the current ENERGUIDE program (Tryfos and Fenwick, 1984) and could be implemented in cooperation with Consumer and Corporate Affairs.

Objectives of such a program would be threefold:

1. to enable purchasers to compare the water consumption of available models and to choose from comparable models the one that consumes the least amount of water;
2. to allow retailers to assist their customers in making purchase decisions based in part on the water consumption of the featured models, and;
3. to encourage fixture manufacturers to improve the water efficiency of fixtures and appliances through research, design and development.

Initially at least, the program should be based only on water closets. If successful, other fixtures and fittings could be added in the future.

One step toward this goal occurred with creation of a water conservation standard for water closets discussed above in section 4.3.2.

Such standards are desirable as an intermediate phase in helping shift purchases to models below the threshold. However, they do not serve to differentiate among fixtures meeting the standard, although as implied in section 3.3.1, there are wide efficiency variations among fixtures meeting a low-use standard.

The ENERGUIDE program appears to have had a significant effect on domestic appliance energy consumption. (Tryfos and Fenwick, 1984, p. 52). The least efficient models disappeared from the market, but only small efficiency improvements over existing technology had occurred within the first three years of the program. The net effect in that time was to increase the market share of the most efficient models. The market by itself did not work this way until the program started. The prior problem may have been that efficiency was unrecognizable, or was not valued before ENERGUIDE, or that the market was not competitive. Nevertheless, while many other factors clearly were involved, the ENERGUIDE program is credited with a substantial proportion of the responsibility for the change (Tryfos and Fenwick, 1984, p. 59).

A WATERGUIDE program would be an ideal lead to a next step, revision of plumbing regulations, which would require some discussion and time to implement.

(b) Request the Canadian Standards Association to Develop a "Water Conservation" Standard for Shower Fixtures

While a "water conservation" standard has been developed for water closets as discussed above in section 4.3.1, and while installation of low-flow showerheads can reduce per capita consumption significantly (section 3.3.1), a complementary "water conservation" standard has not yet been developed for the latter.

While showerheads are covered in CSA Standard B125, the requirements are not very well related to code requirements for water flow and pressure in the distribution system (Beach, 1985). Development of a new standard based on flow rates and pressures is somewhat more difficult when the existing standard is not clearly consistent internally.

Nevertheless, existence of such a standard could be used in modification of plumbing regulations (above) or in standards for an incentive program for installation of water-efficient fixtures (section 4.3.1).

(c) Revision of the Canadian Plumbing Code to Incorporate Provisions to Require Low-Use Fixtures

The Canadian plumbing code serves as a model plumbing code for the entire country. Environment Canada and the National Research Council could work to propose limitations as to where fixtures which are not "conservation type" may be used, i.e. where resource efficiency and its economic effects may be less desirable. There is precedent for this: the use of one type of water closet is already restricted (Beach, 1985). In the short term, there may be relatively few limitations. In the longer term, if concerns about water use and cost escalate, the "conservation type" might become the norm. In any case, this approach ensures that provision exists for local circumstances, yet the code remains based on CSA standards.

5.2.8 Inter-Governmental Support

Closer inter-governmental consultation and support for provincial initiatives under provincial jurisdiction is also recommended. Example initiatives are policy research with respect to:

1. Potential changes to provincial legislation governing new irrigation development, e.g., formula for farmer contributions, formula for water prices and quantities, formula for regional improvement taxes, etc.
2. Potential changes to provincial legislation governing the use of frontier lands made available to new farmers, e.g. caveats to avoid environmental

degradation. (This has a U.S. precedent in frontier agricultural areas in Alaska).

These opportunities might be particularly relevant where no legal precedents had to be overturned. That is, they would not apply to existing resource users, only to new users.

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Study Terms of Reference

OBJECTIVES

To describe existing and potential applications of demand management to municipal, industrial and agricultural water uses; and to recommend means and advantages of incorporating them more widely into Canadian water management practices.

Tasks:

1. to describe the range of demand management measures which have been or could be applied in Canada to reduce the rate of growth in water use, including measures for recycling, reclamation, recovery and reduction at source.

2. to assess the socioeconomic, environmental, and legal implications of such measures.

3. to indicate the advantages of and obstacles to integrating demand and supply-oriented water management.

4. to recommend appropriate means by which the federal government can encourage greater application of water demand management in Canada, taking into account its jurisdictional limitations.