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Challenges for Water Researchers in Alberta in a Climate of Policy Uncertainty

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The Issue

A safe and plentiful supply of surface water is crucial to the well-being of every resident of Alberta. The effective and efficient use of surface water is central to economic growth and environmental sustainability. As the necessary but competing demands on surface water intensify, the awareness of its limited supply increases. This is particularly evident in southern Alberta, which has experienced significant agricultural, industrial and population growth. In addition to its use for extensive irrigation, surface water in the South Saskatchewan River basin is vital to meet drinking and sanitation needs in rural and urban communities. Management of this key resource involves many researchable issues – water supply, water treatment, water distribution, wastewater collection and processing, flood control, navigation, hydropower production, aquatic recreation – which interact with each other and with government policies. The purpose of this article is to outline the priorities for socio-economic research on surface water resource issues in light of the ever-changing legal and policy frameworks in Alberta.

Implications and Conclusions

Research priorities were developed in four major areas. First, research is needed in the area of marginal-cost pricing of water in order to answer several questions relating to how water can be more efficiently allocated among competing users. Second, understanding the consequences of global warming on Alberta agriculture and developing strategies to deal with it require several critical types of research, including investigation of how warming might affect plant growth and pest infestations and how it might change optimal farming practices. Third, research is needed on the extent of third-party effects emanating from growing water usage accompanied by land-use and population pressures in Alberta. Fourth, research is required on farm management issues, especially crop responsiveness to different levels of water application, costs and returns of alternative water conservation strategies, and opportunities to improve farm profitability through enterprise shifting, sales of water rights, and other production and investment strategies.

Introduction

A safe and plentiful supply of surface water is crucial to the well-being of every resident of Alberta. The effective and efficient use of surface water is central to economic growth and environmental sustainability. As the necessary but competing demands on surface water intensify, the awareness of its limited supply increases. This is particularly evident in the semi-arid[1] area of southern Alberta, which has experienced significant agricultural, industrial and population growth. Surface water in the South Saskatchewan River basin is fully allocated at present, and there is little opportunity to increase supply by enhancing off-stream storage facilities. Alberta Environment has prohibited the allocation of additional surface water from the southern tributaries of the Oldman River.

In southern Alberta, irrigation accounts for about 90 percent of the consumptive use of surface water. Water is also required for many industrial processes, ranging from food processing to thermal electricity generation to oil and gas extraction. In addition to these consumptive uses of surface water, it has many non-consumptive uses, including hydroelectricity generation, fisheries, recreation and effluent dilution. Many non-consumptive uses, however, alter the quality of the water and affect the stability and channels of flow. For example, the salinization or contamination of surface return-flows or groundwater by nutrients, microbes or pesticides can lead to environmental degradation. This is important, as southern Alberta's extensive network of irrigation canals, reservoirs and sloughs create wetlands and habitats for some of the region's most threatened, rare and endangered species of birds and animals.

In March 2003, Alberta Environment released a draft document entitled "Water for Life: Alberta's Strategy for Sustainability". A major recommendation in that document was to establish a research program to address new and emerging water management issues. Management of this key resource involves many researchable issues – water

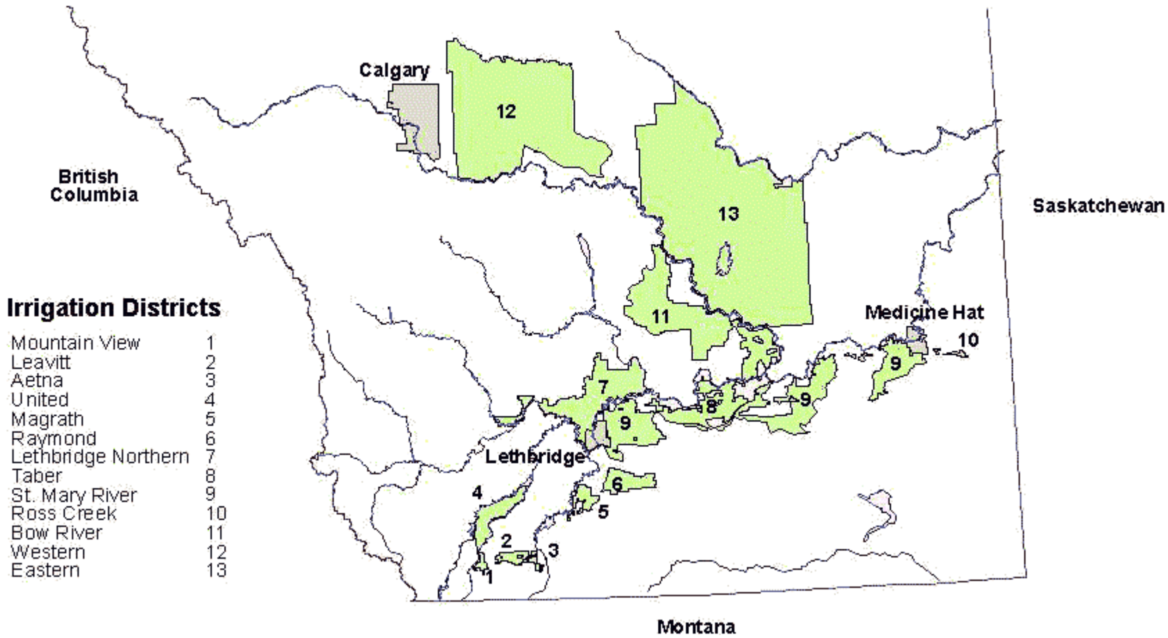

Figure 1 Location of the South Saskatchewan River basin

supply, water treatment, water distribution, wastewater collection and processing, flood control, navigation, hydropower production, aquatic recreation – which interact with each other and with government policies.

The purpose of this article is to outline the priorities for socio-economic research on surface water resource issues in light of the ever-changing legal and policy frameworks in Alberta. Socio-economic research can provide a logical description and interpretation of the complex interactions involving the use and supply of water. The next section describes the legal and policy framework for surface water in Alberta. Challenges facing socio-economic researchers in their quest to understand and resolve problems of water management in the semi-arid ecosystem of southern Alberta are discussed in the third section. The last section provides concluding thoughts.

Legal and Policy Framework

Evolution of the Legal Framework

The earliest irrigation developments in the region that became the Province of Alberta consisted of ranchers diverting water from the smaller streams to adjoining native grasslands to grow winter feed. During the 1880s and 1890s, many ranchers throughout southern Alberta developed small irrigation projects. Their efforts demonstrated the value of irrigation and foreshadowed the future possibility of extensive water use for irrigation. However, unlike land, there was no transfer of ownership, management and control of surface water to private hands. To avoid jurisdictional and legal problems there arose a desire for a governmental authority to oversee the use and allocation of surface water resources. To this end, the Parliament of Canada passed the Northwest Irrigation Act in 1894.

Following the formation of the Province of Alberta in 1905, the Irrigation Act of 1906 superseded the Northwest Irrigation Act. In 1915, the provincial government passed the Alberta Irrigation Districts Act, which established irrigation districts in which farmland could be mortgaged (provincially guaranteed) to provide funds for irrigation development. The act also provided for an elected board of trustees that was empowered to levy taxes to fund the operation and maintenance of irrigation projects.

In 1931, the Water Resources Act superseded the Irrigation Act. This act followed the 1930 transfer of jurisdiction over natural resources (including water) from the federal government to the provinces. Manitoba, Saskatchewan and Alberta formed the Prairie Provinces Water Board in 1948 to ensure that surface water activities were managed according to geographic water basins and that upstream users would not use water to the detriment of those downstream. By this time, Alberta was allocated 2,759,585 cubic decametres of water yearly to irrigate 508,490 hectares.

In 1968, all former acts governing irrigation districts were replaced by a new Irrigation Act, which updated administrative and operational procedures of the irrigation districts. Two years later the province established a program to assist irrigation districts with the rehabilitation of their capital works, whereby the districts would cover 14 percent of the cost and taxpayers 86 percent. Taxpayers were also responsible to fund the necessary engineering and agrologic assessments. In accordance with revisions made to the Water Resources Act in 1975, water use for irrigation was given priority over industrial, power or recreational use and is third in water allocation behind domestic and municipal use.

Current Legal Framework

A review of Alberta's water management policy and legislation, begun in 1991, culminated in the passage of the Water Act (1999) and the Irrigation Districts Act (2000). While the old Water Resources Act (1975) was primarily a tool for allocating water, the Water Act (1999) recognizes the present challenge is allocating limited surface water among competing users. The purpose of the Water Act is to support and promote the conservation and management of water, including its wise allocation and use, while recognizing the desirability of, among others, environmental sustainability and economic growth and prosperity. The objectives of the Water Act are to:

1. protect existing water licence holders that are in good standing,
2. prohibit the export of Alberta's water to the United States,

3. enable the transfer of water licences on a temporary or permanent basis, and
4. prohibit interbasin transfers of water between Alberta's major river basins.

The ability to transfer water licences is a significant development for irrigators who hold private irrigation licences. This legislative provision relates directly to the government's broad strategy of addressing economic development and conservation priorities. The draft Water for Life document notes:

> "It is believed that this system of water transfers will, through market mechanisms, move water to higher value uses. … Transfers also provide an incentive to the current licensee to become more efficient, as any reduction in water use is allowed to be transferred to another user, resulting in monetary benefits for water saving" (Alberta Environment. 2003, 37).

Under this legislative provision, irrigation licence holders can transfer licences on a temporary or permanent basis to other licence holders, who may include other private irrigators, irrigation districts, municipalities and industries. Under the Water Act, a director appointed by the minister of the environment is responsible for most of the administration and operations outlined in the act, including the lengthy and detailed process of approving a water licence transfer.[2] The director also has the authority to withhold up to 10 percent of a transfer to protect the aquatic environment or to implement a water conservation objective (*Water Act*, 1999, 42).

The purpose of the Irrigation Districts Act is "to provide for the formation, dissolution and governance of irrigation districts in order that the management and delivery of water in the districts occur in an efficient manner that provides for the needs of the users" (*Irrigation Districts Act*, 2000, 14). Among other things, the act establishes the purposes and powers of a district, outlines conditions for various delivery agreements and requires districts to set expansion limits for irrigated acreage. A district board for each of the irrigation districts is elected from among the irrigators in the electoral division. An irrigation council is appointed by and makes recommendations to the minister regarding the monitoring of operations and finances of the districts.

Districts maintain the irrigation infrastructure and are responsible for diverting water to agricultural assessment areas and other uses. Some irrigation districts supply rural municipalities with water for domestic and industrial use. Districts also set up fee structures for the different uses of water from their irrigation works.

Under the Irrigation Districts Act, an owner of irrigated acreage can transfer the water for that acreage to other irrigators within the same district. These transactions occur privately through informal markets. Irrigation districts themselves, as licensed water holders, can also transfer water licences on a temporary or permanent basis under provisions of the Water Act.

Future Policy Directions

The draft Water for Life strategy document outlines the future direction of irrigation policy in Alberta. Formulation of the water strategy began in the fall of 2001 with a consultation process that continued until June 2002. The consultation process consisted of three components: ideas generation, public outreach and consultation and a Minister's Forum on Water. The draft strategy was released in March 2003 and focused on three priorities in water management: water conservation, environmental sustainability and efficient water management to maximize production. Albertans were invited to comment on the initiatives related to the three water management priorities. Until the Water for Life strategy is finalized sometime in late 2003 it is uncertain which of the initiatives will be implemented. Examples of proposed initiatives include the following:

- Implementing a review of existing water licences and ensuring that the water allocation reflects actual water use and needs; in addition, where required, using provisions of the Water Act to reduce the water allocation to match the actual use.
- Exploring and developing a system of water pricing and polluter charges, as well as other economic tools and incentives, to stimulate changes in behaviour and patterns of water use.
- Implementing, as part of a water use monitoring program, water metering for all large (size to be determined) agricultural operations.
- Setting water conservation objectives as part of watershed planning programs and prohibiting new water allocations when water conservation objectives would be compromised.
- Monitoring and evaluating the results of water allocation transfers and, if required, recommending changes to the administrative guidelines.

Challenges and Research Priorities

Socio-economic research needs to address the many roles water plays within society, focusing on the efficiency and sustainability of its use and reuse, the accompanying distribution of costs and benefits, and the role of institutions and economic incentives in promoting socially optimal use of this valuable resource. Four key priorities for this type of research are discussed below.

Demand Management – Administered Pricing and Water Markets

This priority includes research on the instruments used to allocate water, from strict, government-controlled pricing systems to free-market mechanisms. Whichever approach along that continuum is used, evidence clearly suggests that water is increasingly being treated as an economic good. The respective roles government, private and not-for-profit organizations play in the allocation and pricing of water are central issues. Property rights and legal issues are also of primary interest, including the projected effects of alternative systems of transferability, pricing and apportionment. It is important to investigate and evaluate systems of innovative monitoring, enforcement and management of the water resource base that have been proposed and implemented in other jurisdictions.

Demand for water in southern Alberta comes from four primary sources: agriculture (cattle and crops), urban and industrial needs, in-stream flow requirements (for the maintenance and health of the rivers) and interprovincial apportionment agreements with the United States and Saskatchewan. Irrigation acreage in southern Alberta has been steadily increasing, placing a high demand on limited water resources in the region. More than a decade ago the Alberta government placed limits on water that could be used for irrigation purposes. In 1991, guidelines were established that limit the amount of water that can be allocated to irrigation districts and private irrigation projects in the South Saskatchewan River basin. The Alberta government has identified water issues and "vulnerabilities" which include "potential limitation to economic development due to extensive water use, especially in the southern part of the province" (Alberta Environment, 2003, 5).

In most countries, agricultural production uses a very large share of water resources but pays the least for water relative to other major consumers such as municipal and industrial users (Easter, Becker and Tsur, 1997). This leads to agricultural users consuming more water for crop production than is socially optimal (Easter, Becker and Tsur, 1997). The most efficient allocation of water occurs when the price of water is equal to its marginal cost. The literature on marginal-cost pricing is extensive, including Dinar, Rosengrant and Meinzen-Dick, 1997; Johannson, 2000; Briscoe, 1997; Thobani, 1998; Saleth, 2001; Milliman, 1956. Full marginal-cost pricing takes into account all costs to users and society, including externalities such as increased salinity and reduced downstream flow in the case of irrigation, plus the social cost of any decrease in water supply in the future. In Alberta, the "price" for irrigation water has not been based on its marginal cost. Irrigators within irrigation districts are charged flat fees on an acreage basis, which are as low as $7.50 per acre. This fee covers administrative costs but some irrigation districts use a portion of the funds for infrastructure maintenance.

Full marginal-cost pricing of irrigation water is rare in the world. Since the need for metering equipment makes implementation expensive, obtaining information about all costs is virtually impossible (Thobani, 1998; Johannson et al., 2002). Charging full marginal costs would result in much higher water prices, and many farmers would face financial hardship if they had to pay that amount (Briscoe, 1997).

Australia comes closest to full marginal-cost pricing. Its water prices are based on operating and maintenance expenses, administrative expenses, environmental externalities, depreciation on a "replacement cost" basis and the opportunity cost of capital (OECD, 1999). Many European countries also seem to be generally adopting administered pricing methods that approach the supply cost of water (OECD, 1999).

The assessment of costs for water use is an area of policy uncertainty in Alberta. Marginal-cost pricing cannot be implemented without a metering system. The draft Water for Life strategy speaks of implementing water metering for users on municipal systems, licensed commercial and industrial users and all large agricultural operations. Which agricultural operations water metering would affect remains as unclear as the degree of resolve on the part of government to implement such a scheme.

Research in the area of marginal-cost pricing of water is needed to answer several questions, including the following:

- What would full marginal costs of water be?
- Would such a system succeed in allocating water among competing users and uses, including uses for environmental purposes? If so, what would the allocation look like?
- What could variations on full marginal-cost pricing include?

In the absence of an administrative pricing system, water markets, if unimpeded, allocate water efficiently. The genesis of water markets for irrigation water has recently occurred in Alberta. The Water Act and the Irrigation Districts Act facilitate water sales for private irrigators (the former act) and for irrigators within irrigation districts (the latter act).

Irrigation water markets around the world have tended to evolve over time, such that a wide variety exist, ranging from rudimentary to sophisticated systems (Livingston, 1998). Generally, these markets can be divided into two types: formal and informal. As described by Bjornlund (2003, 2) “in the formal market, the longer-term entitlement to the water is transferred from the seller to the buyer, while in the informal market, only the right to use a given volume of water, for a given period of time, is traded.”

Alberta has both formal and informal water markets based on two different types of irrigation users. First are the private irrigators who hold licences and are governed by the Water Act, administered by Alberta Environment. These irrigators can sell to other licence holders including municipalities, industries, irrigation districts and other private irrigation licence holders. The second type of irrigation water user falls within irrigation districts, under the Irrigation Districts Act, administered by Alberta Agriculture, Food and Rural Development. The districts are the licence holders and the individual irrigators have specific irrigated acreages and are the rate payers.

In Alberta the formal process of selling water is lengthy, involving a review, conducted by Alberta Environment, to ensure the absence of damage to the environment and the water rights of other users, and ultimately approval through an order-in-council. One such formal transfer has been approved, involving a permanent sale between an irrigation district and two small municipalities. About twenty other applications are in the process of being reviewed.

Studies of market activity in other jurisdictions provide evidence that, as in Alberta, utilization of formal irrigation water markets has been limited. The factors that impede formal water market activity are numerous and varied. In California they include legal barriers to trade, fear of long-term detrimental effects to farming communities and deeply embedded distrust between farmers and cities and government (Archibald and Renwick, 1998; Dosi and Easter, 2000; Haddad, 2000; Thompson, 1997). In Australia impediments are less related to legal barriers and lack of trust and due more to administrative barriers and policy uncertainty (Bjornlund, 2002). Although there are impediments to the establishment of formal markets, it is predicted that formal markets will develop in jurisdictions where non-agricultural demand for water intensifies (Easter, Rosengrant and Dinar, 1998).

Temporary sales of irrigation water in Alberta, on the other hand, are administratively very simple and there is some evidence to suggest the market has been active. Because buyers and sellers are exchanging the same off-stream water, the process simply involves determining the terms of sale between the two parties and notifying the irrigation district of the change in water diversion.

Temporary water sales activity has succeeded in moving water to higher-valued uses in California and Australia. In California, water has been transferred from low-value fodder and food-grain crops to fruit, vegetable and nut production and municipal use. In Australia, water in the State of Victoria has been moved from mixed farming to dairy and horticulture production. Whether the limited informal water market that has developed in southern Alberta has resulted in water moving to higher-value use is unknown. Further research is needed to answer the following types of questions:

- How active have water sales been?
- Among those sales, has water moved to higher-value use?
- What factors trigger water sales and purchases?
- What water institutions are in place or are lacking to facilitate or inhibit water sales?
- What factors result in temporary versus permanent sales of water rights?
- What are the distinguishing features of sales by private irrigators (the formal market) versus sales within irrigation districts (the informal market)?
- Is irrigation water moving to higher-value uses?
- What is the future viability of the market?

The institutions that underpin these water markets generally include laws, constitutional provisions, statutes, court decisions, water agency policies and central information systems, among other components (Archibald and Renwick, 1998). Culture also plays an important role in water markets (Haddad, 2000). California's and Australia's temporary water markets have, for example, been supported by central agencies that have been instrumental in facilitating the sale and purchase of water – the drought water banks in California and the water exchanges in Australia (Haddad, 2000; Bjornlund and McKay, 2001). No such institutions exist in Alberta. Buyers and sellers typically gain information by word of mouth, newspapers and bulletin boards. Little is known about the nature of the actual contracts themselves.

Considerable research is needed to gain a greater appreciation of the institutional framework around which irrigation water markets operate in Alberta. Areas of research should focus on identifying

- the nature and structure of current institutional arrangements;
- the effect of institutions in facilitating (or hindering) water sales;
- the institutional systems needed to foster water sales;
- attitudes that surround the sale of water for profit; and
- the effect of the differences between formal and informal water institutions.

Global Warming

Since the beginning of the industrial revolution, the level of atmospheric greenhouse gases such as carbon dioxide, methane, chlorofluorocarbons, nitrous oxide and tropospheric ozone has been increasing at an accelerating rate due to human activities such as fossil fuel combustion, deforestation and agriculture. If greenhouse gas emissions continue at the current rate, as some predict, the average annual temperature is expected to rise 1.5 to 4.5°C in Canada, and variability in several other weather-related variables, such as precipitation, will increase (Touré, Major and Lindwall, 1995).

Increasing atmospheric concentration of CO_2 can affect agricultural production both directly and indirectly. A higher CO_2 concentration will have a stimulating effect on plant photosynthesis (Cure and Acock, 1986) and lead to improved water use efficiency of crops (Gifford, 1979; Sionit, Hellmers and Strain, 1980). On the other hand, increased CO_2 concentration will induce climatic changes that affect plant growth indirectly. Accompanying the surface warming from the increased concentration of greenhouse gases, changes are expected in other weather variables such as heat, drought, soil degradation and erosion by wind and water, which collectively may alter plant growth and distribution.

Climatic warming is likely to increase the variability of precipitation, which could affect the agricultural sector in the semi-arid ecosystem of southern Alberta. The potential for increased severity and frequency of drought poses a threat to the viability of grain production in some parts of the province while it increases the opportunities in other parts. There is concern also that soil degradation and erosion may increase because of reduced soil moisture as a result of the predicted climatic change.

Farmers who irrigate may have increased demands for water when rivers are at lower levels due to the warming climate (Byrne, Barendregt and Schaffer, 1989; Byrne and McNaughton, 1991). An increase in drought frequency and/or severity may result in increased reliance on irrigated areas for food production, and could create political pressure to expand irrigation agriculture. This strategy has been advised in some studies (Parry, 1990) but may not be possible if runoff supplies shrink.

Virtually all of the runoff in this region is due to spring snowmelt on frozen soil (Byrne, 1989a, 1989b). Most of the runoff water in the region originates as snow in the Rocky Mountains. In the semi-arid region, irrigation has been developed from alpine snowmelt water supplies in the Oldman and Bow River basins. These rivers provide municipal and industrial water and a means of sewage effluent disposal for the cities of Calgary, Lethbridge, Medicine Hat and Saskatoon. There is also significant hydroelectric development on the Bow River. Warmer temperatures may decrease snow accumulation and increase average runoff. Shorter winters could result in less precipitation falling as snow. At the very least, warmer winters and earlier springs would cause runoff to occur much earlier in the year, creating management problems and increasing the need for and/or creating a strain on water storage facilities.

Global warming could have a major impact on the agricultural economy of this region, and through that on the rest of the economy. The assessment of economic and other impacts of global warming can be a difficult task. Little formal modeling has been undertaken of global warming in Canada. Neither the impacts on agriculture nor the development of appropriate strategies for coping with its effects have been studied in a comprehensive manner. Understanding the consequences of global warming on Alberta agriculture and developing of strategies to deal with it require research dealing with several critical questions, including the following:

- How would global warming affect key climatic variables in different regions of the province?
- How would plant growth be affected by changes in climatic variables?
- How would major pests of agricultural crops be affected by changes in climatic variables?
- What adjustments in crop selection and farming practices would be optimal with changes in climatic variables?
- How would regional production patterns alter as a result of changes in climate and cropping practices around the world?

Ecological and Environmental Issues

The irrigation network throughout southern Alberta has evolved over more than a hundred years. The area, which had been written off as a “vast wasteland” by some early explorers (Nerbas, 1993), is now an economically thriving region where more than 50 crops are produced. With this development, the ecological changes have been profound (Nerbas, 1993). While most economic effects have been positive, the ecological changes, and their effects on birds, wildlife and fish, have not consistently been advantageous.

Without irrigation, southern Alberta would be a grassland region. The development of irrigation has permanently altered the landscape, creating more than 80 reservoirs and thousands of miles of canals and drains (AIPA, 1993), increasing cultivated acreage and reducing wetlands and water levels in rivers.

Nerbas (1993) reported on the impact irrigation has had on the natural resources of the region. His report chronicles both positive and negative impacts on species. Shoreline birds, for example, thrive in sloughs created by irrigation seepage, dugouts, canals and man-made lakes. There are no shorebird habitats of significance south of Calgary except in irrigation districts. Deer, which are well suited to grassland areas, are also thriving in the irrigation area, to the detriment of some crops. The environment is not as amenable for various other species. Nerbas noted the loggerhead shrike, a threatened species, is more suited to grassland than to irrigation areas. Populations of the burrowing owl are likely lower than in surrounding dryland and rangeland areas because the irrigated areas have a high degree of cultivation. Nerbas observed that cultivation and wetland drainage has also greatly reduced the habitat for the great plains toad, classified as very rare.

Diversions for irrigation purposes are often cited as key factors in the degradation of fish habitat within southern Alberta streams and rivers (Nerbas, 1993). The reason is that reduced flow rates in the natural river cause an increase in water temperature and reduction in dissolved oxygen levels. The extent of this impact on fish has never been quantified (Nerbas, 1993). Alternatively, the reservoirs have created a previously unavailable habitat for fish.

Additional water-related problems arise from irrigation. Nerbas (1993) notes that while agricultural runoff is not exclusive to irrigated agriculture, the application of irrigation water creates a greater problem because runoff increases. Also, greater amounts of pesticides and fertilizers generally are applied to irrigated crops, having a significant effect on the quality of the receiving water (Nerbas, 1993).

While opportunities for some species to develop in harmony with irrigation exist (AIPA, 1993), the significant alteration to the original environment has had detrimental effects on the ecosystem for others. Because of the priority society places on environmental quality, and the deleterious effects irrigation can have, trade-offs between economic development and ecology will likely become more apparent. Research is needed on the extent of third-party effects emanating from growing water usage accompanied by land-use and population pressures in Alberta. These effects include changes to surface water and groundwater quality and quantity and to the natural ecosystem including aquatic life, watershed and riparian vegetation. Public health issues, in-stream water quality effects and water conservation flows are of special importance, along with prevention and remediation of naturally occurring and anthropogenic contamination of water resources. The following types of economic questions require study:

- What role can economics serve in allocating water between economic development and ecological purposes?
- Can economics effectively allocate water, or is there a continuing role for government where ecological issues arise?
- What value does society place on the preservation of various species?
- What sectors of the economy can reduce water use with the least economic cost?
- Should alternate water pricing strategies for water users – municipal, industrial, agricultural, recreational and ecological – be considered in order to better allocate scarce water supplies? What would those pricing strategies look like?
- Is setting land aside for natural preserves a viable option from an economic and ecological point of view?
- Can water transfers allocate water efficiently between economic and ecological uses?
- Should environmental groups be able to buy water from licensed water holders, as is the case in some jurisdictions?

Farm Management

Irrigation is by far the largest consumptive use of water in the semi-arid ecosystem of western Canada. Decisions made by farmers on their use of water can have large impacts on the efficiency and sustainability of water use throughout the region. To obtain maximum efficiencies in their operations, farmers require information on crop responses to water under different soil and climatic conditions and possibilities for substitution of water with other resources. In addition, they require information on all the other determinants of farm profitability, including expected prices of products and inputs. Hexem and Heady (1978) estimated relationships in the United States among grain yields and numerous explanatory variables, including water used, nitrogen applications, soil acidity, electrical conductivity, hydraulic conductivity and evapo-transpiration. UMA (1982) developed water production functions for crops in southern Alberta; however, they did not consider the effects of differential soil type, location, year, fertilizer or other agronomic variables. Kulshreshtha, Scheutz and Brown (1991) estimated water production functions for several cereal and forage crops in Saskatchewan using farm-level survey data from irrigated areas in Saskatchewan.

A wide range of irrigation technologies is available. These range from capital-intensive, low-labour methods to those that are highly labour intensive but have low capital requirements. Each has different operating costs; thus, the optimal water application rates may differ among irrigation systems.

At present, irrigators in Alberta are assessed a fixed charge per unit area for their rights to use water that is made available by the irrigation district in which the land is located. The variable costs for water use are only those associated with the application of water, since water is not charged on a quantity basis. However, increasing demands on the limited water resource mean that changes in the allocation schemes may occur in the future. Any changes that affect the cost of water will change the efficient levels of application.

Irrigators face a great deal of uncertainty regarding the optimal use of their inputs. Farming in a semi-arid environment is fraught with unknowns. The availability of stored water to supplement plant growth reduces the variability of yields. To make optimal use of this limited resource, a great deal of farm management information must be researched and made available to farmers. The need for research includes (but is not limited to) the following areas:

- crop responsiveness to different levels of water application (on different soils, at different stages of plant growth and in combination with alternative fertilization levels);
- costs of and returns from alternative water conservation strategies;
- costs of, returns from, and optimal watering strategies for different types of irrigation systems;
- energy requirements of different irrigation systems;
- simulation modeling of impacts on water quality, leaching, salinity and other externalities of various levels of water application; and
- opportunities to improve farm profitability through enterprise shifting, sales of water rights and other production and investment strategies.

Concluding Remarks

The intent of this article was to discuss priorities for socio-economic research on water in the semi-arid region of southern Alberta. Given the current physical structure of surface water resources and the legal framework governing the use of these resources, five broad research themes were identified: demand management, institutions and attitudes, global warming, ecological and environmental issues and farm management.

How can the conflicting interests associated with the use and allocation of surface water be successfully harmonized? At present the demand for surface water is rationed by legislative means. The legislation reflects the sentiment that surface water users cannot be left free because the result will be destruction of this resource, and government intervention is essential for the sake of avoiding environmental damage. Vast and complex systems of law have been developed in Alberta to deal with questions of who has the right to the use of surface water and how it may or must be used. It is important to determine the extent to which the laws and customs relative to surface water contribute to or hamper its efficient use. Future economic growth and prosperity depend on institutional frameworks that facilitate the efficient and sustainable use of surface water resources. To this end, a well-considered socio-economic research program can provide information to help policy makers make the necessary critical choices.

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Endnotes

[1] Semi-arid refers to the condition where evaporation potential from the ground surface exceeds precipitation that typically occurs over a given period.

[2] The formal transfers of water licences are discussed in more detail later in the paper.