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WISE – A Multidisciplinary Water Research Institute in Southern Alberta

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The Issue

Water is one of many economic drivers for southern Alberta. Industries such as intensive livestock operations and food processing depend on irrigation infrastructure for water. Lethbridge is the location most often associated with irrigation, though much of the irrigation is actually located east (Taber to Medicine Hat) and northeast (Strathmore to Brooks) of Lethbridge. Multidisciplinary research projects are needed to analyze and document the stream flow requirements of aquatic and riparian ecosystems; such research would allow the development of river regulation strategies that preserve these ecosystems. Research on water quality and water quantity is of high priority. How do dams affect downstream ecosystems in the South Saskatchewan River basin, including the Oldman, Bow and Red Deer sub-basins? How does water use affect the ecosystem? How do irrigation and intensive livestock operations affect the environment?

Implications and Conclusions

A Water Institute for Semi-arid Ecosystems (WISE) was formed to study the impacts of human activity on water quality and water quantity in the South Saskatchewan River basin, including the Oldman, Bow and Red Deer sub-basins. WISE has a multi-agency

governance structure coordinated from the University of Lethbridge. Lethbridge is ideally located for the study of water in a semi-arid environment because of the proximity of irrigation and dryland agriculture to industry, human resource capacity at the university and other agencies, and businesses with an irrigation focus in the immediate area. A scientific advisory committee sets the research priority areas, with input from all agencies.

WISE has four themes: water safety and quality, aquatic ecosystems, climate change and prairie ecosystems, and economic and social impacts. Objectives of the first three themes are to better understand the biological processes at work in the ecosystems and their effects on water. Economics is an integrating theme, utilizing information from the biological themes as well as from other relevant sources to evaluate overall impacts. Geographic information systems provide spatial analysis capabilities to support the multi-disciplinary research. It is anticipated that WISE will fill a gap in long-term water ecosystem analyses by facilitating the building of multi-agency, multidisciplinary teams of researchers to study water problems and the interrelationships within the ecosystem.

Reasons for a Water Research Institute in Southern Alberta

Development balances economic activity with quality-of-life issues. The environment of southern Alberta is fragile. Rivers in arid southern Alberta play a critical role for native plant and animal life. Most of the river system in southern Alberta is charged with water from rain and the melting snow pack from the eastern slopes of the Rocky Mountains. The important ecological role of river water is threatened by the high competing demand from human populations for water. Degradation of river and riparian habitats will ultimately have adverse feedback effects for crop irrigation, livestock production, water quality, and recreation in southern Alberta. Documented weather data on the Canadian prairies over the last 50 years indicate winters have become warmer with less precipitation. This has important implications for the recharge of rivers and the functioning of arid-land ecosystems.

Canadians consider an abundant supply of clean water as their birthright, thus water quality and water management have become highly charged and contentious issues. WISE was formed to address these and other challenges in semi-arid ecosystems in southern Alberta and around the globe. Its vision is to be a world leader in research and education in water resource management for semi-arid ecosystems.

The institute's structure requires the board and agency administrators to promote and to solicit funds for the institute and to foster linkages among agencies to obtain the maximum benefit from collaboration. WISE has a multi-agency governance structure coordinated from the University of Lethbridge. A scientific advisory committee sets the research priority areas, with input from all agencies. Collaboration among researchers requires that researchers take the initiative to bring others into projects, but there is also a need to have networking activities.

A Multidisciplinary Approach to Research on Water

WISE has four major research themes, and there is interaction among these themes (see figure 1). Water safety and quality, aquatic ecosystems, and climate change and prairie ecosystems are physical and biological research themes. Economic and social analysis is an integrating theme that helps to tie together the results of the physical and biological research. Geographic information systems will provide spatial analysis capabilities.

Water Safety and Quality

Research in this theme area will focus on the survival of pathogenic micro-organisms in aquatic habitats in semi-arid regions. The presence of pathogens, such as *Escherichia coli* (*E. coli* 0157:H7), is a major health and water quality concern. Identification of the conditions for the microbial communities to survive and thrive is important in order to determine the risk of water-borne diseases in human and animal populations. Livestock and other mammals share a number of enteric microbial pathogens with humans. Water contamination by animal fecal material and by municipal and other effluent is a growing concern in Alberta. The transmission of these pathogenic micro-organisms from animals to humans has been responsible for significant outbreaks of infectious diseases in human populations. It is critical to develop appropriate strategies for control of water-borne infectious micro-organisms, so that morbidity and mortality caused by these infections in human populations can be reduced.

The objectives of research in this theme are to develop new and more effective assays for the detection and identification of viable pathogens in water and wastewater, assess systems to evaluate the public health risk of reusable water, find ways to reduce or eliminate hazardous materials from water and wastewater, and identify potential sources of microbial pathogens in non-point sources of contamination of surface waters. Information from these studies will be helpful to policy makers in the formulation of science-based best management practices to control point and non-point sources of pollution and to promote water safety and quality.

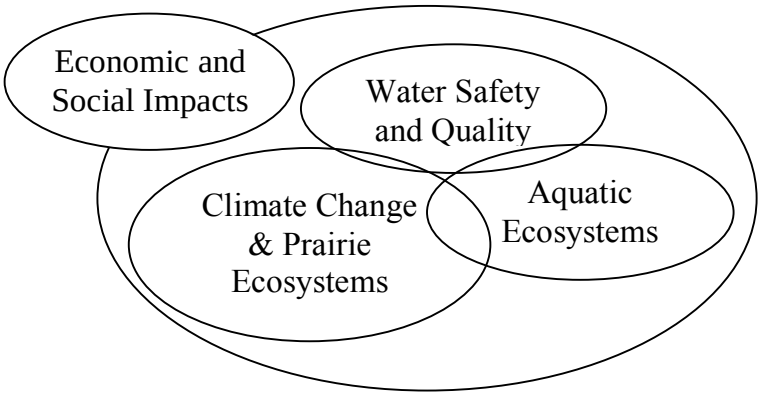

Figure 1 Themes of WISE

Aquatic Ecosystems

This theme will analyze and document the stream flow requirements of aquatic and riparian ecosystems to allow the development of river regulation strategies that will help to preserve these ecosystems. Research in this theme will determine the impacts of dams on downstream ecosystems in the South Saskatchewan River basin, including the Oldman, Bow and Red Deer sub-basins. In addition, the use of riparian woodlands by birds and other wildlife will be investigated in order to estimate the consequences of degradation to these ecosystems and the adjacent aquatic and prairie habitats. A better understanding of riparian tree water requirements and water-use patterns will aid in the development of strategies to restore and conserve these important dominant plants.

Riparian (streamside) zones provide dynamic interfaces between ground and surface waters and between aquatic and terrestrial ecosystems. The flood cycle determines recruitment of riparian forests, which in turn feeds back to affect channel structure and maintenance. Priority research includes determination of the linkage between intact riparian forest and the stability of streambanks as well as the subsequent effects on channel structure and habitat establishment. The primary benefit of this research is the development of predictive models that characterize the requirements of sustainable riverine ecosystems.

It is known that biodiversity affects ecosystem function and dynamics but it is unknown if biodiversity confers resistance to invasion by exotic species. There are numerous examples of widespread social, ecological, epidemiological, and economic costs of species invasions and outbreaks. A notable example is the invasion of lakes and rivers by Eurasian milfoil, an aquatic plant that is expensive to harvest and mitigate. High biodiversity may reduce invasions of aquatic weeds by providing a form of biological "insurance" imparted by more complete use of resources by a greater variety of organisms. Biodiversity may also play a role in mediating pest outbreaks, such as spring blooms of noxious algae, which can cause undesirable taste and odour. In summary, research in this theme will deal with the maintenance of riverine ecosystem integrity – including determination of the impacts of biodiversity on risks of exotic species invasions and outbreaks of pests – and with the maintenance of underlying ecosystem processes and functions. The main benefit of this research will be the construction of an "early warning" system based on potentially subtle changes in biodiversity and ecosystem function that may lead to undesirable and even catastrophic consequences for aquatic systems if left unchecked.

Climate Change and Prairie Ecosystems

A scientific consensus now exists that the buildup of greenhouse gases in the atmosphere is warming the earth. Future changes in elements of the water cycle, such as shifting patterns in the amount and timing of precipitation and runoff and changes in snow pack in the mountains, will be especially important for prairie ecosystems. Climate change is

certain to affect in-stream flow needs and biodiversity in rivers since much of Alberta is already vulnerable to slight variations in temperature and precipitation patterns.

Research in this theme will focus on how water inputs control plant productivity, carbon and nutrient cycling, and energy exchange in native prairie and agricultural ecosystems in southern Alberta. Models will then be applied to 1) scale up or extend knowledge gained at specific sites for regional analyses and 2) predict ecosystem responses to climate change scenarios. This research program will make extensive use of geographic information systems to integrate databases that exist for the province with those developed through other research activities undertaken within WISE.

These analyses will allow better understanding of the potential for increasing carbon sequestration in prairie soils and of the susceptibility of ecosystem productivity to climate change and altered water inputs. Additional studies will investigate variation in winter snow accumulation and water runoff for a series of watersheds. These analyses will allow estimation of changes to river water supplies, the primary surface water resource in arid southern Alberta. The major benefit of research in this area will be the contribution of realistic projections that can provide the basis for decisions on water allocation.

Economic and Social Impacts: An Integrating Theme

The economics research program provides an integrating theme in WISE. Economics addresses the many roles that 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. This is an integrating theme, since knowledge gained from the physical and biological research will provide crucial inputs for the economic analyses. Socio-economic research will be conducted in five areas:

1. **Economics of water availability and supply** includes research on optimal development and use of watersheds, basin management, groundwater resources, conjunctive use of surface- and groundwater sources, and adjustments to climate change. Basin transfers and water markets will affect supply (Mahan, Horbulyk, and Rowse, 2002). Seasonality of supply, interprovincial and international water treaties on stream flow and use, and in-stream flow requirements will affect the supply of water available for non-stream consumption and use. Research in this area seeks to evaluate and guide resource decisions affecting all sources and supplies of water at the potential points of use.

2. **Economics of water use and demand** includes research on the agricultural, industrial, municipal, recreational, hydroelectric, household, in-stream flow, and other uses of water in Alberta. Water conservation, demand-side management, water reuse, and the efficiency of water storage, conveyance, distribution, and application will be investigated from quantity, quality, and reliability perspectives. The quality of water for human consumption could be affected by other uses and demands. Basinwide modeling is required to evaluate all competing uses and demands for water (Berger, 2001;

Chakrovorty and Umetu, 2003; Diaz, Brown, and Sveinsson, 2000; Ivanov et al., 1995; Matthews et al., 2001; Rosegrant et al., 2000).

3. **Institutions and pricing of water** includes an examination of the roles played by government, private, and not-for-profit organizations in the allocation, pricing, and use of water in Alberta (Horbulyk, 1995; Horbulyk, 1997; Horbulyk and Lo, 1998). Property rights and legal issues will be of primary interest. The projected effects of alternative systems of transferability of water rights, pricing, and apportionment will be evaluated. The ability to create or improve existing management approaches within Alberta's jurisdiction could be affected by First Nations' lands and rights, by federal lands, by approaches to interprovincial and international apportionment, and by federal regulation of fisheries or energy. Economic analyses need 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.

4. **Externalities of water use** include actions that affect water quality and quantity and riparian habitat (Adamowicz and Horbulyk, 1996; Dinar and Loehman, 1995; Dosi and Tomasi, 1994; Segerson, 1988). These effects could include changes to surface and groundwater quality and quantity through affecting stream flow or facilitating the entrance of nutrient additions or contaminants to the river system. Similarly, the natural ecosystem, including aquatic life, watershed, and riparian vegetation, could be affected by the same actions. Research in this area will attempt to identify the socio-economic consequences of these types of externalities and to propose policies and approaches that can diminish the negative effects of these externalities on the lives of Alberta's people and industries. Public health issues, in-stream water quality effects, and water conservation flows will be of special importance, along with prevention and remediation of naturally occurring and anthropogenic contamination of water resources.

5. **Risk considerations for water** include both use and quality. For irrigation, optimal water use is affected by many variables, including uncertain commodity prices, incomes, capital costs, weather variables, varying water charges and availabilities, and technological advances (Kulshreshtha and Klein, 1994). In addition to production risks, there can be a risk to timely irrigation water supply and risk associated with changes to institutions and water laws. The risks inherent in private and public use of water will be analyzed in light of present and proposed policies and regulations. For example, a current topic in some utilities research is the evaluation of optimal levels of investment in various dimensions of system reliability, where this is often linked to balancing the associated costs and risks that users are prepared to bear. The implications of extreme events such as droughts, flooding, climatic change, and contamination must be evaluated and integrated across research themes (Klein, 1997; Klein and Walburger, 1996). Risks associated with quality are primarily related to pathogens and how water use and other activities in watersheds affect the likelihood of creating an environment conducive to pathogens.

A Multi-agency Approach to Research on Water

WISE serves as an umbrella organization to foster and facilitate collaborative water related research among institutions in southern Alberta that have expertise in various disciplines. The administration of WISE is at the University of Lethbridge (UL), which has 18 faculty with some level of commitment to the institute. Other agencies (and personnel with a commitment) include: Agriculture and Agri-Food Canada, Lethbridge Research Centre (11 researchers); Canadian Food Inspection Agency (2); Health Canada (1); Alberta Agriculture, Food and Rural Development (6); Alberta Environment (1); Alberta Research Council (3); the Chinook Regional Health authority (3); and the Alberta Irrigation Projects Association (1). WISE can mobilize key personnel from a number of agencies that have a common interest in water but not the capacity individually to address all of the complex interrelationships that relate to a particular problem. Some agencies within WISE have overlapping areas of expertise, which can be beneficial because of the different perspectives provided due to the variety of backgrounds, experience, and agency roles.

The primary role of the Chinook Health Region (CHR) is to deliver health services in southwest Alberta. In addition to providing medical services, the health region is also proactive in preventing the spread of communicable diseases through water. The Health Canada (HC) satellite Laboratory for Foodborne Zoonoses provides scientific information on minimizing risks of human illness arising from animal and human interaction. The CHR and HC are interested in ensuring healthy water for urban and rural residents. Water treatment at public and private treatment systems and management practices that affect the water prior to treatment are concerns.

The Alberta Irrigation Projects Association (AIPA) is an umbrella organization representing 13 irrigation districts in southern Alberta. Nearly all irrigation is with surface water from mountain runoff. AIPA is primarily concerned with water supply for irrigation, the efficient use of irrigation water, and regulations that affect water allocation and use. The association partners with institutions and organizations to undertake irrigation and water quality research. The AIPA promotes efficiency of irrigation systems to increase the benefits of irrigation to southern Alberta.

Water quality standards in Alberta are set by Alberta Environment (AE). By monitoring and enforcing water quality standards, AE contributes to improvements in water quality. Research into diverse water related activities is supported to provide information to assist in setting standards and to determine how the standards should be monitored.

The Irrigation Branch of Alberta Agriculture Food and Rural Development (AAFRD) provides agronomic and water management services to producers using irrigation and to the industry. It conducts research, demonstration, and extension activities related to irrigation. Research programs develop information on the effects of agricultural

management practices on water use and quality. Knowledge of nutrient (fertilizer and manure) management and the effects of management practices on nutrient utilization and movement are essential to understanding the potential impacts on water quality. Mechanisms by which bacteria enter surface water are being investigated, and water quality and irrigation management are being evaluated.

The Alberta Research Council (ARC) assists by developing technology and innovations to meet current and future needs of industry and government in Alberta. ARC's mandate regarding water is to promote sustainable use for human consumption and industrial development. Its current programs related to water include water treatment and watershed and rangeland ecology.

Laboratory facilities at the Canadian Food Inspection Agency (CFIA) are capable of providing microbiological and chemical support services. The CFIA laboratory in Calgary provides specialized testing services, develops laboratory methods for analyses, and accredits laboratories. Quality laboratory analyses are required by CFIA for their food inspection mandate.

The Research Branch of Agriculture and Agri-Food Canada (AAFC) has an agricultural research centre at Lethbridge. Studies being conducted within national research programs that are relevant to water management in semi-arid ecosystems include investigations of water quality, nutrient use and recycling, greenhouse gases and climate change, range management, economics, pest management, remote sensing, and microbiology of ruminant microbes. Crop and animal production systems can affect the quality of surface water and groundwater. The processes and interactions by which this happens are being explored through research. Results of this research can be used in the development of best management practices. Intensive livestock production and rangeland production systems can affect the quality of water at local and regional levels. Implications of climate change for water supply and demand can be used to develop adaptation and mitigation strategies on local and regional scales. Economic drivers are important for adoption of best management practices.

The University of Lethbridge carries out an active research program in addition to teaching students. The potential impacts of agricultural production systems on water quality, including the presence of nutrients and pollutants, are being explored to understand the processes. Biodiversity and health of river valley ecosystems could be influenced by industrial and agricultural use of water. Institutional arrangements and economic considerations are major factors determining the quantity and quality of water. Among the areas of research being pursued at the University of Lethbridge are the impacts of pathogens and bacteria; nutrients in water; river and freshwater resources and riparian health; aquatics; exposure to metals, pesticides, and pharmaceuticals; climate change and water resources; hydrology; GIS; and economics.

Multi-agency cooperation is required for comprehensive and integrated analyses of most water issues. A study of pathogenic micro-organisms in the water supply, for

example, will require the expertise of health officials (CRH, HC) for impacts on humans and laboratory expertise (AAFC, CFIA) for identifying and classifying micro-organisms. Understanding the processes by which the organisms enter the water supply, and the industrial and agricultural practices and natural processes that encourage or prevent the presence of the organisms, will require range ecologists, livestock specialists, agriculturalists, and riparian habitat researchers (AAFC, AAFRD, AE, UL). The effects of management practices feed directly back to quality; production practices affect economic costs (AAFC, UL). An integrated study is required to establish linkages within the entire system to enable the identification and development of technical and economic solutions to water quality problems.

A different set of skills is required to address a water supply and demand problem. Water demands for streams and riparian habitat (ARC, UL), for irrigation (AAFRD, AIPA), for interprovincial or international treaties and for industry (AE) are influenced by institutions, legislation, and economic factors (UL). Changes in water supply, especially considering long-term impacts of climate change, will directly affect those with water demands (AAFC, AE, UL). Solutions could range from water enhancing activities to increased irrigation-use efficiency to increased industrial- and municipal-use efficiency. All uses need to be considered simultaneously to fully account for competing demands and interactions among users.

Concluding Note

One of the main resources affecting long-term development of industry and agriculture in southern Alberta is water. There are increased demands for water from current users as well as increased public concerns about water quality. The long-term supply of water is increasingly an issue because of uncertainty related to the effects of climate change and regulations that can dictate use rates. It is important to examine issues related to supply, quality, use efficiency, riparian and in-stream flow needs, and institutional structures in order to develop sound scientific information that can be used for future decision making. To facilitate the research work required for informed water policy, a research institute was formed in southern Alberta. The Water Institute for Semi-Arid Ecosystems (WISE) is supported by nine organizations and agencies in southern Alberta and promises to develop the type of research program that is in high demand.

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