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Water Resources Evaluation and Millennium Ecosystem Assessment Framework: Application to Value of Water in the South Saskatchewan River Basin

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WATER RESOURCE EVALUATION AND MILLENNIUM ECOSYSTEM ASSESSMENT FRAMEWORK: APPLICATION TO VALUE OF WATER IN THE SOUTH SASKATCHEWAN RIVER BASIN

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INTRODUCTION

In spite of numerous encounters with scarcity of water world over, and mounting evidence on its scarcity, water is still treated as a free resource. Although some water users pay a charge for it, there is seldom a charge for withdrawing water from the surface water bodies or from aquifers. User charges are levied to cover water treatment and transportation costs, and perhaps for the disposal of return flows. Typically no considerations are given to opportunity cost of water in making planning or investment decisions.

Water is a critical input into the society welfare. It is vital for many reasons: it is an essential input into the production of agricultural, industrial (manufactured), and energy goods; its role in proper functioning of the natural ecosystems on which society depends; and disposal of human and industrial wastes. In spite of this importance, or perhaps because of it, water is a resource that is associated with a fair amount of sentiments.

With water being threatened on account of supply as well as demand related changes, policy makers need information about water resource development and management, including water allocation. Social valuation of this resource is a key input into this process. Several studies have attempted to answer this issue (see Young and Gray 1972; Gibbons 1986).

Much of the past valuation is based on a framework that is typically anthropocentric in nature, although other frameworks are also plausible. More recently, the linkage between ecosystems and human well-being have been drawn through the development of the Millennium Ecosystem Assessment (MEA). Although the MEA is developed for a generic ecosystem, its appeal to examine water resources is obvious. In this paper, the feasibility of adopting the MEA framework of valuation is applied to water resource. Scope of this investigation is limited to the South Saskatchewan River Basin in Canada.

SOUTH SASKATCHEWAN RIVER BASIN

The South Saskatchewan River Basin (SSRB) is a shared river basin between the provinces of Saskatchewan and Alberta. It is a part of a larger basin – Saskatchewan –

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Nelson basin, since the South Saskatchewan River joins the North Saskatchewan River, enters into Manitoba, and there joins the Nelson River system. Location of the SSRB is shown in Figure 1.

The basin is subdivided into four sub-basins: Oldman River sub-basin, Bow River sub-basin, Red Deer River sub-basin, and the South Saskatchewan River sub-basin. The last sub-basin can be split along administrative boundaries – for Saskatchewan and Alberta.

The size of the drainage basin for the SSRB is estimated to be 150,000 km^2. Although relative to the other river basins, it is smaller in size, its importance to the human well-being is relatively high. This is because this basin houses some large urban areas, city of Calgary, as well Saskatoon. The total population living within the SSRB in 2001 is estimated to be 1.55 million, of which 84% resides within the Alberta portion of the basin.

Figure 1 Map showing location of the South Saskatchewan River Basin

Major water use within the basin is for irrigation, mineral extraction, and municipal (including domestic, commercial and industrial) purposes. Much of the irrigation is group irrigation through the construction of dams and reservoirs for this purpose. However, most of the reservoirs are multi-purpose in nature. Limited amount of thermal electric power generation does exist.

INTRODUCTION TO MILLENNIUM ECOSYSTEM ASSESSMENT

The Millennium Ecosystem Assessment (MEA) is a United Nations program designed to meet the needs of decision-makers for scientific information and on the links between ecosystem change and human well-being. It is a four-year program announced in June 2001.

Components

An overview of the MEA is shown in Figure 2. Major components include the ecosystem services and

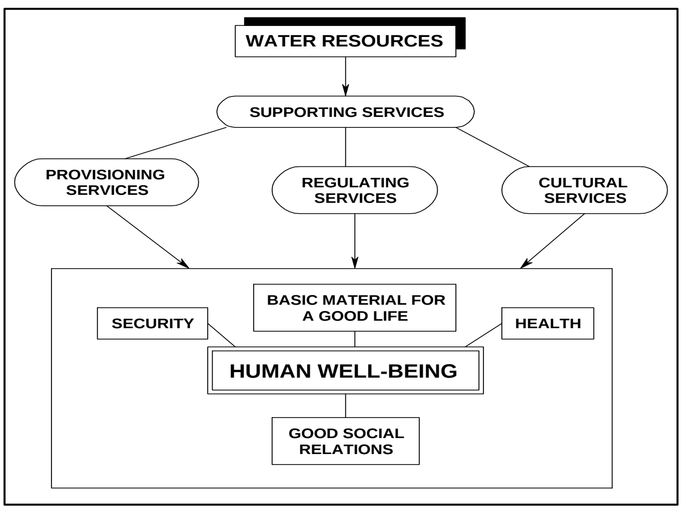

Figure 2 Components of Millennium Ecosystem Assessment

human well-being and its relationship with water resources. The former includes a variety of functions that may be related to water resources. These include supporting services, such as nutrient cycling, further feeding into services more closely related to the human-well-being, such as the provisioning services (food production, fresh water), regulating services (such as water purification), and cultural services (recreation and ecotourism, aesthetics, spiritual and religious, and cultural heritage). Human well-being similarly has several components in the MEA, including security, basic material for a good life, health and good social relations.

In order to assess the relationship between ecosystem services and human well-being, the MEA suggests the process of identifying the nature of change in the level of services and the value members of the society place on these changes. The conceptual framework adopted by the MEA is shown in Figure 3. Ecosystem services are affected by both direct drivers and indirect drivers. Human well-being in turn, is affected by all these changes plus the changes in the ecosystem services.

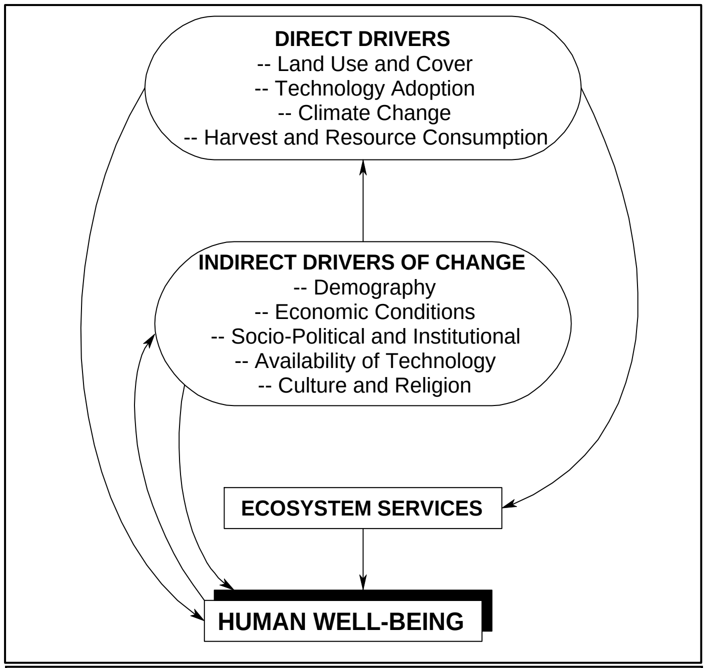

Figure 3 Conceptual Framework for the MEA

Types of values associated with water under MEA

The MEA identifies four types of values associated with natural ecosystems: utilitarian, ecological, socio-cultural and intrinsic. The utilitarian or anthropocentric values are based on the Total Economic Value (TEV) framework of valuation. These values include both use values and non-use values. Ecosystem values relate to the ecosystem services. Again here the utilitarian framework is used to value them. The last two sets of values are non-utilitarian values. These values exist even though they do not directly contribute to human well-being directly. For this reason, these values are not an aggregate sum of values held by individuals, but ascertained though a process of open public deliberation.

ESTIMATION OF VALUE OF WATER IN THE S.S.R.B.

Water available in the SSRB has several sources of values associated with it. These values differ across users. For instance, households use water directly to provide utility enhancing services (food preparation, cleaning, sanitary services, recreation, etc). Business enterprises use water directly as a critical input into production (watering, processing, cooling, cleaning, etc). Businesses and households also benefit from water *in-situ* in terms of recreation possibilities (fishing, boating, and scenery) and as productive inputs (hydropower generation and transportation). They also benefit from supporting and regulating services provided by a healthy watershed in terms of flood control, habitat preservation, and water cleansing. A broad categorization of these values is shown in Table 1. Various types of values that could be associated with water resources are identified. Presence of some values, such as option values and non-use values, have not been explored in the literature, although it is felt that such values should be associated with groundwater.

Among the various utilitarian based values, those related to direct use, indirect use and option values are critical. Similar to the non-use values, existence of option values remains to be determined for the water resources.

Table 1: Conceptual Categorization of Value of Water in the SSRB

Category of Value	Sub-Category	Example of Source of Value
Direct Use Values (Provisioning services)	Agriculture and Food Production	Irrigation
		Stockwatering
	Fisheries	Commercial
		Aquaculture
	Municipal	Domestic
		Industrial-Manufacturing
	Non-Municipal Industrial	
	Mining	Mineral extraction and processing
	Power generation	Hydro
		Thermal
Indirect Use Values	Commercial Navigation	
	Recreation	Recreational fishing
		Water-based recreation
		Water fowl viewing
		Ecotourism
	Regulating services	Flood protection
		Erosion protection
		Habitat maintenance
		Storm protection
		Drought recovery
		Biological diversity
		Climate regulation
		Nutrient cycling
	Cultural services	Aesthetics
		Property values
		Cultural and religion based values
Option values		
Non-use values		Existence values
		Bequest values

Valuation Framework

The utilitarian values can be estimated using alternative frameworks. Two such frameworks that are used include: One, water can be looked at in terms of its contribution to the wealth creation for the society (Net Economic Benefits). An alternative is to use economic impacts as the basis for valuation. The first one is often referred to as the national economic efficiency criterion, whereas the latter one as the regional economic development criterion.

Indirect use values generally include ecological and socio-cultural values. The former include the regulating services provided by water, whereas the latter often involves the use of implicit markets, artificial markets, or participatory assessment or group valuation. These services differ across users. Similarly, social-cultural values are very group-specific.

The purpose of the valuation process is to identify these contributions to well-being. Contributions may be of an explicit monetary value, such as the revenue from increased harvests on irrigated lands, or of a non-monetary value, such as the pleasure of watching waterfowl. In a world where water is unlimited, withdrawal and consumption in one activity will have negligible effects on other users in other spheres. However, the reality is very different from such a world. Rather, given the current demands for water in its alternative uses, activities by one affect others and one faces tradeoffs between users and usages. For example, water used in irrigation may not be available for downstream industries. Changes in water supply induced by global climate change, as well as continued population and economic growth, will tend to make these tradeoffs more acute as demand for water, in each of its uses, increases.

The MEA framework stresses this multidimensionality of ecosystem services as well as the interdependence between communities of users. A useful approach to dealing with both dimensionality and interdependence is to measure the benefits of water resources across its uses and functions using a common metric. This facilitates, though does not guarantee, a more careful assessment of potential tradeoffs facing policy makers.

ESTIMATION OF VALUE OF WATER WITHIN THE M.E.A. FRAMEWORK

For the SSRB, two valuation schemes are relevant. The economic efficiency approach is to monetize the benefits of water that accrue to different users by valuing water in its alternative functions. This allows one to identify the marginal value of water in its different uses and focuses on the ability of agents to adapt to or accept changes in water resources over time. It can also capture the spatial nature of water resource as one can identify users by location.

The regional economic development criterion is used to assess the contribution to economic development supported by water resources. This approach attempts to identify and measure the impact of economic growth as a direct and indirect driver within the water basin. It also allows one to assess the impact of changing water resources on economic development. This is particularly relevant for assessing the impact of global climate change on human communities as the pattern and intensity of precipitation is also expected to change. One can focus on employment, production, exports, imports, and income as measures of economic development. Issues, such as security, health, freedom, and access to basic material for life, need not be considered as directly relevant given the high per capita incomes of the basin communities and the relatively small size of the river basin.

In this paper, only the selected results using the first scheme are presented, although application of the second scheme is planned. However, results are not available at this time. The basis for economic efficiency valuation of water is entirely anthropocentric. The initial step in this valuation process is to identify and differentiate user groups and water functions within the water basin. The second step is to estimate the value of water for each group. Since water provides a different type of service for each type of user and is often allocated in a different manner, the valuation method employed reflects the special characteristics of the user group as well as different data sources.

One observes that individuals are willing to give up income/revenue, time, and effort to use or preserve water resources. This *willingness to pay (WTP)* for water is equated with the value of water.[4] The focus is on the WTP of individuals or firms within the river basin though allowances can be made for those outside of the basin. At the margin, willingness to pay declines as quantity rises: the more water one has, the less one is willing to pay for additional quantities. This study approach is to identify the *marginal willingness to pay (mWTP)* schedule in some relevant range of reductions/increases for each user. This schedule is sometimes called a *penalty function* as it relates social costs of adjustment to restrictions in water.

The challenge one faces is to identify the *mWTP* schedule. When agents pay for each unit of water they use, the price they pay reflects their *mWTP*. In this study, the demand function is used to directly impute the penalty function for households and businesses supplied by municipal sources. However, formal markets for water do not always exist; so direct observations of *mWTP* can be difficult, if not impossible. This is either because water use is un-metered (as with irrigation and livestock), water use is un-meterable (such as with most recreation activities), or agents derive benefits without actually "using" the resource (as with the pleasure derived from knowing that an ecological area exists). In these cases, a strategy that can be followed is to apply studies that directly illicit a *WTP* through surveys (the *Contingent Valuation* method), to identify other activities that reflect *WTP* for water (such as expenditures on recycling activities or travel), or to simulate agent responses to hypothetical scenarios based on available production technologies (such as with livestock or irrigation).

As the value of water is equated to the *WTP*, in order to avoid reductions in access one needs to account for three factors.

(1) The time frame considered for agents to adjust to changes in water supply. In general, the more time agents have to adjust, the lower their costs of adjustment, and so the smaller their *WTP* to avoid water reductions. The *short-run value of water* will often exceed the *long-run value* by orders of magnitude. Further, the time it takes to fully adjust differs across agents.

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[4] See Shabman and Stephenson (2000) for a cogent summary of the critique of this approach.

(2) Homogeneity of the basin. The SSRB is not uniform; the spatial location of users matters as well as the location of water resources. This implies that one should observe differential impacts across sub-basins. To account for this heterogeneity, one needs to identify spatially relevant values that can be scaled to the sub-basin level and reflect sub-basin activities.

(3) Recognition that how water restrictions are allocated matters. Economic efficiency is attained when the *mWTP* for water restrictions is equal across users. This is seldom the case in practice.

Following is a brief description of some of the methods used to value water. The Environment Canada's Municipal Use database, which contains water and sewage information from Canadian municipalities with populations over 1000 and reports annual consumption and water prices for 1991, 1994, 1996, and 1999, was used for this estimation. It separates municipal supplies according to use (domestic, commercial and institutional, industrial, and others). The data allows one to estimate the elasticity of demand for water by type of user. The marginal value of water was calculated using reported community consumption, imputed marginal prices for water, and a constant elasticity of demand in the range -0.1 to -0.6. Commercial and industrial water use values were also estimated from the same database. Note that the elasticity of demand for commercial enterprises was estimated to be around -0.25. This is much higher than reported in the literature. The value reported assumes that all communities have to reduce consumption by 10%. An alternative calculation was completed that allowed for an efficient allocation of restrictions that reflected the differences in initial prices in 1996. The value of water in this case was about 50% lower.

Water values for industrial water use were calculated using Environment Canada's Industrial Water Use database for 1996. Two methods were used, both reflecting the opportunity costs of a water shortage, thus providing a measure of their willingness to pay for access to water. The first method estimates the value of reduced economic activity that could occur due to a scarcity of water. Data for value-added were obtained from the OECD (2002). The average value is extremely high at \$49,000 per dam^3 in lost value added. However, this corresponds to a very short run as firms are assumed to be unable to adjust to the water shortage except to reduce production. The second approach uses reported costs of recycling water to impute what firms would be willing to pay to avoid a reduction in water supply. This long run value is much lower at \$80 per dam^3 and reflects the ability of firms to fully adapt to water restrictions.

In thermal power generation, water is used as a source for steam or to cool the steam for re-circulation. The value of water in thermal power generation is the cost to firms of either replacing electricity generation by other means (gas-turbine or imports) or the cost of investing in, and operating, less water intensive cooling technologies. Cost data were obtained from the same source as used for the industrial water use. If firms have to replace generation (a short run response) then water has a value around \$627 per dam^3 but much lower at \$1.12 per dam^3 if water-cooling technologies can be changed.

In hydroelectric generation water is used to drive turbines, and except for some additional evaporation from reservoirs, is not used up in the process. The value of water is the cost of using an alternative generation process to replace hydro generation. If coal thermal plants are used then costs are relatively small at \$0.11 per dam^3. If this power is replaced by gas-turbine generation, this value increases to \$0.24 per dam^3.

Results using the above set of methodologies are presented in Table 2 for six economic uses of water. It should be noted that this is not a comprehensive list of uses as shown in Table 1. The primary message of the table is that the value of water services differs substantially across users, as does the range of values within a user group.

Each represents the marginal value of water accruing directly to users and does not include indirect or induced effects. The ability to adjust is clearly important. The differences in values for each user reflect different abilities to adjust to changes in water resources. The difference between high and low values is significant for each user. This suggests that long lead times are critical to reducing the impact of future water shortages. It also means that values across groups are not always directly comparable. The reported values are for withdrawals and so do not measure the trade-offs associated with water consumption. What are also hidden in the table are the significant differences in values across communities and industries.

Table 2: Estimated Value of Water in the SSRB, 1996.

Type Of Water Use	**VALUE (\$CAN Per 1,000 m^3 of Water)**	
	Low	**High**
Municipal Water Use		
Residential	1,270 [1]	2,040
Commercial	1,410 [2]	2,170
Industrial	1,410 [2]	2,170
Business Water Use		
Industrial	80 [3]	49,000 [4]
Thermal Electric	1.119 [5]	627 [6]
Hydro Electric	0.11 [7]	0.24 [7]

[1] Based on a 10% reduction in water use with constant elasticities of -0.10 and -0.60. Data source: Environment Canada (2004).
[2] Based on a 10% reduction in water use with constant elasticities of -0.10 and -0.40. Data source: Environment Canada (2004).
[3] Industry average based on implicit WTP for raw intake water. Data source: Environment Canada (2002).
[4] Industry average for value-added per 1000m^3 of water. Data source: Environment Canada (2002), and OECD (2002).
[5] Long run cost of new technology
[6] Short-run cost of replacing lost generation. Data source: US Department of Energy (2003).
[7] Based on replacing lost hydro generation with coal thermal generation (average for all sites in the SSRB).

REGIONAL ECONOMIC DEVELOPMENT ANALYSIS:

The starting point for a regional economic analysis is the input-output (I-O) model. The model allows one to estimate the effects on economic variables of changing water resources. For instance, one can look at the impact on output, income, employment, exports, or imports of a reduction in water resource in a particular sector or across all sectors. The model also allows one to identify effects on water demand of changes in economic activity. The strength of this modeling approach is that it captures direct effects as well as indirect effects and so assesses the overall impact of water on the economy. For instance, a reduction in water used in irrigation may increase the demand for more water efficient irrigation equipment. This can lead to an increase in manufactures that is otherwise not a direct user of water.

The model can also be used to identify feedback effects since changes in water resources will affect the economy, which will, in turn, alter demands for water. This is important since economic effects will spill across river basins and ecosystems. This interaction between the physical supply of water and economic activity is critical to understanding policy choices and policy outcomes and is at the heart of the MEA framework.

Estimation of this type of valuation for the SSRB is still to be completed. However, the value of water using this framework can be significantly higher than that using the net national economic efficiency criterion. For example, Kulshreshtha (1994) using the groundwater in the Assiniboine-Delta (Carberry) aquifer indicated that aggregated value of water using the regional economic development perspective was \$4,343 per dam^3 as against only \$464 per dam^3 for the net economic benefits approach.

Most of our data is taken from provincial or national databases and mapped onto the SSRB. It was presumed that individual residents and businesses in the SSRB can be represented by national or provincial data. Similarly the uniqueness of the SSRB was accounted for by accounting for its unique pattern of activities rather than in terms of any differences in technology employed, partly because of data availability permitting such a distinction.

CHALLENGES

Most of the valuation of water undertaken for the SSRB makes up only a portion of the total valuation required for the MEA framework. Even in the context of the use-related values, those based on the regional economic development perspective need to be estimated for the SSRB. In addition, many non-use values, particularly those related to ecosystem functions, and socio-cultural values, could not be estimated and required better information and data. One cannot, nor pretend one can, identify and quantify all the ecosystem services provided by water resources. Simply put, water is essential to many different social activities, many of which are near impossible to identify let alone quantify. Further, available data is sketchy and incomplete. This is partially because water has been treated as a free good and so few cared to monitor its use but partly because some relevant information is held privately and is not publicly available.

Although the MEA provides a good conceptual framework, in the context of valuation of water in the SSRB, one faces many challenges. Value of water is spatially variable within a basin or sub-basin, in addition to a high degree of variability across sub-basins. Such variability is important for water allocation decisions. In this context, one can further encounter another difficulty – the measure of value of water that is relevant. Two alternative measures are commonly used – an average value (similar to those estimated here) and the marginal value. The latter types of values are useful in deciding the economic value of flow in water bodies (such as rivers), as well as for allocation among various uses. Estimation of marginal values is replete with problems. Ecological values related to the regulating services of the water are very hard to estimate, for at least two reasons. One, data on various aspects leading to the valuation of water is thin, and of very poor quality. Two, the linkage between water quality and quantity and the ability to perform these functions is not properly understood. For example, water required for in-situ functions is not a very well researched topic in the context of the SSRB. For these reasons, the valuation methodology remains to need further improvements.

Relationship between ecosystem services provided by water resources and human well-being is another major stumbling block in the proper valuation of water. What aspects of the human well-being are affected by the availability of water in various quantities of water in the SSRB needs further investigation. Furthermore, since value of water can be recognized both in terms of gain in net economic benefits vs. net economic impact on the regional economy, which one of these comes closer to the human well-being, as being posed in the MEA, is still subject to further inquiry.

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REFERENCES

Environment Canada, 2002, *Industrial Water Use*, *1996.* Ottawa.

Environment Canada, 2004, *Municipal Use Database.* Ottawa.

Gibbons, Dianna. 1986. *The Economic Value of Water.* Washington, D.C.: Resources for the Future.

Kulshreshtha, S. N. 1994. *Economic Value of Water in the Assiniboine-Delta Aquifer in Manitoba.* Social Science Series No. 29. Ottawa: Environment Canada.

Millennium Ecosystem Assessment, 2003. *Ecosystems and Human-Well-being.* London: Island Press.

OECD (2002). *Structural Statistics for Industry and Services.* Paris.

Shabman, Leonard and Kurt Stephenson, 2000, Environmental Valuation and Its Economic Critics, *Journal of Water Resources Planning and Management*, 126(6): 382-388.

US Department of Energy, 2003. *Electrical Power Annual 2001*. Energy Information Administration. Office of the Coal, Nuclear, Electric and Alternate Fuels. Washington, D.C.

Young, R. A. and S. L. Gray (with R. B. Held and R. S. Mack). 1972. *Economic Value of Water: Concepts and Empirical Estimates.* Technical Report to the National Water Commission, NTIS no. PB210356. Springfield, VA.: National Technical Information Service.