Evaluating Sustainability Criteria: Application in the Assiniboine Delta Aquifer Region

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A practicum completed in partial
Fulfillment of the requirements of the degree
Master of Natural Resource Management

January, 1999

0-612-41663-1

THE UNIVERSITY OF MANITOBA

FACULTY OF GRADUATE STUDIES

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EVALUATING SUSTAINABILITY CRITERIA: APPLICATION IN THE ASSINIBOINE DELTA AQUIFER REGION

BY

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A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University of Manitoba in partial fulfillment of the requirements of the degree

of

MASTER OF NATURAL RESOURCES MANAGEMENT

ABSTRACT

For the last ten years, sustainable development has been discussed and debated by experts in a variety of disciplines. Although the concept and ideals of sustainable development are well understood, bridging the gap between theory and practice has been more difficult. One of the most pressing issues has been the measurement or evaluation of relative sustainability. Traditional decision making tools such as benefit-cost analysis or environmental assessment do not provide a complete picture of the impacts associated with development. While some methods have been proposed for incorporating sustainability considerations into the planning process, few have been tested in a practical setting that addressed the issues of data needs and feasibility.

This research examined three sustainability criteria: reversibility, risk and equity in the context of groundwater use in the Assiniboine Delta Aquifer (ADA) region. The objectives of the study were to design a strategy for implementing the three sustainability criteria, to test the feasibility of the criteria, to recommend improvements to the criteria and to provide insight into the sustainability of groundwater use in the ADA region. The criteria were used to evaluate three separate policy structures that could be used to manage the aquifer. The status quo scenario represented the policy structure in place in 1997. The development scenario represented a change in the policy structure to encourage development and use of the groundwater resource. The conservation scenario considered a suite of policy tools that emphasized preservation and waste minimization. The study used both quantitative and qualitative data. The data were collected from three sources: existing government and industry data, stakeholder preferences collected during a series of workshops and expert opinion.

Analysis of the date provided mixed results. No one scenario was preferred by all the criteria. The development scenario was preferred as least risky on average the consulted stakeholders and was considered the most economically reversible. The conservation scenario was considered the most environmentally and socially reversible and was rated the highest in terms of intra-generational equity. A complete understanding of the sustainability of groundwater use in the ADA would require a multiple criteria decision making process which included the results of the three sustainability criteria and traditional decision making tools such as benefit-cost analysis and environmental assessment.

Recommendations for improving the sustainability criteria include refinement of the tools used to collect the data for the risk criteria, further development of the proportionality- and need-based aspects of the equity criteria and further research into the issue of expert opinion in sustainability and environmental assessment. Recommendations for the future management of the ADA include investigation of modifications to the Water Rights Act and continued consultation of stakeholders. It is also recommended that decision makers give serious consideration to the sustainability criteria evaluated in this study as a means to incorporate sustainability considerations into the decision making process.

ACKNOWLEDGEMENTS

This practicum could not have been completed without the help of a number of people. First, I would like to thank my academic committee. My advisor, Dr. Slobodan Simonovic, provided vision and direction during all stages of the research. Stella Fedeniuk was an invaluable source of information, guidance and patience. Dr. John Sinclair was instrumental in helping me design the workshops and provided a much needed reality check from time to time. Dr. Don Burn provided important comments at several stages of the process. Dr. Betsy Troutt also reviewed the draft and contributed to a stronger overall product.

I received assistance along the way from people at a variety of agencies. Lorry Broatch and Sherree Olmstead at the Manitoba Crop Diversification Center were always cheerful and helpful. Valuable data was provided by Vern Funk of Mid-West Processing Ltd. Numerous employees of Manitoba Agriculture, Manitoba Environment, Manitoba Health, Manitoba Natural Resources and PFRA took time out of their busy schedules to answer my questions and share their experiences. Bruce and Lynne Hood generously shared their ideas and their home with me during my numerous trips to Carberry.

Thank-you to all my classmates at the NRI. You have played an important role in my academic growth and development over the last two years. Thanks also to all my friends for their support and encouragement.

A special thank-you to my family. Dave and Paul, thanks for the spirited dinner table debates and late night Scrabble games. Mom and Dad, you have been a constant source of support and understanding throughout my academic career. I truly could not have done this without you. Finally, I would like to dedicate this practicum to my Grandma, Fan McLaren. Her example of quiet grace and dignity has been one of my life's most valuable lessons.

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Chapter 1: Introduction

1.0 Preamble

Ever since the Brundtland Commission issued its report, *Our Common Future* (WCED, 1987), the terms "sustainability" and "sustainable development" have been examined by people in many different disciplines. These terms are sometimes used interchangeably but there is a subtle difference between the two. One useful analogy is that sustainable development is the process by which we achieve sustainability. The definition given in the Brundtland Commission report, that sustainable development "meets the needs of the present without compromising the abilities of future generations to meet their own needs", has been interpreted in a variety of ways. However, most interpretations have two themes in common, a consideration of the future and, as Piel (1992) puts it, "the accommodation of the human species to the resources of the Earth." Although there is a good degree of consensus on those two points, agreement on related issues has been more difficult to achieve. Matters of scope and implementation have been debated since the report was first published. Perhaps the most enigmatic question has been "How can we measure in a meaningful way something so intangible?" One response to this question has been the development of sustainability criteria.

Sustainability is considered to have three facets: environmental, economic and social. Any assessment of sustainability would be incomplete if it did not address all three facets. In Canada, many resource managers are attempting to integrate sustainability considerations into resource planning (Slocombe, 1992). However, evaluating sustainability can be challenging. There have been some assessment criteria developed in the literature but most have not been extensively tested. This study will focus on groundwater use in the Assiniboine Delta Aquifer region as a case study for testing sustainability criteria.

The Assiniboine Delta Aquifer (ADA) is centred around the town of Carberry, Manitoba, approximately 50km east of Brandon (Figure 1.1). The aquifer extends over an area of 3 885 square kilometres. The estimated capacity of the aquifer is 12 million acre-feet with an annual recharge capacity of 166 000 acre-feet/year (Render, 1988). Of the annual recharge capacity, 106 000 acre-feet/year is considered developable and 50% of this, or approximately 58 000 acre-feet/year, is made available for allocation. 58 000 acre-feet/year represents the maximum allowable allocation under current Manitoba legislation and policy. Currently, the ADA is allocated beneath this level.

Major human water use from the aquifer can be divided into three broad categories, irrigation, industrial and domestic. Kulshreshtha (1994) estimates that 11% of the water withdrawn for human purposes is used in industrial processes, 20% for domestic uses and 69% for irrigation. He also notes that the major threats to the aquifer are overuse and point and non-point pollution.

The Manitoba Department of Natural Resources currently monitors water levels in the aquifer. In 1994, the Manitoba Crop Diversification Centre (MCDC) initiated a small scale monitoring program to quantify the chemicals present in water from the aquifer. Both programs provide baseline data that is useful for evaluating sustainability.

1.1 Issue Statement

The ADA provides the region with water that is valuable for a number of purposes. Farmers, Industry and the local people all have an interest in using this

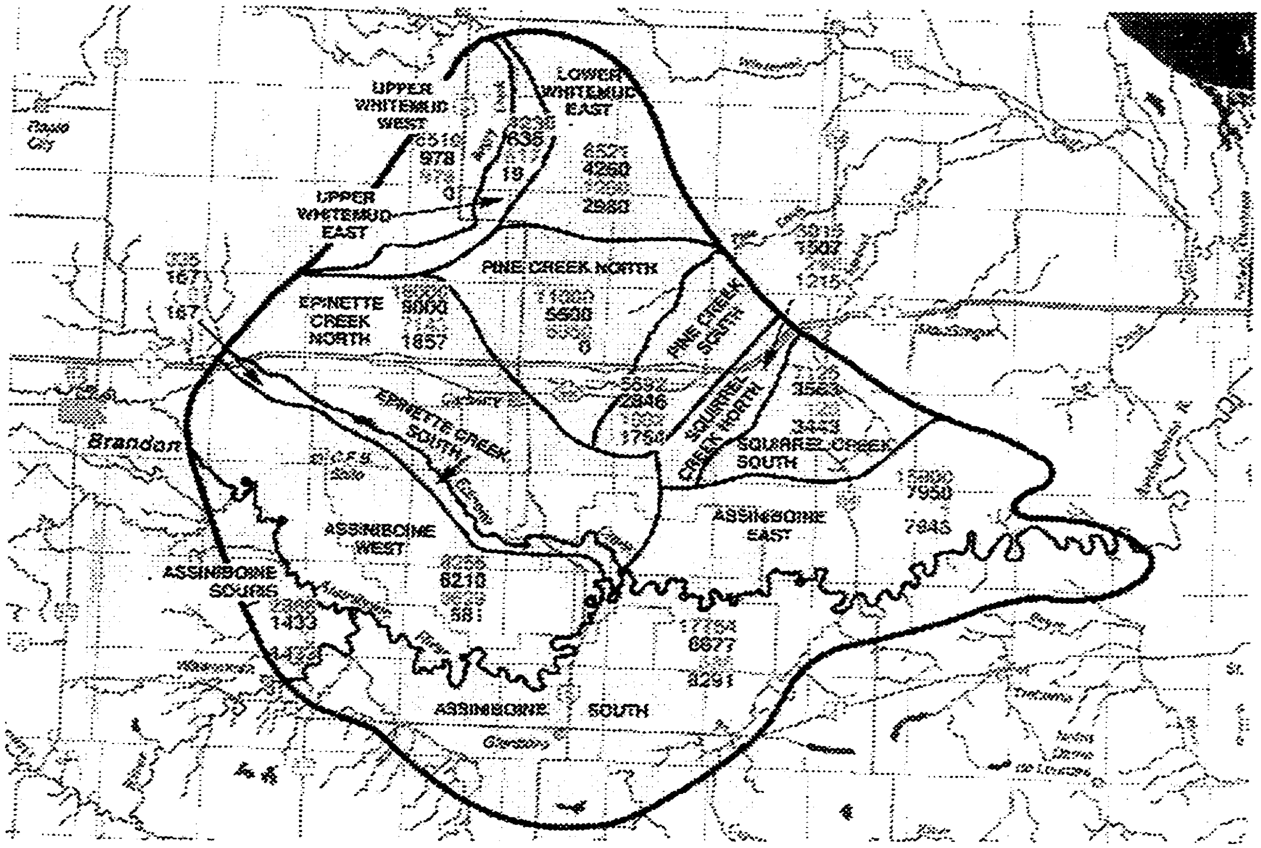

Figure 1.1 The Assiniboine Delta Aquifer. (courtesy Water Resources Branch, Manitoba Natural Resources.)

resource sustainably. There is a need for a method to assess the sustainability of current groundwater uses, as well as to measure the success of any future sustainable development initiatives. A set of sustainability criteria, such as that proposed by Simonovic et al. (1997), could be valuable for these purposes.

1.2 Objectives

1. To design a strategy for implementing the three sustainability criteria in a practical setting.
2. To test, using the Assiniboine Delta Aquifer as a practical case study, the feasibility of the three sustainability criteria as evaluation tools.
3. To recommend improvements to the criteria as necessary.
4. To provide insight into the sustainability of water use from the Assiniboine Delta Aquifer.

1.3 Methods

Developing a practical way to measure or evaluate sustainability has been difficult. Although some sustainability criteria have been proposed, few have been extensively tested. This study will use a method, developed specifically with water resource use in mind, to evaluate sustainability of groundwater use in the ADA region.

The method to be considered was proposed by Simonovic et al. (1997). This work establishes three main criteria for addressing sustainability as being reversibility, risk and equity. The authors discuss reversibility as a measure of how easily a system can be returned to its initial condition after a project is undertaken. Risk considers the probability of detrimental environmental or socio-economic impacts associated with a project. Equity is a measure of the distribution of costs and benefits associated with a project or development.

1.4 Organization of the Study

This project tests the sustainability criteria in the context of groundwater use in the ADA region. This research used existing data as much as possible, although some primary data collection was undertaken. Chapter three contains a detailed description of the three sustainability criteria. Chapter four offers a review of the case study, including the implementation methods and the results of the analysis. Chapter five discusses the role of the sustainability criteria as project and policy evaluation tools while chapter six reviews some conclusions and recommendations. The following chapter contains a brief literature review.

Chapter 2: Sustainable Development and Resource Theory

2.0 Sustainable Development

2.0.1 Origins

Although we often think that the concept of sustainable development originated within the last decade, some believe that the idea was developed much earlier. Van den Bergh and van der Straaten (1994) argue that ideas such as limits to growth and development toward a steady state can be found in the classical economic theories of Ricardo, Malthus and Mill. In the late 1960's, Rachel Carson's *Silent Spring* brought the issue of chemical pollution to the public eye while Paul Ehrlich's *Population Bomb* discussed the dangers of unrestricted population growth. Starke (1990) notes that "sustainable development" appeared in the title of a document published by the International Union for Conservation of Nature and Natural Resources, the World Wildlife Fund and the United Nations Environment Programme in 1980. These works, and certainly many more, served to heighten public interest in the relationship between development and the environment. This increased public awareness led the United Nations to establish the World Commission on Environment and Development. It was the Commission's final report, *Our Common Future*, that brought the concept of sustainable development to international attention.

2.0.2 The Concept

Sustainable development is defined on page 43 of *Our Common Future* as:

> ...development that meets the needs of the present without compromising the ability of future generations to meet their own needs. (WCED, 1987)

Although the definition is deliberately vague, it encompasses two concepts that are discussed in the report:

- the concept of 'needs', particularly essential ones that must be given priority.
- the notion of limitations that exist on the environment's ability to meet these needs, both at the present and in the future.

The second concept is the one that creates most of the problems for people trying to find applications for sustainable development. Taken independently, the words "sustainable" and "development" seem to be mutually exclusive. If we accept the idea that there are limitations on the environment's ability to meet the human population's needs indefinitely we have to realise that development or growth cannot continue ad infinitum and be sustainable. The Brundtland Commission addresses this concern by stating that:

> Sustainable development involves more than growth. It requires a change in the content of growth, to make it less material- and energy-intensive and more equitable in its impact.

By modifying the definition of growth to include the idea of increased efficiency or quality, the Commission has addressed the potential paradox of the term sustainable development and given it a broader scope.

Even after resolving the philosophical questions that the concept of sustainable development raises, there is still the problem of developing ways to apply the theory. Many authors have discussed the problem of how best to achieve sustainable development. In response to the implementation question Daly (1994) suggests that "operationalizing sustainable development requires investment in natural capital".

2.1 Natural Resources and Sustainable Development

The earth's natural resources are both the keys and the limitations to human growth and development. Jenkins (1993) discusses the fact that we live on a finite planet and that our productive resources have limits. He also notes that since the sum of our material desires will always exceed the capacity of the available resources, scarcity forces us to decide how we are going to make use of these limited resources. However, development has often proceeded as though the Earth's resources were limitless. As Haimes (1992) notes:

> Technological hubris is the source of the utopian delusion that science, engineering and technology can solve any and all problems, and therefore economic development need not be constrained by environmental considerations.

The belief that technological advances will enable us to conserve natural resources in the future stems from the idea that technology or man-made capital is a substitute for natural resources or natural capital. Daly (1994) argues that man-made capital and natural capital are in fact complementary and states that:

> Man-made capital is itself a physical transformation of natural resources which come from natural capital. Therefore, producing more of the alleged substitute (man-made capital), physically requires more of the very thing being substituted for (natural capital)- the defining condition of complementarity!

Given Daly's assertion, it is necessary to realise that each resource has a boundary or capacity. These finite capacities collectively define the limits or carrying capacity of the Earth which in turn establishes the limits to growth. As Ehrlich (1994) notes

> Both biological and economic knowledge are essential to understanding ecosystem/economic system relationships and rationalizing them so that the human enterprise can prosper.

Since the concept of growth includes not only biological population growth but also economic development, it seems logical that the natural resources that define the limits to growth should be examined in the economic facet of sustainable development as well as the environmental. In order to incorporate natural resource considerations into economic theory, Daly (1994) discusses the idea of natural capital versus man made capital.

Daly defines natural capital as "the stock that yields the flow of natural resources". This definition includes the fish stocks that replenish those caught and taken to market and the forests that replace the trees culled for timber. This expands the traditional definition of economic capital and allows natural resources development to play a role in the economic decision making processes.

The distinction between natural capital and man made capital should be of particular interest to Canadians because our national identity and economy are so closely linked to our natural resources. As Anderson (1985) notes, many Canadians would describe the most prominent feature of their economy to be natural resource extraction. Given that our economic welfare is so closely linked to our resource base, Anderson asks the question "What would happen to us if we were to run out of some of our resources?"

Tisdell (1990) suggests that to prevent resources from being overused, it is necessary to reduce the gap between the demand for resources and the availability of them. Although the question of limits to natural resources focuses primarily on either non-renewable resources, such as minerals or petroleum, or biological resources such as forests or fish stocks, the Brundtland Commission report reminds us that "so-called free goods like air and water are also resources".

2.1.1 Water

Few people would argue that water is one of our most important natural resources. In 1988 the Science Council of Canada estimated that the measurable contribution of water to the Canadian economy was between $7.5 billion and $23 billion annually (SCC 1988). Despite this, water is often omitted from discussions of natural resource management and policy. Borden (1993) acknowledges this omission and states that

> Unlike other natural resources, water has been distributed according to a centrally-planned system of public ownership that ignores the real costs of production, storage and distribution.

Defenders of this separate treatment would make the assertion that water is different than other natural resources to which Borden replies "Nonsense. It is exactly like all those other commodities and there will be more of it if we use a rational allocation system." Spulber and Sabbaghi (1994) support this argument, saying:

> ...water can no longer be considered a public and free commodity, and its

> allocation cannot be made by administrative and judicial decisions using a supply-oriented approach. We have to look at water from an economic perspective as a multi-product commodity, with its price representing not only the cost of the water supply, but also its value to the user.

If water as a resource poses management problems, groundwater, which we cannot readily see, presents an even greater dilemma.

2.1.2 Groundwater

When we think about freshwater resources, we tend to think of lakes, rivers and streams. Very rarely do we consider groundwater, yet groundwater plays an important role in the lives of many people. In the global context, Israel is perhaps the most advanced in terms of groundwater use and conservation. Huerta (1991) notes that necessity has driven the Israelis to develop advanced groundwater collection and recycling methods and to monitor the quality of their groundwater carefully. Despite the care with which the Israelis monitor and allocate their groundwater resources, they have still encountered difficulties. Pearce (1991) notes that hydrologists who help to shape Israel's water policy fall into one of two philosophical categories, those who stress the need to reduce the demand for water and those who call for the further development of resources. Pearce states that both camps are optimistic about the future of water resource use in Israel. Pearce guards against this sort of optimism by discussing the state of the Israeli water resource situation in March of 1991. Israel's rainfall for the period from March 1990 to March 1991 amounted to 1.3 billion cubic metres compared with an average water consumption of 1.9 billion cubic metres. This resulted in a net loss of water from the nation's aquifers and reservoirs. 1991 was not an extraordinary year. Pearce notes that such a net loss had been the trend for much of the previous 10 years. This accumulated loss led to a "parched earth policy" that addressed the drastic decrease in both water quantity and quality.

Canada does not have to maintain as strict a water budget as Israel does. We have a much higher annual rainfall and a much lower population density. This does not mean that groundwater is not important to Canadians. In discussing the importance of groundwater, the Science Council of Canada (1988) offers these statistics:

- At any one time, groundwater represents about 37 times the total amount of water contained in rivers and lakes.
- 26% of Canadians rely on groundwater for domestic purposes
- 38% of all Canadian municipalities rely partly or totally on groundwater
- Groundwater flows through the soil at extremely slow rates and may reside in the ground for thousands of years from the time of entry to discharge.

In the specific case of Manitoba, Karvinen and McAllister (1994) discuss these statistics

- groundwater constituted 24% of all water used in the province, and approximately 24% of the population was reliant on groundwater in 1981
- 39% of Manitoba municipalities derived some or all of their water from groundwater sources.
- Manitoba is Canada's highest user of groundwater in irrigation.

Within Manitoba, one of the largest sources of groundwater is the Assiniboine Delta

Aquifer which is located in the south-western portion of the province.

2.1.3 The Assiniboine Delta Aquifer

The Assiniboine Delta Aquifer is centred around the town of Carberry, Manitoba, approximately 50km east of Brandon (review Figure 1.1). It is composed of unconfined deltaic sand and gravel (Render, 1988). The aquifer extends over an area of 3 885 square kilometres. The area includes the towns of Carberry and Glenboro, as well as CFB Shilo and Spruce Woods Provincial Park. Water from the aquifer is of high quality. Kulshreshtha (1994) estimates the population of the area to be approximately 12 400 many of whom obtain their drinking water from the aquifer.

Water use from the aquifer for human purposes can be divided into three categories: irrigation, industrial and domestic. Kulshreshtha estimates that of the water extracted for human purposes, 11% is used for industrial purposes, 20% for domestic uses and 69% for irrigation. The increased development of irrigation in the region is a relatively new phenomenon. As Render (1988) notes, prior to the 1960s the major use of water from the aquifer was for domestic purposes in the towns of Carberry and Glenboro and CFB Shilo. Since the 1960s, irrigation has increased primarily as a hedge against inadequate rainfall during important parts of the potato crop season. Since 1976, the number of irrigation pivots in the region has also increased. The incentives to irrigate are great. Kulshreshtha (1994) estimates that irrigation increases the average value of a potato crop from $218.20/ha to $937.20/ha. This amounts to a value added of $719. The recent increase of irrigation has prompted some concern about overusing the aquifer. As of January 1, 1997, allocation for human purposes represented only 16.7% of the estimated annual recharge capacity of the aquifer and actual use is even lower. This is not to imply that overuse is not a valid concern, only that present levels of consumption seem to be well within the capabilities of the aquifer.

Kulshreshtha estimates the economic value of the aquifer to be between $57 million and $121 million in 1990 dollars. Kulshreshtha's figures are based only on direct human use values for the aquifer. Kulshreshtha does not attempt to incorporate non-use or existence values into his analysis. These figures emphasize the importance of the aquifer to the region and the care and attention that management of the aquifer deserves. A management scheme or decision making process that considers the issues of sustainable development presented by the Brundtland Commission could be useful for evaluating future development of this particular resource. Before any process is proposed, it is necessary to address some of the difficulties associated with sustainable development.

2.2 Applying Sustainable Development

Ever since "sustainable development" appeared in the Brundtland Commission report the term has been the subject of much discussion. Many people have had difficulty in finding a meaningful definition. Redclift (1987) states that:

> Sustainable development requires a broader view of both economics and ecology than most practitioners in either discipline are prepared to admit, together with a political commitment to ensure that development is 'sustainable'.

Van den Bergh and van der Straaten (1994) add that sustainable development has generated "a mass of literature...in various fields of science, most of which does not go far beyond the descriptive stage." Beckerman (1992) echoes this concern by stating that "It is far from clear what concept of 'sustainable development' can be both morally acceptable and operationally meaningful." This difficulty in moving from the theoretical phase to the implementation phase has been the major criticism of sustainable development. However, Redclift makes the point that sustainable development should "express more than a pious hope, but rather less than a rigorous analytical schema". Finding the area between pious hope and analytical schema that best maintains the ideals of sustainable development is the next challenge.

2.2.1 Developing a Process

As acknowledged earlier, achieving sustainability through sustainable development requires a change in the priorities of conventional planning and development. Change comes about only through actions and it is therefore necessary to develop a process for implementing sustainable development in water resource management. However, before the implementation of sustainable development in water resources management occurs, it is necessary to establish an understanding of what sustainability means to water resource systems. The word "needs" in the Brundtland definition of sustainable development is somewhat problematic because of the difficulty in distinguishing between "needs" and "wants". Loucks (1997) offers a modified definition that is more specific to the case of water resource management:

Sustainable water resource systems are those designed and managed:

> to fully contribute to the objectives of society, now and in the future, while maintaining their ecological, environmental, and hydrological integrity.

This definition eliminates the requirement of distinguishing between needs and wants by stating that water resource systems can be sustainable as long as they are contributing positively to society without degrading their ecology or environment. With this definition in hand we can consider how to implement sustainable development in a practical way.

2.2.2 Water Resources Planning and Sustainable Development

Goodman (1984) lays out the following steps for developing a water resource project:

- 1. *Establishment of goals and objectives*: consider broad policies as well as legal and other restraints.
- 2. *Problem identification and analysis*: collect data, project demand/supply relationships.
- 3. *Solution identification and impact assessment*: structural solutions, management solutions, preliminary assessment of impacts.
- 4. *Formulation of alternatives and analysis* - criteria and procedures for comparison of alternatives, detailed assessment of impacts.
- 5. *Recommendations*
- 6. *Decisions*
- 7. *Implementation*
- 8. *Operation and Management*

Biswas and Kindler (1989), in discussing a similar breakdown of the planning process, note that the problem identification stage and the monitoring stage (part of

Goodman's operation and management stage) are of critical importance. Extra care and attention applied to these two tasks can make the rest of the planning process that much easier. As Kuiper (1965) notes, there are often problems in carrying out the planning process. Kuiper states that

> ...it happens too often, particularly in the field of water resources development, that not all pertinent facts are taken into consideration. Instead, irrelevant aspects are introduced, unwise political pressure may be applied, the clear concept of resources development becomes obscured, and the eventual plan falls short of its ideal.

In this observation Kuiper has indirectly stated one of the problems that the Brundtland Commission attempted to address, that is, that too often decisions are based entirely on economic factors without considering their environmental or social implications.

The line between the goals of development and the process by which the goals are achieved is often obscured. This has led to much of the "unsustainable development" we have seen. Moving toward sustainable development requires a process that allows planners and developers to remain focused on the goals of their project. Leusink (1992) discusses four characteristics that such a planning process should consider:

- Planning and decision making are continuous, dynamic processes. All inputs to the water resources system are subject to changes, such as the demand side, the resources, the technological options and the social and political preferences regarding objectives and criteria.
- Groundwater resources planning as part of the water resources system is strongly interrelated with other planning areas, e.g. agricultural development, industrial development, urbanization and family planning.

- Planning takes place at different administrative levels (supra-national, national, regional, local).
- Planning must take into account a variety of constraints which play an important role in the pre-screening and evaluation of alternative strategies.

The last point requires the most attention because it involves the sort of analytical thinking about sustainable development that has been difficult to develop. Leusink notes that, for groundwater planning, analysis requires information on

- anticipated demand for groundwater or groundwater related conditions over the given planning horizon;
- the configuration of the system, its present state (e.g. water levels, water quality, volume in storage, discharges) and its trend relative to the demand;
- feasible controllable measures and corresponding actions which can aid in closing the gap between supply and demand of available resources;
- anticipated exogenous inputs to the system (water and substances), natural and anthropogenic;
- anticipated state and supply of the groundwater as a result of alternative courses of action;
- resulting payoffs and losses in each alternative.

For the specific case of the Assiniboine Delta Aquifer, the information referred to in the first two criteria is possible to obtain. The third can be estimated to a reasonable extent. The last two criteria pose a greater difficulty. They require something that has been lacking from the sustainable development process, a comprehensive evaluation method. This deficiency in the sustainable development process is addressed by Ekins (1994) who states that:

> (The analytical) framework first entails the mapping of the processes contributing to environmental sustainability. The boundaries of the processes and their environmental impacts need to be considered. Instruments to act in the processes to promote sustainability need to be devised. Standards of sustainability need to be set, and the costs of the instruments required to meet these standards must be calculated.

The instruments and standards Ekins refers to are what has been lacking from sustainable development. Sustainable development is often thought of in qualitative terms, yet resource planning decisions are most often made on the basis of quantitative information. Sustainable development encompasses environmental, economic and social impacts, all of which are made up of many variables. It would be impossible to accurately model all of the environmental, economic and social variables relevant to each individual resource management issue. Therefore, it is necessary to select a manageable set of indicators or criteria that could be used to make resource management choices.

2.2.3 Measuring sustainable development

When we evaluate management strategies considering environmental, economic and social criteria we are, as Milon and Shogren (1995) state,

> ...trying to inform policy decisions by constructing systems that capture the full consequences of our production and consumption choices.

Constructing these evaluation systems requires careful selection of criteria. As scientists we tend to be preoccupied with variables that can be measured on a continuous scale. Since economic factors are often readily quantifiable, economic considerations generally have great weight in the decision making process. Sustainability, however, requires an equal consideration of economic, environmental and social factors. At the Federal level in Canada, the National Round Table on the Environment and the Economy (NRTEE) has devoted considerable time and energy to examining the question of measuring sustainability. A 1995 NRTEE publication states that

> Without the means of measurement, without relevant information, progress cannot be charted, goals cannot be set, existing situation cannot be assessed, plans cannot be laid – cannot, that is, with any degree of composure or assurance.

Proposed measures of sustainability generally fall into two broad classes of metrics, indicators and criteria. Verbruggen and Kuik (1991), writing on the topic of sustainable development indicators note that indicators serve a dual purpose:

a) a planning purpose: problem identification and policy assessment; and

b) a communication purpose: monitoring and legitimisation of policy measures.

Indicators range in scope from broad (air quality, biodiversity) to specific (nitrate loads in drinking water). Some may be uniform across diverse ecosystems, others will be particular to local scales. A package of indicators would have to be selected based upon the needs and values of the situation. Selecting indicators is a delicate task which must consider the availability of current, reliable information, relevance and accuracy. The Manitoba *State of the Environment Report* for 1997 divides sustainability indicators for the prairie ecozone into four broad categories: natural resources, human made capital, community assets and individual well-being. Within these broad categories are a number of more specific indicators such as hospital beds/1 000 population, average weekly earnings and soil organic matter components. All of these indicators are useful for monitoring and measuring the state of sustainability in the prairie ecozone. However, as both van den Bergh (1996) and Opschoor and Reijnders (1991) note, such indicators are not useful as static pictures or impressions. Rather their value comes as a benchmark by which to relate an ideal condition or goal. In order to establish such goals, it is necessary to develop what Opschoor and Reijnders term " a criterion for sustainability".

2.2.4 Sustainability criteria

Opschoor and Reijnders discuss a sustainability criterion as a yardstick against which a sustainability indicator is measured. The specific criterion the authors use as an example is deviation from a steady state. McMahon (1995) suggests that sustainability is better measured by the use of a sustainability metric which measures what he terms "ecological scarcity". McMahon states that ecological scarcity:

> ...encompasses all limits to growth including increased economic costs and diminishing returns of technology, shortages of nonrenewable natural resources and minerals, environmental degradation, and social and political turmoil.

McMahon further contends that sustainability metrics essentially attempt to measure entropy. Entropy is traditionally considered to be a measure of disorder or randomness in a system. McMahon and Mrozek (1997) note that neoclassical economic theory implicitly accepts the first law of thermodynamics, that energy and matter cannot be created or destroyed, merely transformed. Each transformation of matter or energy from one state to another results in movement from a low entropy system to a high entropy system. This observation leads to the second law of thermodynamics, that systems over time tend toward a state of higher entropy. The process of moving from low-entropy to high-entropy is irreversible. This being the case, in McMahon and Mrozek's view, sources of low-entropy are the ultimate scarce economic good and therefore sustainability can only be evaluated by using a metric that attempts to measure entropy. McMahon's sustainability metrics seem theoretically sound but may be difficult to operationalize.

Bender and Simonovic (1997) take a more practical perspective by suggesting that consensus among stakeholders may be an effective measure of sustainability. The authors define consensus as it relates to sustainability as:

> ...an equitable compromise which is robust with regard to a) resource management uncertainties, and b) stakeholder perspectives.

The consensus measure is sensitive to the opinions and value judgements of the stakeholders involved. Although consensus seems less scientifically rigorous than the metrics proposed by McMahon, it may be a more useful tool for practical purposes.

Baetz and Korol (1995) have developed a list of seven sustainability criteria which they feel may be useful for evaluating project and policy alternatives. Their sustainability criteria are:

- Integration/Synergy: a measure of how well integrated development is with the natural environment.

- Simplicity: so that natural and man made developments mirror each other.
- Input/Output characteristics: the authors cite as an example two factories with similar energy demands. Under this criteria, the proposal using the greater proportion of renewable energy would be preferred.
- Functionality: a single structure that serves a variety of functions is preferable to several structures designed for individual tasks.
- Adaptability: development options should be sustainable under a variety of environmental, economic and social conditions.
- Diversity: in design terms, a development that considers the needs and values of a variety of stakeholders will be more sustainable than a development designed to serve a select few.
- Carrying Capacity: technical alternatives that have low impacts on the carrying capacity of their environments will be preferred.

Baetz and Korol test their criteria with the hypothetical example of evaluating different waste management options. Their results indicate some of the benefits which could be derived from including sustainability considerations in the development process but the authors admit that more practical exercises are required before any judgement on the usefulness of the criteria may be made. Simonovic et al. (1997) propose a set of three criteria: equity, reversibility and risk. These criteria are the subject of three theses by Matheson (1997), Fanai (1996) and Kroeger (1997) respectively. These three sustainability criteria were tested using Manitoba Hydro's North Central Project as a case study, with data supplied by Manitoba Hydro.

Simonovic et al.'s criteria have been taken a step further than Baetz and Korol's in that they have developed an algorithm for implementing their criteria and tested those criteria with data from a practical case study. However, the case study analysis used by Simonovic et al. was conducted post-project. This gave the researchers the advantage of hindsight. A weakness of both sets of sustainability criteria then is that neither has been tested in a case study which addresses data availability or implementation issues. This is one of the deficiencies addressed by this study.

2.2.5 Policy evaluation

Although Simonovic et al.'s criteria were originally developed as project evaluation tools, important sustainability decisions are being made at the policy and program level of government. In this study, the criteria will be applied to a series of policy options instead of the project alternatives they were initially designed to evaluate. The policy options result in fuzzier impact classes than a project alternative might and this is somewhat limiting to the analysis. However, increasing attention is being paid in the environmental assessment literature to evaluation techniques that consider policies or general development categories. O'Riordan and Sewell (1981) recognise this trend and state that

> (Environmental Assessment) as a mere information display can confuse rather than enlighten the elected representatives who are responsible for a final decision and it has caused many people to lose site of the merits or otherwise of the *policy environment* (their italics) in which any major development scheme is proposed.

Spaling and MacDonald (1997) undertake a broad analysis of the impact of agriculture on water quality. Among their explanations why such investigations aren't common is that:

> ...analytical tools for impact analysis are more highly developed for site-specific assessment than regional- or national-scale assessments.

The authors follow up this explanation with the assertion that:

> There is a need to develop methods of environmental assessment for application at broader spatial and temporal scales.

Barbier et al.(1990), writing on the issue of sustainability in agriculture, have also noted the inability of traditional project and policy evaluation techniques to incorporate considerations such as long-term environmental and resource security stating :

> ...justifying the conservation of these essential resources requires an additional 'intergenerational equity' or 'sustainability' criterion.

The authors also note that:

> Of particular concern is how the objective of agricultural sustainability can be incorporated into conventional analyses of agricultural development projects.

Although Barbier et al. go on to suggest modifications to a traditional benefit-cost analysis that would accomplish these goals, they have paved the way for the application of new project and policy evaluation techniques in the field of sustainable agriculture.

This is not to say that policy assessment is without its pitfalls. There are added difficulties associated with evaluating a policy in environmental, economic and social terms compared to a traditional environmental assessment. Freeman (1993) discusses two of these problems, stating

> The first concerns the choice of parameters for describing the resource or environmental quality. The second involves determining the functional relationship between the policy instrument and the resource service flow or environmental quality measure.

Both of these issues are important to this study. The relationship between the policy instrument and the environmental, economic and social conditions under each scenario is an important consideration.

The role of science and expertise in environmental assessment has been debated in Canada for decades. Beanlands and Duinker (1983) published what is still considered one of the most comprehensive reviews of the role of science in assessment. Often science and values are considered to be separate entities in the assessment process. Lee et al (1993) state that:

> ...many researchers feel that the integrity of the scientific research can only be maintained by the screening out of extra-scientific pressures ("subjective judgements involving values, feelings, beliefs and prejudices").

The authors go on to say that:

> The uncertainty and gaps in data bases...force assessors to make value-based interpretations. Often under these circumstances the available data are insufficient for scientifically defensible conclusions and methodologies are insufficiently refined and accepted to meet rigorous scientific standards.

It seems reasonable then, that given the broad nature of environmental, economic and social impacts a sustainable policy evaluation must consider, that some amount of scientific, value and expert opinion inputs must be incorporated into the analysis.

2.3 Conclusions

Sustainability and sustainable development are difficult concepts to grasp. To try to apply these concepts to a resource as complex to manage as water is a great challenge indeed. However, more and more resource managers are realising that we must start incorporating some form of sustainability consideration into our project development and selection process. Although we can never know everything about how a system will react to a given management plan, by using evaluation criteria that consider social, economic and environmental progress toward sustainability, we can hopefully make better management choices.

We have seen the attempts of numerous authors to address the evaluation gap in the drive toward sustainability. There is abundant discussion in the literature of sustainability indicators and different metrics or measures of sustainability. It is the opinion of the author that too much attention has been focused on the establishment and development of sustainability indicators without first establishing the benchmark against which these indicators will be measured. Both Simonovic et al. (1997) and Baetz and Korol (1995) have identified a set of sustainability criteria which may be useful across a variety of settings and purposes. The major deficiency of both sets of criteria is the lack of a practical application. Such an application is necessary for three purposes:

- To develop a strategy for implementing the methodologies, including identifying data requirements and gaps in the knowledge base which may hinder implementation;

- To evaluate the functionality and adaptability of the criteria themselves; and
- To identify weaknesses or redundancies between the criteria.

The goal of this research is to use a proposed set of evaluation criteria in a practical setting with the hopes of alleviating the deficiency identified in the literature. Simonovic et al.'s proposed criteria were selected for this case study because they seemed better developed and explored than others examined by the researcher. The following chapter discusses the methodological aspect of each of Simonovic et al.'s sustainability criteria in detail.

Chapter 3: Methods

3.0 Introduction

As noted earlier, the process of evaluating sustainability has proven to be a large hurdle in the implementation of sustainable development. While the literature discussing the theoretical implications and philosophical merits of sustainable development is extensive, the literature proposing or critiquing evaluation methods is comparatively thin. If we combine the problems of sustainability evaluation with the inherent difficulties associated with water resource management and policy discussed in the previous chapter, we arrive at an even greater quandary.

Although some measures of sustainability have been proposed, few have been extensively tested. As stated in chapter one, the aim of this study is to provide not only an evaluation of the sustainability of the study area, but also a practical setting to utilize a sustainability evaluation procedure proposed by Simonovic et al. (1997). In their paper, Simonovic et al establish three main criteria for addressing sustainability as being reversibility, risk and equity.

Simonovic et al. discuss reversibility as a consideration of how easily a system can be returned to its initial condition after a project is undertaken. Risk considers the probability of detrimental environmental or socio-economic impacts associated with a project. Equity is concerned with the distribution, both in time and space, of positive and negative impacts. For a given project, these three criteria could form part of a multi-criteria analysis, with each project receiving a ranking on each of the criteria. The following sections describe the equations and criteria to be used in this study. A complete explanation of the application of these criteria to the case study is contained in chapter four.

3.1 Reversibility

Reversibility is a measure of how easily a system can be returned to its initial condition after a project is undertaken. Fanai (1996) examined the reversibility criterion in detail and stated that this criterion would address the anticipated impacts of a project. Ideally, the reversibility should be high so that any negative implications that may result from present decisions can be mitigated in the future. An operational concept to be used in the proposed research is that decisions that are highly reversible result in the stakeholders being able to maintain their traditional uses of the system.

The reversibility criterion consists of four stages:

- **Stage 1**: Select impacts and characteristics and classify from general to specific.
- **Stage 2**: Determine the units of measure for each impact and determine the expected value in each scenario, along with the best and worst possible values.
- **Stage 3**: Apply R-metric
- **Stage 4**: Perform sensitivity analysis.

The first stage in the process is the most important and the most time consuming. This stage involves identifying the impacts and classifying them as economic, environmental or social, as well as indicating whether they are true impacts or characteristics of impacts. After all the possible impacts are identified, it becomes important to determine how each of the impacts can be measured.

Some impacts may be easily quantifiable and at this point in the analysis the units of measure should be specified. Often times, however, the impacts are not easily quantifiable and must be measured on a subjective scale. In these cases, experts may be consulted to provide a qualitative estimate of the impacts. The reversibility criterion requires that the best and worst possible values for each impact be known or estimated. The expected value for each scenario is then either derived or predicted. The generation of the expected values can be aided by considering the concepts of resilience, option value or quasi-option value, time preference, tolerance values and cumulative effects. The third stage in the reversibility evaluation is the analysation of the quantified impacts. The impacts or their characteristics are used as metrics to derive a measure of the reversibility of a scenario. Because the impacts are not measured on a common scale, they must either be rendered commensurate or converted into dimensionless numbers. Commensuration is accomplished by employing a simplified version of the distance metric termed the R-metric (equation 3.1)

$$R_{cj} = \left(\sum_{i=1}^{N_c} w_{ci}^{2} \left| \frac{M_{ci} - f_{cij}}{M_{ci} - m_{ci}} \right|^{2} \right)^{1/2} \qquad (3.1)$$

where:

c = index for category (c = 1 for environmental, 2 for economic, 3 for social);
j = index for alternative;
R_{cj} = Reversibility index in category c for alternative j;
i = index for impact;
N_c = total number of impacts in category c;
w_{ci} = weight assigned for impact i in category c *(scale from 0-1)*;

M_{ci} = best value for impact i in category c;
m_{ci} = worst value for impact i in category c;
f_{cij} = expected value of impact i from implementing alternative j in category c.

The inputs M_{ci}, m_{ci}, and f_{cij} are quantified in Stage II of Fanai's framework. The impact weights, w_{ci}, allow the researcher to account for the fact that all impacts may not be of equal importance. The weighting values will be selected on a scale from zero to one depending on the perceived importance of each impact. After the *R*-metric is calculated for each scenario, the threshold values can be calculated. The threshold values set the boundaries of the *R*-metric. The minimum reversibility, Tc_{min}, is simply equal to zero while the reversibility limit, Tc_{max}, is calculated by assigning all the impacts their worst possible values. These values are useful for comparison purposes as they establish the range of possible values for each scenario. A perfectly reversible alternative then would receive an *R*-metric value of zero, as all the impacts are at their ideal value. A larger *R*-metric value represents a more irreversible (less desirable) alternative.

The final stage in the reversibility framework is the sensitivity analysis. This is important because of the subjective nature of many of the values assigned to the impacts. This analysis helps to evaluate how changes in the subjective impact values affect the final index. The first sensitivity analysis involves individual manipulation of the qualitative impact values to judge their effect on the outcome of the *R*-metric. For this analysis, the researcher will replace individual values and recalculate the *R*-metric, comparing the outcome of the original calculation with the altered version. The second sensitivity analysis addresses the issue of the impact weightings. Recall that the original impact weightings are assigned by the researcher according to the perceived importance of each impact to stakeholders in the region. Admittedly this process leaves considerable room for the researcher's personal bias to enter the analysis. The second sensitivity analysis is designed to address this issue. This analysis involves assigning random weight values to the impacts and recalculating the R-metric. If the random weights significantly alter the results, then the robustness of the original calculation is brought under scrutiny.

3.2 Risk

Risk is traditionally defined as being the product of the magnitude of an event or act and the probability of that event occurring. Kroeger (1997) notes that there is a shortcoming associated with this definition, in that it fails to address the difference between the products of low probability high magnitude events and high probability low magnitude events. In keeping with the three facets of sustainable development, Kroeger discusses types of social, economic and environmental risks. As in the reversibility framework, many of the variables are measurable only on a subjective scale. Also, different stakeholders are likely to have different ideas of what is an acceptable risk. Therefore, the risk model requires that the different stakeholder groups be identified and consulted as part of the risk assessment process.

The risk measure algorithm (Kroeger, 1997), to be used as one of the sustainable project evaluation criteria, consists of the following steps:

- **Step 1**: Identify the risks which will contribute to the analysis

- **Step 2**: Estimate the probability of the risks occurring in each alternative.
- **Step 3**: Calculate the risk value for each risk by each participant using:
  sustainable development category weights; and
  risk weights.
- **Step 4**: Estimate risk separately for each alternative and each participant by multiplying the values and probabilities and summing them.
- **Step 5**: Compare the alternatives by combining the participant estimates in a joint estimate.

The first step in this process is similar to the initial stage of the reversibility framework. The second step, estimation of risk probabilities is subjective. Experts in the relevant field should be consulted for their assessment of the risk probability. The third stage requires the consultation of as many stakeholder groups as can be identified. Each group is given the opportunity to weight both the importance that they attach to each of the sustainable development categories and also their willingness to accept each of the identified risks. This is a significant improvement over traditional risk assessment methodologies in that individual stakeholders are actually consulted and their values and preferences are used in the analysis. In step four, each alternative receives a ranking from each of the participant groups. The two types of information obtained from the stakeholders are combined by means of equation 3.2.

$$v_{r_c j} = \frac{d_{cj} * k_{r_c j}}{\sum d_{cj}} \qquad (3.2)$$

where:

v_{rcj} = the value for risk r_c for participant j;
d_{cj} = the sustainable development category weight for participant j;
k_{rcj} = the risk weight assigned to risk r_c by participant j.

Once the risk values assigned by the participants are calculated, the risk values are multiplied with the probability values. A lower risk value indicates a less risky alternative. In step five, the values for different participant groups may be combined according to an average or weighted average, to obtain one aggregate ranking for each alternative.

3.3 Equity

Matheson (1997) lists the three possible components or norms of equity as being equality, need and proportionality. Equality refers to a uniform distribution of benefits and costs among stakeholders. Such a distribution may be considered fair if there is no basis on which to differentiate between the stakeholder groups. However, Matheson states that an equal distribution is not always an equitable one. A more equitable distribution considers need and proportionality. Need addresses the different requirements of each stakeholder group. Proportionality requires that an individual user's level of benefit be determined by his level of input or contribution toward achieving that benefit. An effective evaluation of equity considers equality, need and proportionality on distance- and temporally-based distributions of costs and benefits.

3.3.1 Distance-based equity measures

Distance-based equity measures have been developed and utilised by a variety of disciplines, from economics and engineering to psychology and other social sciences. However, there is no good method discussed in the literature for choosing the most practical of these for a given situation. Matheson evaluates the appropriateness of several distance based measures and recommends some of these for the sustainable project evaluation process. Distance-based measures are grouped according to whether they are essentially measures of proportionality, equality or need. Matheson evaluates each of the distance-based measures using a number of principles, the most important of which are the Fundamental Principle and the Principle of Transfers. The Fundamental Principle is summarised by Matheson as requiring that:

> ...when a group's relative outcome remains constant, the group's outcome should increase monotonically with that group's input.

Basically, a group's outputs should be maintained in proportion to their inputs. The Principle of Transfers is discussed as requiring that:

> ...measures show an improvement in equality when a unit amount of some benefit is transferred from someone better off to someone worse off.

After evaluating the proposed fairness measures, two equality based measures, two proportionality based measures and four need based measures are recommended as satisfying most of the principles used to evaluate them. These measures are summarised in table 3.1.

3.3.2. Temporal distributive based equity measures

Temporal considerations, as discussed by the Brundtland Commission and subsequent works, consider inter-generational equity (equity between generations) and intra-generational equity (equity within generations). The formulae listed in Table 3.1 were not constructed to

Table 3.1 Distance-based equity measures.

Name	Equity Norm	Formula
Walster Formula	Proportionality	$\sum_{i=1}^{I}\sum_{j=1}^{I}\left\|\frac{E(i)-A(i)}{A(i)}\right\|$
Equal Excess Formula	Proportionality, Need	$\sum_{i=1}^{I}\left\|E(i)-A(i)\right\|$
Coefficient of Variation	Equality	$\frac{\left[\sum_{i=1}^{I}(E(i)-\overline{E})\right]^{1/2}}{\overline{E}}$
Gini Coefficient	Equality	$\frac{\sum_{i=1}^{I}\sum_{j=1}^{I}\left\|E(i)-E(j)\right\|}{2I^2\overline{E}}$
Adams Formula	Need	$\sum_{i=1}^{I}\sum_{j=1}^{I}\left\|\frac{E(i)}{A(i)}-\frac{E(j)}{A(j)}\right\|$
Coulter Method	Need	$\left[\frac{1}{I}\sum_{i=1}^{I}\left[\frac{E(i)}{\overline{E}}-\frac{A(i)}{\overline{A}}\right]^2\right]^{1/2}$
Coulter Method #1	Need	$\sum_{i=1}^{I}\left[\frac{E(i)}{A(i)}-\frac{\overline{E}}{\overline{A}}\right]^2$
Hoovers Concentration Index	Need	$\frac{1}{I}\sum_{i=1}^{I}\left\|\frac{E(i)}{\overline{E}}-\frac{A(i)}{\overline{A}}\right\|$

where:

I = total of all groups evaluated
i, j = individual group indexes
E(i) = actual impacts experienced by group i
$\overline{E}$ = average impact experienced by all groups
A(i) = impact that group i deserves to receive
$\overline{A}$ = average impact that all groups deserve to receive

account for temporal variation. Matheson suggests an expansion of the recommended distance based measures to incorporate temporal considerations. Intra-temporal equity is evaluated using an appropriate distance-based measure across all groups in a single time period. Inter-generational equity is evaluated by applying one of the distance-based measures over each time period during which the group in question exists. Matheson expands upon the distance-based equity measures listed in Table 3.1 and derives six equations to evaluate intra-generational and inter-generational equity by need, equality and proportionality. However, there are operational difficulties in implementing the need- and proportionality-based measures of equity. As such, this study will consider only equality-based measures. Equations 3.3 and 3.4 are the measures used for evaluating intra-generational and inter-generational equity in this study.

A lower value for either the intra-generational or inter-generational equity measure indicates a more equitable alternative. Although Matheson's measures are capable of considering any number of impacts, for the purpose of this study, only one impact, distribution of water licenses to irrigators is considered. As such, the impact weighting component (w_g) included in Matheson's measures is not required in this analysis.

$$B_2(x) = \frac{1}{GI}\sum_{t=1}^{T}\sum_{g=1}^{G}\left[\frac{w_g \sum_{i=1}^{I}\sum_{j=1}^{I}\left|E(i,g,t,x) - E(j,g,t,x)\right|}{2I^2 \overline{E_{gtx}}}\right] \qquad (3.3)$$

$$B_2^{'}(x) = \frac{1}{GI}\sum_{g=1}^{G}\left\{w_g \sum_{i=1}^{I}\left[\frac{\sum_{s=1}^{T}\sum_{t=1}^{T}\left|E(i,g,s,x) - E(i,g,t,x)\right|}{2T^2 \overline{E_{igx}}}\right]\right\} \qquad (3.4)$$

where:

B_2(x) = intra-generational equity measure which is the weighted sum of deviations from an equal distribution of impacts;

B'_2(x) = inter-generational equity measure which is the weighted sum of deviations from an equal distribution of impacts;

G, I, T, X = number of different impacts, number of groups, number of time steps and number of alternatives;

i, g, t, x = indices for group, impact type, time step and alternative;

j, s, = group and time indexes that are required for pair-wise comparisons;

w_g = weights on impact types;

E(i, g, t, x) = magnitude of impact type *g* acting on group *i* during time timestep *t* that results from alternative *x*;

$\overline{E_{gtx}}$ = average impact over all groups for a given combination of impact type, time step, and alternative;

$\overline{E_{igx}}$ = average impact over all time steps for a given combination of group, impact type and alternative.

3.4 Application

The purpose of this project, as stated in the first chapter, is to apply these three criteria to the practical case study of water use in the Assiniboine Delta Aquifer. It should be stated outright that these criteria are not meant to replace other classical project evaluation methods, but rather enhance the decision making process by incorporating a consideration of sustainability. The three sustainability criteria, together with evaluation criteria, form the basis of a multiple criteria analysis.

3.4.1 Multiple criteria decision making

Zeleny (1984) states that:

> ...decision making with multiple criteria is fundamentally and *qualitatively* different from 'decision making' with a single criterion. In fact, there is no decision making involved in situations characterized by a single criterion of choice: mere acts of measurement and subsequent search suffice for making the choice.

Zeleny uses the example of selecting players for a basketball team based on height. In this case the "decision" is arrived at simply by measuring the height of the players and selecting them in descending order. However, if other criteria are factored into the decision making process such as the players' ability, age, speed and consistency, selecting the team with the best mix of these criteria becomes more difficult. The resulting team, however, is likely to be more robust, and fare better than teams assembled using only one selection criterion.

Sustainability decisions are inherently multi-faceted and consider a wide array of disciplines and issues. Traditionally, policy and resource allocation decisions have been made on the basis of primarily economic criteria, such as benefit cost analysis. Since the late 1960s, environmental considerations have been slowly added to the mix as the environmental assessment process has matured. Still, important issues for sustainability are not being considered in the decision making process. Simonovic et al. (1997) note that the sustainable decision making process should consider multiple disciplines and participants. The authors list five broad classes of criteria which should make up the sustainable decision making process:

- Economic criteria: traditionally weighted the most heavily. Inputs from benefit-cost analysis or other methods.
- Financial criteria: such as the distribution and flow of costs, returns and subsidies.
- Social impact assessments: considering changes to quality of life, health or well-being which may result from development.
- Environmental impact assessment: modelling changes and predicting impacts on the natural environment as a result of development decisions.
- Sustainability criteria: the most under-explored decision criteria and one which the reversibility, equity and risk criteria attempt to address.

Recall from the previous chapter that the fourth step in Goodman's project evaluation process was the formulation and analysis of project alternatives. The three sustainability criteria discussed in this chapter have been designed to fill some of the gaps in the planning process as identified by Simonovic et al. Before the criteria can be applied, it is necessary to generate a set of alternatives. In this case study, a wide range of alternatives are possible. However, for the purposes of this research the alternatives will consist of a series of policy scenarios that consider the larger scale of the aquifer, without evaluating the sub-basins independently.

3.5 Summary

The three sustainability criteria discussed in this chapter form part of a larger multiple criteria decision making process. Each criterion can be calculated independently considering the relevant environmental, economic and social factors. However, the development alternatives are intended to be evaluated in view of the larger setting of a multiple criteria analysis. For practical purposes, a series of three policy scenarios governing the distribution and allocation of water to different individuals and activities in the Assiniboine Delta Aquifer will be examined. Each scenario will receive a value for each of the criteria. The sum totals generated for each alternative plan can then be used in the decision making process. Although other criteria, such as benefit cost analysis or environmental assessment will not be taken up in this study, the hope is that the criteria examined in this work will allow sustainability considerations to be incorporated into the project development and selection process. In the next chapter, the specific scenarios to be evaluated in the case study are discussed.

Chapter 4: Case Study

4.0 Introduction

As discussed in the previous chapter, the three sustainability criteria are used as part of a larger multiple criteria decision making process to evaluate the sustainability of different project alternatives. For this case study, no particular project proposal is at hand so instead the alternatives will take the form of different policy scenarios. Each policy scenario represents a unique approach to managing the aquifer and consists of a set of programs, policies and legislation designed to reflect a different set of goals and objectives for water resource allocation and use. Care and attention has been taken to ensure that the three policy scenarios are as realistic and practical as possible. Having said that there were some restrictions placed on the development of the policy scenarios which may impact their precision:

- All of the policy scenarios were set under the assumption that they would take place in similar climatic years. Climate undoubtedly has a major role in the regulation of water levels in the aquifer. Therefore the appropriateness of a policy option will be influenced by the climate of a given year or series of years.

- Similarly, the policy scenarios are defined only in terms of actions which can be taken directly by humans. Therefore irrigation and domestic uses are considered but transpiration and wildlife uses are not. Once again, it is assumed that in comparable climatic years, such values would be similar and can therefore be excluded without significantly impacting the analysis.

Demographic data specific to the Assiniboine Delta Aquifer (ADA) region are difficult to obtain. Most provincial data are collected according to Rural Municipality (RM). For the purposes of this study, RM figures were deflated based on the land area included within the ADA boundaries. For example, if 50% of an RM's land area was considered to fall within the ADA and the total number of cattle in the RM was 10 000, the functional population considered to be within the boundaries of the ADA for this study would be 5 000 cattle. Table 4.1 summarizes the land area considered to fall within the ADA boundaries. These values are consistent with Kulshreshtha (1994). All RM based data used in this study represents a deflation of the aggregate RM figures except where other exclusions are noted.

Table 4.1 RM areas included in the ADA region.

Rural Municipality	% of land area considered part of the ADA region
North Cypress	100
South Cypress	100
Langford	60
Victoria	50
Cornwallis	40
Lansdowne	40
North Norfolk	40
Elton	20
South Norfolk	20

Recall from chapter one that the first objective of this study was the development of an implementation strategy for applying the sustainability criteria to the case study. The implementation strategy included determining what alternatives would be compared by the criteria and how the criteria would be applied. As has already been noted, the decision was made to compare three policy alternatives for managing ground water in the case study region. The greatest task associated with developing the implementation strategy was determining what types of data would be required by the study and how the data might be collected. The broad categories of data required for the sustainability criteria were discussed in chapter three. Data collection for this study fell into three broad categories:

- Existing data collected by government or other agencies;
- Primary data collection of information previously uncollected; and
- Expert opinions and values.

Existing data

This source of data was used wherever possible. All of the data used for establishing the parameters of the policy scenarios and much of the environmental and economic data used for calculating the sustainability criteria was of this type. Data in this category was collected from agencies such as the Manitoba Provincial Government Departments of Agriculture, Health and Natural Resources, the Prairie Farm Rehabilitation Administration, the Manitoba Crop Diversification Centre, P.M. Associates Ltd. and MidWest Foods Ltd.

Primary data collection

Primary data collection was necessary for aspects of the risk criteria. Collection of this information was undertaken during a series of workshops conducted by the researcher in June of 1998. Three workshops were held and attended by irrigators, environmentalists and government employees (Federal and Provincial). Eligible participants were identified through organization membership lists and transcripts of previous public meetings on issues concerning the aquifer. Participants were sent an invitation by mail and attendance was voluntary. The number of participants in each workshop was small and thus the data considered by the risk criteria was not statistically robust. Overall the researcher felt the quality of the responses was higher than would have been achieved by a mail out survey for two reasons:

- Several of the irrigators consulted during this study noted that they receive mail surveys from agricultural chemical companies and other sources on an almost weekly basis and their interest in filling out such surveys has waned.

- The survey required answers to some very broad questions. The researcher believed the answers to these questions would be more meaningful if a common understanding could be achieved among the participants. The workshop format gave the participants the opportunity to discuss the issues and offer their insights in a way that a mailed survey would not allow.

Expert opinion

Occasionally there were data requirements for the risk and reversibility criteria which were not easily measurable. In these cases, such as the risk probabilities or impacts measured on a qualitative scale for the reversibility criteria, an expert in the field was consulted to provide an informed estimate for the value. This is perhaps the most suspect source of data used in this research because it allows personal bias to colour the analysis. However, two issues are important to note:

- Expert opinion was only used where other estimates or indicators were absent or suspect. Expert opinion was never used in place of robust, reliable quantitative data.

- Expert opinion as used in the reversibility criteria was subjected to a sensitivity analysis to determine the impact of changes in the inputs on the outcome of the analysis. The results of the sensitivity analyses are discussed later in this chapter.

Table 4.2 lists the data types required for this study and the source of the data. Further notes on individual sources of data are included as that data is taken up later in this chapter. The second part of the implementation strategy involved establishing the parameters of the alternatives being compared by the criteria. The following section discusses the qualitative and quantitative aspects of each of the policy scenarios.

Table 4.2 Data requirements and sources for application of sustainability criteria in the ADA region.

Data Type	Criteria Used :			Source
	Reversibility	Risk	Equity	
Change in Arable Land.	X			Census data.
Water Quality.	X	X		Expert estimate and workshop responses.
Streamflow and water table levels.	X			Water Resources Branch, Manitoba Natural Resources.
Erosion Impact.	X	X		Expert estimate and workshop responses.
Irrigated potato acreage.	X			P.M. Associates survey.
Livestock populations.	X			Census data.
Processing employment figures.	X			Mid-West Food.
Domestic water availability.	X			Expert estimate.
Landscape aesthetic values.	X	X		Expert estimate and workshop responses.
Stakeholder value of increased agricultural revenue.		X		Workshop responses.
Stakeholder value of increased employment.		X		Workshop responses.
Stakeholder value of increased infrastructure costs.		X		Workshop responses.
Stakeholder value of increased recreation opportunity.		X		Workshop responses.
Stakeholder value of wildlife habitat		X		Workshop responses.
Water licensing figures.			X	Water Resources Branch, Manitoba Natural Resources.

4.1 Policy Scenarios

The policy scenarios used for this study are constructed by manipulating water use data in four broad use categories, domestic, irrigation, industrial and livestock. The water budget associated with each scenario is assembled using the best available data. This section will provide a qualitative description of each scenario along with a brief outline of the policy tools which might be used to achieve the water budget.

4.1.1 Status Quo Scenario

The status quo scenario represents the prevailing water use policy of 1996-7. As such it is a result of existing policy tools and legislation such as the Water Rights Act. Tables 4.3 to 4.5 list the demographic and agricultural statistics by RM. Human water use is based on an estimate of 100 gallons/person/day and irrigation water use is estimated at 6 inches irrigation coverage, both figures provided by PFRA (Stella Fedeniuk pers. com, October, 1997).

Livestock water use was calculated using average rate values provided by the American National Research Council's "Nutrient Requirements of Domestic Animals" series (National Research Council, 1985; 1988; 1989; 1994; 1996). The current water allocation system in Manitoba is based on the western prior appropriation model. As Lucas (1990) notes, this allocation system originated in the western regions of the United States during the late 19th century gold rush as an alternative to the traditional riparian allocation model. Lucas provides this synopsis of the prior appropriation model:

> (Prior appropriation starts) from the premise that the first person to put either water flowing in defined channels or percolating water to beneficial use acquired an enforceable water right. Subsequent appropriators also obtained rights, but these were subject to prior appropriators receiving their full share. As flow diminished in periods of drought, appropriators were required to close their in-takes in reverse order from the date of the

Table 4.3 Population of ADA Region by RM and township. (Manitoba Health, 1997)

Municipality	Population *
North Cypress	1 671
South Cypress	673
Langford	370
Victoria	724
Cornwallis	1 280
Lansdowne	379
North Norfolk	1 323
Elton	274
South Norfolk	238
Carberry	1 544
Glenboro	746
CFB Shilo	1 213
Total	**10 435**

Table 4.4 Irrigated Crop areas within the ADA region. (P.M. Associates Ltd., 1996)

Crop	Irrigated Acreage
Potatoes	6 353
Wheat	610
Rye	600
Beets	100
Grass	30
Forage	5
Barley	22
Bent Grass	6
Canola	31
Mixed Vegetables	108
Linola	164
Total	**8 029**

Table 4.5 Livestock populations by rural municipality (RM). (Manitoba Agriculture, 1998)

RM	Cattle and Calves	Poultry	Hogs	Sheep and Lambs	Horses
North Cypress	22 549	88 184	21 597	498	268
South Cypress	11 202	0	19 209	0	2 298
Langford	4 552	16	1 423	211	201
Victoria	4 542	23	5 146	47	650
Cornwallis	1 848	32 127	2 239	335	266
Lansdowne	6 238	0	5 450	126	315
North Norfolk	8 972	34 780	7 766	180	529
Elton	1 865	32 520	2 242	336	266
South Norfolk	2 375	0	4 578	50	30
Total	**64 143**	**187 650**	**69 650**	**1 783**	**4 823**

first appropriations.

Water licensing is administered under the Manitoba Water Rights Act and follows this use hierarchy:

- domestic;
- municipal;
- agricultural (non-irrigative);
- industrial;
- irrigation; and
- other uses.

In times of shortage, allocation would follow the prior allocation model so that users would receive their allocation according to the date of their license application. If two users existed who had licenses with the same application date, the use hierarchy would come into play such that domestic uses would be supplied ahead of municipal ones and so on. For example, a user who had a license dating from 1972 for 160 acre-feet would be allowed to withdraw the full 160 acre-feet before a user with a license dating from 1975 could use any of their allocation. This brief overview of the status quo scenario establishes a baseline condition which will be modified through different policy changes in the other two scenarios.

4.1.2 Development Scenario

The development scenario represents a policy change which encourages expansion and continued development. More money would be earmarked for expanding agricultural facilities and funding water development infrastructure. Water licensing restrictions would be eased under this set of policies and agricultural production, both crop and livestock, would increase. The Mid-West processing plant would operate at its economic short run capacity. The accelerated economic growth of the region would attract more residents, increasing the population. All of these developments would increase the demand on the water budget of the aquifer, the quantitative description of which is included later in this chapter.

4.1.3 Conservation scenario

The conservation scenario represents a policy change which emphasizes waste minimization and frugality. Under this scenario the population remains stable but domestic use decreases through behavioural change induced by a public education campaign. Livestock populations and associated water use decrease slightly. Irrigation, particularly of potatoes, is decreased resulting in somewhat lower yields. These lower yields will impact the processing plant resulting in lowered production. The single greatest change between the conservation scenario and the status quo scenario is a revision of the water licensing procedure.

Lucas (1990) notes that one of the main legal and economic problems with the western prior appropriation model of water allocation is the insecurity of property rights associated with the water license. Lucas states that a water license is neither a conveyance of a real property interest, nor a guaranteed contractual arrangement. This lack of security of title creates an inefficient property rights regime. Tate et al (1992) have also noted this problem in Canadian water policy and state that

> Public policy in Canada has exhibited an almost total disregard for the potential uses of economics in carrying out the tasks of water management.

One of the solutions Lucas suggests to ameliorate this inefficiency is the clarification of property rights through the development of an alternative allocation system. For the purposes of this project, the conservation scenario will consider an alternative allocation system, for irrigation only, that takes the form of a tradeable water share system. It should be noted that at this stage the water share system is merely a proposal developed by the researcher. It has received no formal approval from any agency with a water rights jurisdiction.

The tradeable water share system is a modification of the tradeable emissions permit system used for some environmental amenities in the United States. The goal of any of these permit systems is environmental protection and resource conservation. These goals are accomplished through market creation and establishment of property rights. Similar water share systems have been in place in the Australian states of Victoria and New South Wales for several years (Alaouze, 1991). For the purposes of this study, the province and the community would enter into a co-management agreement for managing the aquifer. The province would retain the title to the resource, but would cede management and use rights to the community for a period, perhaps 25 years, similar to an area based forestry tenure.

The Assiniboine Delta Aquifer Advisory Board (ADAAB), or a similar entity, would be responsible for the day to day management of the aquifer. Under the new administration, allocations within sub-basins would not exceed the current limits imposed by the Water Resources Branch (WRB) of Manitoba Department of Natural Resources. The ADAAB would be required to submit a use plan at five year intervals subject to the approval of the Water Resources Branch. WRB would retain the right to alter the allowable withdrawal as new information became available. WRB would also retain emergency powers. ADAAB would allocate water shares among irrigators on a per acre basis initially. Any land owner would be eligible to apply for a water share for his/her property. The water shares would in essence be owned by each irrigator subject to the conditions that:

- The irrigator be required to purchase the equipment necessary to make use of the water share (i.e. he must have the capacity to irrigate the land to which the water share is allocated.)
- The irrigator purchase monitoring equipment conforming to specifications developed by the ADAAB.

Each water share would be valid for the five year term of each management plan submitted by the ADAAB. Within that five year term, share-holders would be allowed to transfer their shares, within their sub-basin, under guidelines set up by the ADAAB. Thus water shares could be bought by landowners who require more than their initial allocation from landowners who have more shares than they need. At the end of each five year management term, landowners would have to reapply to the ADAAB for the next period. This would allow new landowners, or previous landowners who wish to begin irrigating, the opportunity to obtain a water share. The successfulness of this program, and indeed any establishment of property rights, hinges on monitoring and enforcement.

4.1.4 Quantitative Scenario Description

Now that we have discussed the qualitative elements of the policy scenarios we can focus on the quantitative aspects of the water budget under each policy regime. A detailed modeling of the aquifer water budget under each policy scenario is beyond the scope of this study. It should be noted therefore that these water budgets represent only one possible physical manifestation of the policy structure. Care has been taken, however, to ensure that the water budgets do represent a feasible set of circumstances.

Table 4.6 shows the population and agricultural statistics projected to exist under each of the policy alternatives while Table 4.7 presents the human use water budget for the aquifer under each scenario.

It should be noted that the water budgets are a function of both the demographic statistics and the use rates associated with each activity. In the development scenario, human and livestock populations increase by 3% but the use rate associated with each individual in those populations remains the same. Similarly, the irrigated crop acreage increases by 10%, but the average use rate remains constant at six inches/acre/year. To accommodate the increase in agricultural yield, the processing plant also increases its use by 10%. In the conservation scenario, the human population remains stable, but domestic water use decreases. Graham (1997) states that individuals can decrease their domestic water consumption by 30% through simple behavioural changes and the installation of a few inexpensive (under $10 U.S.) devices on household appliances. For the purposes of this study, a more conservative consumption decrease of 20% is used. The conservation scenario also considers a 2% decrease in the livestock population and a reduction in the average irrigation rate to four inches/acre/year. The reduced yield in the potato crop then causes the processing plant to reduce output, resulting in an associated decrease in their water consumption. This discussion offers a brief portrait of how the study area could be affected under the three policy scenarios. The following section offers a more detailed view of how the three sustainability criteria will be used to evaluate the policy scenarios.

Table 4.6 Projected agricultural and population statistics under three policy scenarios.

	Status Quo	Development	Conservation
Population	10 931*	11 259	10 931
Poultry	187 650**	197 033	183 897
Cattle	64 143**	67 350	62 860
Hogs	69 650**	73 133	68 257
Sheep	1 783**	1 872	1 747
Horses	4 823**	5 064	4 727
Irrigated Acres	8 029***	8 832	8 029

* Source: Manitoba Health Population Statistics, 1997
** Source: Manitoba Agriculture, 1998
***Source: P.M. Associates Ltd. 1995

Table 4.7 Projected water budgets under three policy scenarios. (measured in acre-feet/year).

Use Category	Status Quo	Development	Conservation
Domestic	1 224.4	1 261.2	979.5
Livestock	693.8	728.5	679.9
Irrigation	4 014.5	4 415.9	2 673.7
Industrial	2 016.0	2 217.0	1 814.4
Total	**7 948.7**	**8 622.6**	**6 147.5**

4.2 Application of Sustainability Criteria

Now that we have considered the qualitative and quantitative implications of each policy scenario, we can discuss the application of the three sustainability criteria reviewed in chapter three.

4.2.1 Reversibility

In chapter three, the steps involved in calculating the reversibility criterion were laid out. The first step in the process is the identification of possible impacts associated with development. Fanai (1997) notes that some impacts will be directly measurable on a quantitative scale while others will have to be measured indirectly, through characteristics or else on a qualitative scale. Table 4.8 summarizes the identified impacts and the associated units of measurement. The list of impacts was generated through brainstorming, a review of previous studies of the region and informal conversations with landowners and government officials. It likely does not represent a complete list of all conceivable impacts associated with each policy scenario, but does summarize the major concerns highlighted through conversations with stakeholders.

Table 4.8 Reversibility criteria: possible impacts.

Impact Name	Impact Type	Units
Loss of Arable Land	Ecological	acres/year
Water Quality	Ecological	Qualitative Scale
Riparian Water Needs	Ecological	Qualitative Scale
Erosion	Ecological	Qualitative Scale
Irrigated Crop Production	Economic	cwt/acre
Livestock Population	Economic	# animals
Direct Employment – Processing	Economic	No. Employees
Water availability – domestic	Social	Qualitative Scale
Landscape aesthetics	Social	Qualitative Scale

The weights necessary for the application of the *R*-metric, on a scale from 0 – 1, were selected by the researcher based on the perceived importance of each impact to those consulted. A sensitivity analysis on the impact which the assigned weights have on the R-metric is carried out as part of the analysis. As noted earlier in this chapter, wherever possible some quantitative characteristic of the impact was used as the input to the reversibility criteria. However, many of the impacts were not easily quantifiable. Rather than exclude these impacts from the analysis, an estimate along a qualitative scale was included. All of the qualitative scale values were estimated along a scale from 0 to

10 with 0 being the worst possible value and 10 being the best possible value. Except where otherwise noted, the impact values were provided by a government professional (PFRA, Stella Fedeniuk, pers. comm. July, 1998). Sources of other impact values and the rationale behind the choice of the impact weights are discussed for each selected impact.

Loss of arable land

A measure of the amount of arable or agricultural land that is removed from production for municipal, infrastructure or other purposes. This impact will increase with development as much of the available land in the region has already been cleared or designated as protected. This impact is classed as an ecological risk as opposed to an economic one because it is indicative of the competing uses for a relatively small land base. The impact is measured in the total number of acres lost per year and estimated from 1991 and 1996 Canadian census data (courtesy Manitoba Agriculture). This impact is given a moderately low weight of 0.40 as it did not seem to be of great concern to those stakeholders surveyed.

Water Quality

The quality of the water in the ADA is extremely high, and maintaining this high quality is important to all users of the aquifer. The Manitoba Crop Diversification Centre (MCDC) has been conducting a water quality monitoring program since 1994. Results of that study may prove to be useful for future evaluations. However, for this study, a qualitative scale was used to estimate conditions under the different policy programs. This impact seemed to be of great concern to residents of the region and receives a high rating of 0.85.

Riparian Water Needs

The association between groundwater levels and surface water flows is not entirely understood. Conversations with area residents revealed concern that increased groundwater usage would result in destabilization of streamflows. A regression analysis between the water table level at Carberry and the flow rates of the Epinette creek near Carberry provided by Water Resources Branch of the Manitoba Department of Natural Resources was used as the basis to estimate the probability of streamflow fluctuations as groundwater usage increases. The complete results of the regression analysis are contained in Appendix A. This impact is assigned a moderately high weight of 0.60.

Erosion

Erosion by wind and water is a concern to both farmers and conservationists in the ADA region. For this study, a qualitative estimate of the amount of erosion taking place under each scenario was used in the analysis. This impact was mentioned by several stakeholders as being important and as such receives a high weight of 0.70.

Irrigated Crop Production

Agriculture is the economic life blood of the region. The economic fortunes of the town of Carberry are directly tied to it. Since potatoes are the major irrigated crop, they provide a good indicator of the economic fortunes of the region. No attempt to model the different potato market conditions under the three policy scenarios was made, so instead the estimator for this impact will be the amount of potatoes produced in hundredweight (cwt). This will be a function of both the number of acres in production and the productivity. A figure of 250 cwt/acre will be used for the status quo and development scenarios while a more conservative estimate of 200 cwt/acre will be used for the conservation scenario. This impact was of considerable concern to many stakeholders and as such receives a very high weight of 0.90.

Livestock Numbers

Crop farming is not the only agricultural activity in the region. There is also a significant amount of livestock farming. Livestock production in the region is therefore an important indicator of the health of the local economy. Once again, no attempt will be made to model the livestock markets under the three policy scenarios and as such the total livestock population will be used as the indicator in the analysis. This impact is assigned a high weight of 0.70.

Direct Employment – Processing

The Mid-West processing plant is also important to the economic life of the community. It adds value to the local potato crop and also directly employs a number of local people. The number of workers directly employed by the plant is another important indicator of the well-being of the local economy and as such receives a very high weight of 0.85.

Water Availability – Domestic

Most of the residents of the ADA region live in a rural setting and depend on groundwater as their domestic water source. A major concern of several area residents was that increased development would lead to the water table dropping thereby causing their household wells to fail. The security of domestic water supplies will be estimated on a qualitative scale. This impact is assigned a moderately high weight of 0.60.

Landscape Aesthetics

Any policy change which affects development rates will have an impact on the way the landscape looks. This indicator, estimated on a qualitative scale, denotes the aesthetic quality of the landscape. This impact was deemed to be relatively unimportant compared to other impacts and receives a moderately low weight of 0.30.

Table 4.9 lists the weights and impact values for each indicator under the three policy scenarios. Recall equation 3.1, the *R*-metric from chapter three. The information from Table 4.9 is entered into the *R*-metric yielding a reversibility index for each alternative and each class of impacts (R_{cj}). Table 4.10 displays the results of the reversibility analysis. As discussed in chapter three, the Tc_{max} values are obtained by entering the worst possible value (m_{ci}) into the R-metric. The scaled R_c values are then obtained by dividing the R_c values for each alternative by the appropriate category Tc_{max} value. Fanai's criterion separates the ranking for each scenario into a result for environmental, economic and social impacts.

As Table 4.10 indicates, the scenarios are ranked differently in the three sustainability categories. The conservation scenario receives the lowest value (least irreversible) in the social and environmental categories, but the highest value (most irreversible) in the economic category. The development scenario receives the best value in the economic category but the lowest in the social and environmental categories. The status quo scenario ranks in the middle on all three criteria.

Two sensitivity analyses were performed to determine the impact on the analysis of the different impact weightings and the qualitative scale values. The complete sensitivity analysis appears in Appendix A. A summary of the results of the impact

Table 4.9 Reversibility impacts and weights for three policy scenarios in the ADA.

Impact	Units	M_{ci}	m_{ci}	w_{ci}	*f*SQ	*f*DE	*f*CO
Loss of arable land	Acres/yr	0	2818	0.40	2562	2818	2306
Water quality	Scale	10	0	0.85	7	7	7
Riparian water needs	Scale	10	0	0.60	6	6	6
Erosion	Scale	10	0	0.70	7	6	8
Irrigated crop prod.	cwt/acre	1746508	0	0.90	1587735	1746508	1270188
Livestock population	# animals	344451	0	0.70	328049	344451	321488
Direct employ. processing	# employees	451	0	0.85	410	451	369
Water avail.-domestic	Scale	10	0	0.60	7	6	8
Landscape aesthetics	Scale	10	0	0.30	7	7	7

SQ = status quo scenario DE = development scenario CO = conservation scenario

Table 4.10 Reversibility R-metric results.

	Category		
Index	c = 1 Environmental	c = 2 Economic	c = 3 Social
Tc_{min}	0.00	0.00	0.00
Tc_{max}	2.55	2.45	0.90
R_{c1}(SQ)	0.75	0.13	0.28
R_{c2}(DE)	0.83	0.00	0.35
R_{c3}(CO)	0.68	0.31	0.23
Scaled R_{c1}(SQ)	0.30	0.05	0.32
Scaled R_{c2}(DE)	0.32	0.00	0.39
Scaled R_{c3}(CO)	0.27	0.13	0.25

weight sensitivity analysis appears in Table 4.11. As discussed in chapter three, this sensitivity analysis is performed by randomly assigning the impact weights a value between 0 and 1. This process was carried out iteratively ten times. Table 4.11 displays the category indices calculated using the R-metric with the randomly assigned weights for each alternative and each of the ten iterations. The number of times an alternative is ranked first (i.e. receives the lowest R-metric value) is listed in the final column of the table. The results of this sensitivity analysis indicate that the reversibility results for this case study are not particularly sensitive to the weighting values. Table 4.12 displays the results of the impact value sensitivity analysis. In this analysis, individual impact values were modified to demonstrate their impact on the overall analysis. Only impacts ranked on a qualitative scale were modified. The percent change in the original value (measured by dividing the difference between the two impact values by the original impact value) is listed in the fourth column of Table 4.12. The eighth column of Table 4.12 lists the percent change in the index value that results from manipulating the impact value. As Table 4.12 illustrates, the ecological component of the reversibility analysis seems relatively stable, despite large changes in individual impact values. The margin of difference between the three alternatives changes but the recommended alternative in all cases is still the conservation scenario.

The social component, however is more vulnerable to changes in the qualitative value of impacts. A possible explanation for this is the smaller number of impacts considered in this category (two, versus four in the ecological category) and the fact that both impacts are estimated on a qualitative scale. Individual views or biases could therefore impact the criteria value in this category. This issue will be addressed further in the following chapter.

Table 4.11 Results of R-metric weight sensitivity analysis for the ADA case study.

		Category Indexes Calculated with Random Weight Sets										
Category	Rcj	1	2	3	4	5	6	7	8	9	10	# rank 1st
Social	Rsq	0.48	0.32	0.34	0.24	0.18	0.39	0.21	0.26	0.39	0.20	0
	Rde	0.58	0.37	0.43	0.29	0.22	0.46	0.24	0.29	0.48	0.23	0
	Rco	0.40	0.27	0.28	0.20	0.14	0.33	0.18	0.23	0.31	0.18	10
Ecological	Rsq	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0
	Rde	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10
	Rco	0.05	0.05	0.03	0.03	0.04	0.02	0.06	0.04	0.02	0.02	0
Economic	Rsq	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0
	Rde	0.14	0.14	.014	0.15	0.12	0.14	0.14	0.13	0.14	0.10	0
	Rco	0.05	0.06	0.06	0.05	0.07	0.05	0.05	0.06	0.06	0.08	10

Table 4.12 Results of the impact sensitivity analysis for the ADA case study.

	Param. tested	Original Impact Value	Chang. Value	% Change	Index Affect.	Original Index Value	Chang. Index Value	% Change	Pref. Altern.
Ecolog.	f112	7	10	+30	R11	0.22	0.19	-14	CO
	f122	7	10	+30	R12	0.27	0.24	-11	CO
	f123	6	10	+66	R12	0.27	0.23	-17	CO
	f113	6	10	+66	R11	0.22	0.18	-18	CO
	f114	7	9	+29	R11	0.22	0.20	-9	CO
	f124	6	9	+50	R12	0.27	0.23	-15	CO
	f134	8	6	-25	R13	0.18	0.22	+22	CO
Social	f312	7	10	+43	R31	0.09	0.06	-33	CO
	f321	6	9	+50	R32	0.14	0.04	-71	DE
	f322	7	10	+43	R32	0.14	0.11	-21	CO
	f331	8	6	-25	R33	0.06	0.14	+57	SQ

4.2.2 Risk

As Kroeger (1997) notes, the value attached to a particular risk varies with the value systems of the decision-maker, analyst or person subject to the risk. Valuation of risk is therefore a highly sensitive undertaking due to the subjective personal nature of the issue. Kroeger's risk criterion takes this into account by considering both traditional risk probability assessments and the values and preferences of stakeholder groups. A list of possible risks associated with the different management regimes for the ADA was generated in a similar fashion to the list of possible impacts for the reversibility criterion.

Table 4.13 Possible risks associated with the three policy scenarios.

Risk Name	Risk Type
Erosion (-)	Environmental
Loss of wildlife habitat (-)	Environmental
Point-source water pollution (-)	Environmental
Stream flow variability (-)	Environmental
Increased Agricultural Revenue (+)	Economic
Increased Employment (+)	Economic
Increased Infrastructure Costs (-)	Economic
Increased Recreation Opportunity (+)	Social
Aesthetic Changes (-)	Social

Table 4.13 summarizes the possible risks. As Kroeger points out, it is important to consider not only the likelihood and magnitude of negative impacts, but also positive impacts which may be forgone or decreased under different scenarios. For the purposes of this study, impacts which might generally be considered negative are marked (-) while generally positive impacts are marked (+).

Erosion

This impact considers the risk of increased wind or water erosion. Increased erosion leads to loss of topsoil and can ultimately lead to losses in crop yields. Erosion is an important issue to farmers, and since farming is the primary economic activity in the ADA region, it concerns all residents. Increased erosion could be associated with development, land clearing or increasing traffic.

Loss of wildlife habitat

Wildlife habitat could be lost to woodlot clearing or wetland draining for development purposes (municipal, agricultural, infrastructure or other reasons). This impact could also reflect increasing disturbance or degraded quality of habitat due to exotic species, noise or contaminants. This risk impact is included because the ADA region contains some of the last examples of tall grass prairie habitat in Manitoba. Several environmentalists and area residents were concerned about the impact which increasing development would have on unique species and habitat.

Point source water pollution

This impact reflects the risk of increased water pollution associated with fuel, industrial or agricultural spills. Such pollution could affect surface or groundwater. Currently, the water quality in the ADA is excellent and most area residents rely on water from the aquifer for all their domestic uses. Replacing the water supply from the aquifer used for domestic purposes would be extremely costly.

Increased stream flow variability

Some residents expressed concern that surface water bodies, particularly smaller ones like the Squirrel or Pine Creek, could be impacted negatively by increased use of groundwater. Some of the small creeks in the ADA region have run dry in drought years. Several area residents are concerned about the stability of surface water flows being compromised by increased groundwater usage.

Increased agricultural revenue

This impact considers the risk of forgoing possible increases in farm gate receipts for crops or livestock. Increased development would tend to increase the likelihood of increased agricultural production while some of the measures associated with a water conservation policy would likely decrease agricultural production. Agriculture is the primary source of economic revenue for the region. Policies or programs which could impact agricultural revenue, either positively or negatively are of considerable interest to many area residents.

Increased employment

Increased agricultural revenue would likely lead to increased employment. Such increases could be directly attributable to agriculture in the form of processing or farm labour jobs, or indirectly in service, health and education sectors. This positive impact would be lessened in a scenario that emphasized conservation measures. Agriculture is the economic foundation of the region and policies that impact agricultural jobs will have a ripple effect through the rest of the local economy.

Increased infrastructure costs

Increasing development comes with the price of greater wear and tear on both private and public capital. Roads and machinery would have to be repaired or replaced more frequently and taxes or operating costs could increase as a result. Several residents expressed concern that with increased development, certain individuals or sectors would make greater use of public facilities. There was also concern that the cost of this increased demand on public services would be borne by all residents in the form of higher municipal and provincial taxes.

Increased recreation opportunities

Development could also lead to the expansion or improvement of recreation opportunities. Higher farm incomes would also mean more time and money for recreation. Slowing development would likely result in fewer recreation opportunities.

Aesthetic changes

Development generally necessitates changes to the landscape. Clearing areas for building or agriculture changes the character of the area. Species composition of some areas may change. Some residents stated that they felt the character of their region had been negatively impacted by development. Quantification of such concern is difficult, but this impact was included to give respondents the opportunity to express their concern over such aesthetic changes.

As noted in chapter three, the risk criterion requires three types of data, the risk probabilities, sustainable development category weights and the risk value preferences of different stakeholder groups. Risk probabilities under each scenario were estimated by a professional in the water resource management field familiar with the case study.

Personal risk preferences and sustainable development category weights were obtained from three identified stakeholder groups: government managers, irrigators and environmentalists. Government managers were identified as specific employees of the Manitoba Departments of Agriculture, Natural Resources, Environment and Rural Development as well as employees of the Prairie Farm Rehabilitation Administration and the Manitoba Crop Diversification Centre. Irrigators were identified as members of the Assiniboine Delta Aquifer Irrigators Association. Environmentalists is a broad stakeholder category that included farmers from the region who do not currently irrigate, non-farming landowners and members of environmental non-government organizations. The researcher felt that these three categories of stakeholders provided a representative cross-section of the different opinions and value systems held with respect to the management of the aquifer.

Individuals identified as belonging to a certain stakeholder group were invited by letter to one of a series of workshops held in June of 1998. One workshop was held for each stakeholder group. The workshop format was considered to be the most appropriate way to obtain the risk preference and sustainable development category weight data because it allowed the researcher the opportunity to administer individual surveys and to be present for group discussions of issues important to the stakeholders. Copies of the invitation letter sent to stakeholders as well as the surveys administered in the workshops are contained in Appendix B.

The workshops began with a brief introduction to the study including a discussion of the purpose and objectives of the study. A general discussion on aquifer management issues important to the participants accounted for most of the workshop time. Despite the low attendance at each workshop (<10 participants) the researcher was impressed with the quality of the discussion. Issues discussed at the workshops ranged from the feasibility of alternative water distribution systems and the effectiveness of local political structures to the economic and social benefits of irrigation and environmental integrity. At the end of each workshop, participants were asked to assign a value to each of the three sustainable development categories (environmental, economic and social) such that the total value for all three equaled 100. Participants were also asked to respond to a brief survey which asked them to rank the value they attached to a particular risk on a scale from zero to ten. For negative risks, marked (-), zero indicated the respondent had no particular aversion to experiencing the risk impact while ten meant the respondent would prefer to avoid the risk impact at all costs. For positive risks, marked (+), zero indicated the respondent was not concerned about achieving the benefit associated with the impact while ten indicated that the respondent wished to achieve the benefit at all costs. It is important to note that respondents were asked to fill out the surveys according to their individual views and preferences. The responses should therefore not be interpreted as representing the official viewpoint of any organization or agency to which an individual respondent may belong. The researcher was present while the respondents were filling out the surveys to answer any questions or offer clarification where necessary.

Tables 4.14 and 4.15 list the participant risk weights and sustainable development category weights obtained from the surveys administered during the workshops. It should be noted that the values presented here are the average values of the respondents in each stakeholder category.

The values in these two tables are converted to the participant risk values by means of the formulae discussed in chapter three. The individual risk values are first divided by the total for that risk class and stakeholder group. This modified risk value is then multiplied by the sustainable development category weight assigned by the stakeholder group to that particular risk class. The resulting figure is then divided by 100. Table 4.16 shows the results of these calculations. The probabilities of each risk occurring were estimated using the scale in Table 4.16 by a professional from PFRA in the field of water management after reading the scenario descriptions presented earlier in this chapter.

Table 4.14 Average risk preferences for three stakeholder groups in the ADA.

Risk	Risk Class	Government Employees	Irrigators	Environmentalists
Loss of wildlife habitat (-)	Environmental	5.2	6.8	7.7
Inc. erosion (-)	Environmental	6.0	7.8	7.3
Inc. water pollution (-)	Environmental	8.0	7.8	9.0
Stream-flow variability (-)	Environmental	5.8	6.0	7.7
Totals		**25.0**	**28.4**	**31.7**
Inc. agricultural revenue (+)	Economic	5.8	7.8	5.0
Inc. employment (+)	Economic	6.0	6.0	7.7
Inc. infrastructure costs (-)	Economic	4.8	5.0	6.0
Totals		**16.6**	**18.8**	**18.7**
Aesthetic change (-)	Social	4.4	5.8	7.3
Inc. recreation (+)	Social	3.6	7.5	4.3
Totals		**8.0**	**13.3**	**11.6**

Table 4.15 Average sustainable development categories weights as indicated by three stakeholder groups in the ADA.

SD Category	Government Employees	Irrigators	Environmentalists
Environment	39.8	21.3	48.3
Economy	32.6	65.0	30.0
Social	27.6	13.8	21.7

Table 4.16 Scaled risk preferences for three stakeholder groups in the ADA.

Risk	Government Employees	Irrigators	Environmentalists
Loss of wildlife habitat (-)	0.08	0.05	0.12
Inc. erosion (-)	0.10	0.06	0.11
Inc. water pollution (-)	0.13	0.06	0.14
Stream-flow variability (-)	0.09	0.05	0.12
Inc. agricultural revenue (+)	0.11	0.27	0.08
Inc. employment (+)	0.12	0.21	0.12
Inc. infrastructure costs (-)	0.09	0.17	0.10
Aesthetic change (-)	0.15	0.06	0.14
Inc. recreation (+)	0.12	0.08	0.08

Table 4.17. Qualitative scale and quantitative equivalent used for estimating risk probabilities in the ADA.

Qualitative	Quantitative	Qualitative	Quantitative
none	0.00	moderate	0.50
negligible	0.05	moderately-high	0.65
very low	0.10	high	0.80
low	0.20	very high	0.95
moderately-low	0.35	certain	1.00

For negative impacts, marked (-), the probability estimate reflects the likelihood of the risk impact occurring. For positive impacts, marked (+), the probability estimate indicates the probability that the impact will be forgone. Table 4.18 summarizes the probability estimates.

The risk probabilities were multiplied with the participant risk values developed earlier in the chapter. Tables 4.19 to 4.21 summarize the risk criteria analysis for the three policy scenarios while Table 4.22 provides an average of the participant weights for each of the three scenarios.

Table 4.18 Summary of risk probability estimates for three policy scenarios in the ADA.

Risk	Status Quo	Development	Conservation
Loss of wildlife habitat (-)	0.35	0.65	0.20
Inc. erosion (-)	0.20	0.35	0.10
Inc. water pollution (-)	0.35	0.50	0.35
Stream-flow variability (-)	0.05	0.05	0.05
Inc. agricultural revenue (+)	0.65	0.20	0.80
Inc. employment (+)	0.80	0.50	0.95
Inc. infrastructure costs (-)	0.20	0.35	0.10
Aesthetic change (-)	0.20	0.20	0.20
Inc. recreation (+)	0.80	0.65	0.80

Recall from chapter three that a lower value for the risk criterion indicates an option that is preferred as less risky. Comparison of the three tables indicates that on average, the three participant groups show a preference for the development scenario as the least risky alternative. The status quo scenario is generally considered somewhat more risky than the development scenario. Government employees and irrigators consider the conservation scenario the most risky while environmentalists find it marginally less risky than the development scenario. The preference for the development scenario could indicate a general desire among those surveyed for more support of economic expansion and diversification. Table 4.22 separates the average risk values for positive and negative impacts under each policy scenario for each participant group.

Table 4.19 Risk estimates for status quo scenario in the ADA.

Risk	Government Employees	Irrigators	Environmentalists
Loss of wildlife habitat (-)	0.03	0.02	0.04
Inc. erosion (-)	0.02	0.01	0.02
Inc. water pollution (-)	0.04	0.02	0.05
Stream-flow variability (-)	0.00	0.00	0.01
Inc. agricultural revenue (+)	0.07	0.18	0.05
Inc. employment (+)	0.09	0.17	0.10
Inc. infrastructure costs (-)	0.02	0.03	0.02
Aesthetic change (-)	0.03	0.01	0.03
Inc. recreation (+)	0.10	0.06	0.06
Totals	**0.40**	**0.50**	**0.38**

Table 4.20 Risk estimates for development scenario in the ADA.

Risk	Government Employees	Irrigators	Environmentalists
Loss of wildlife habitat (-)	0.05	0.03	0.08
Inc. erosion (-)	0.03	0.02	0.04
Inc. water pollution (-)	0.06	0.03	0.07
Stream-flow variability (-)	0.00	0.00	0.01
Inc. agricultural revenue (+)	0.02	0.05	0.02
Inc. employment (+)	0.06	0.10	0.06
Inc. infrastructure costs (-)	0.03	0.06	0.03
Aesthetic change (-)	0.03	0.01	0.03
Inc. recreation (+)	0.08	0.05	0.05
Totals	**0.36**	**0.35**	**0.39**

Table 4.21 Risk estimates for the conservation scenario in the ADA.

Risk	Government Employees	Irrigators	Environmentalists
Loss of wildlife habitat (-)	0.02	0.01	0.02
Inc. erosion (-)	0.01	0.01	0.01
Inc. water pollution (-)	0.04	0.02	0.05
Stream-flow variability (-)	0.00	0.00	0.01
Inc. agricultural revenue (+)	0.09	0.22	0.06
Inc. employment (+)	0.11	0.20	0.12
Inc. infrastructure costs (-)	0.01	0.02	0.01
Aesthetic change (-)	0.03	0.01	0.03
Inc. recreation (+)	0.10	0.06	0.06
Totals	**0.41**	**0.55**	**0.37**

Table 4.22 Average risk preferences of three policy scenarios for three stakeholder groups in the ADA.

Participant Group	SQ	DE	CO
Government Employees	0.40	0.36	0.41
Irrigators	0.50	0.35	0.55
Environmentalists	0.38	0.39	0.37
Participant Average	**0.43**	**0.37**	**0.44**

Table 4.23 Breakdown of positive and negative risk estimates.

Risk	Status Quo			Development			Conservation		
	Gov.	Irri.	Env.	Gov.	Irri.	Env.	Gov.	Irri.	Env.
positive	0.26	0.41	0.21	0.16	0.20	0.13	0.30	0.48	0.24
negative	0.14	0.09	0.17	0.20	0.15	0.26	0.11	0.07	0.13

Table 4.23 indicates that the risk of forgoing positive impacts (generally associated with development) contributes the most to the Risk criterion. Although the conservation scenario receives the lowest risk value (least risky) associated with negative impacts, the greater likelihood of forgoing positive impacts results in a higher overall risk rating.

4.2.3 Equity

Equity is a term that appears frequently in both the economics and sustainable development literature. However, there are a vast array of definitions and applications of equity. As Matheson (1997) notes there are at least three distinct categories of equity: proportionality, equality and need based. Within these classifications there are a number of different ways of interpreting equity and each may be perfectly rational in a given situation. Anytime an agency makes a distribution decision about a finite resource, equity questions are called into play.

The current groundwater allocation system in Manitoba employs a use hierarchy system and the "first in time, first in right" principal as the equitable standard between users. However, for the purposes of this study, equity will be modeled using the availability of groundwater to landowners for irrigation as an indicator. This interpretation of equity falls under Matheson's classification of an equality based norm. A major assumption of this work is that all landowners who wish to spend the initial investment necessary for irrigation should have equal opportunity to obtain a water right. Conditions are examined for two of the 13 sub-basins of the ADA, Pine Creek North and Lower Whitemud East. Pine Creek North was chosen because it is currently allocated above the level set by WRB. To contrast with this situation, the Lower Whitemud East sub-basin was chosen because as of 1997 it had some irrigation development but still had considerable amounts of water available for allocation.

Both inter- and intra- generational equity are considered by modeling the access opportunity of landowners in different sub-basins both in the first year of each policy scenario and over a 30-year planning horizon. Information for the first year of the model is based on the 1997 licensing data from WRB. Subsequent users are added by extrapolating the current user application rate (calculated from the previous 10-year average) for the status quo scenario. This user application rate is then modified for the development and conservation scenarios. Allocations are also based on the historical averages for each sub-basin. Users who might exist in the future after a sub-basin resource is fully allocated are still considered in the analysis but are assigned a zero value for their allocation. This allows the equity analysis to consider those users who would apply for a water license but cannot receive one because the sub-basin resource is allocated to its capacity. Figures 4.1 and 4.2 show the number of users in each sub-basin for each year under the different policy scenarios. It is important to note that the users in the first year are users who held, or had made application for, a water license as of January 1st, 1997. Users in other time periods represent potential users, who might desire a license in that time step. In some cases, such as the status quo and development scenarios in the Pine Creek North sub- basin, these new users have no access to a water license because the sub-basin is fully allocated under those policy scenarios.

Tables 4.24 and 4.25 summarize the results of the intra-generational and inter-generational equity analysis respectively for the two sub-basins. The values in these tables were generated using equations 3.3 and 3.4 from chapter three with the number of

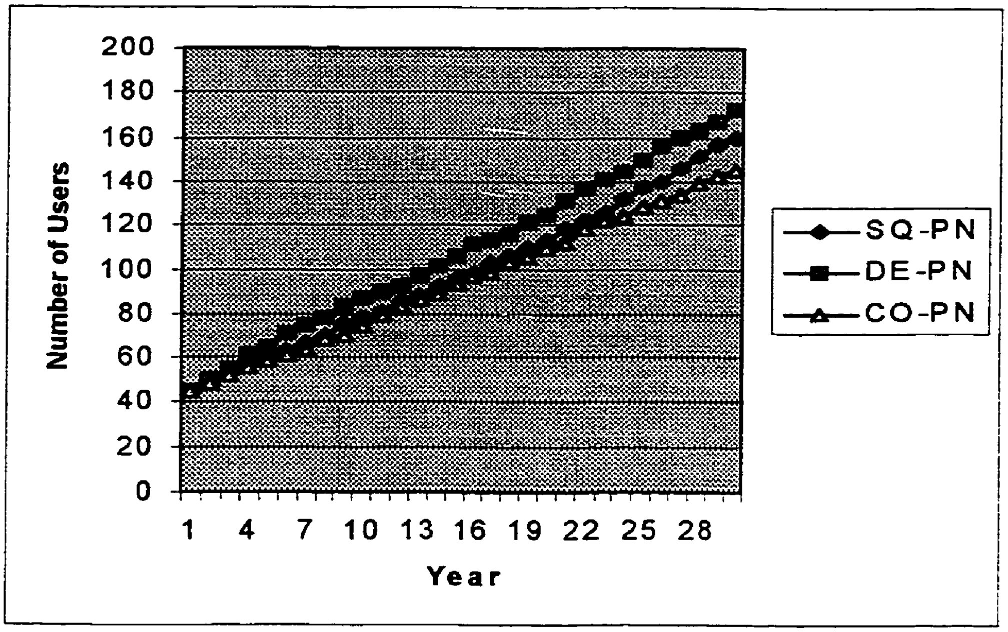

Figure 4.1 Number of users in the Pine Creek North sub-basin (PN) under three policy scenarios over a 30 year planning horizon.

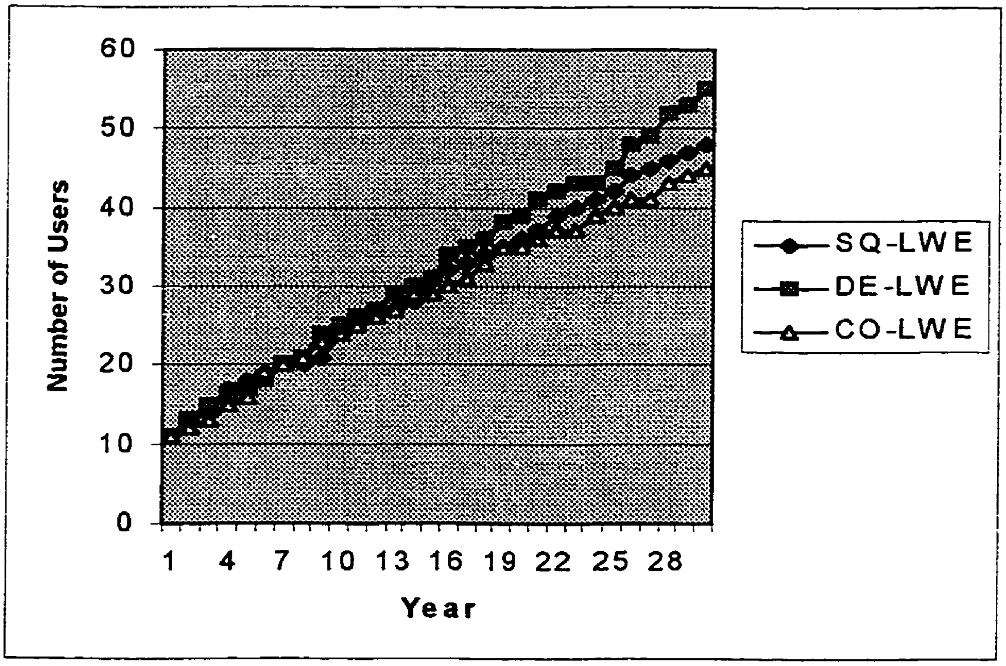

Figure 4.2 Number of users in the Lower Whitemud East sub-basin (LWE) under three policy scenarios over a 30 year planning horizon.

Table 4.24 Intra-generational equity calculations for access to irrigation licensing for two Sub-basins of the ADA.

	Pine Creek North			Lower Whitemud East		
	SQ	DE	CO	SQ	DE	CO
$B_{2(x)}$	0.56	0.60	0.09	0.15	0.19	0.02

Table 4.25 Inter-generational equity calculations for access to irrigation licensing in two Sub-basins of the ADA.

	Pine Creek North			Lower Whitemud East		
	SQ	DE	CO	SQ	DE	CO
$B'_{2(x)}$	0.00	0.00	0.25	0.00	0.00	0.09

impacts (G) being one (the individual user's access to a water right), the number of groups (I) being equal to the number of individuals in each time step (as listed in Figures 4.1 and 4.2), the number of time steps (T) being set at 30 and the number of alternatives (X) being three, representing the status quo, development and conservation scenarios. The test statistics B_2(x) (intra-generational equity) and B'_2(x) (inter-generation equity) are impacted both by the number of users in a given time step and the difference in the size of water licenses allocated to different users. An example of one of the matrices used to calculate the equity statistic is included in Appendix C.

If we review Table 4.25, we discover that the conservation scenario receives a higher (less equitable) ranking in both sub-basins compared to either the development or status quo scenario. In fact, both the status quo and development scenarios receive a zero value because no user's access to water is changing during the planning horizon. This indicates that under the current legislation and policy directives, users have somewhat more security in knowing that the size of their water allocation will remain the same for several time periods into the future.

If we now turn our attention to the comparison of intra-generational equity summarized in Table 4.24, we quickly discover that the conservation scenario receives a much lower (more equitable) rating than either the development or status quo scenarios. In fact the magnitude of the difference between the conservation scenario and the development and status quo scenarios suggests that the allocation procedure used in the conservation scenario is responsible for most of the difference in the equity rating, and not the number of users in each scenario. Table 4.26 summarizes the intra-generational equity calculations for each time period, policy scenario and sub-basin. At five-year intervals, the conservation scenario receives a zero value as the equalization period sets in under the tradeable water share system. The Lower Whitemud East sub-basin receives zero values from the fifth to the twenty-third time period because it is not yet fully allocated during these periods and therefore new users can obtain a water share outside of the regular five-year planning interval. The five-year equalization period, where all interested landowners are given a water right based on the amount of land they own, results in a more equitable intra-generational distribution. Whether the equalization period occurs every year, every five years or every ten years is not as important as the fact that an equalization period seems to have a greater impact on the overall value of the equity calculation than the number of users present in each period.

Table 4.26 Intra-generational equity calculations for two sub-basins of the ADA under different policy scenarios.

	Pine Creek North			Lower Whitemud East		
Year	E(SQ)	E(DE)	E(CO)	E(SQ)	E(DE)	E(CO)
1	0.15	0.15	0.15	0.12	0.12	0.12
2	0.20	0.24	0.21	0.11	0.11	0.11
3	0.27	0.31	0.27	0.11	0.11	0.11
4	0.33	0.38	0.32	0.09	0.11	0.11
5	0.36	0.42	0.00	0.10	0.11	0.00
6	0.40	0.46	0.05	0.10	0.11	0.00
7	0.42	0.49	0.09	0.10	0.11	0.00
8	0.46	0.51	0.15	0.10	0.11	0.00
9	0.49	0.55	0.17	0.11	0.11	0.00
10	0.50	0.57	0.00	0.10	0.10	0.00
11	0.53	0.58	0.06	0.10	0.10	0.00
12	0.55	0.59	0.11	0.10	0.10	0.00
13	0.57	0.61	0.14	0.10	0.10	0.00
14	0.59	0.63	0.17	0.10	0.09	0.00
15	0.60	0.65	0.00	0.11	0.09	0.00
16	0.61	0.66	0.04	0.11	0.10	0.00
17	0.63	0.67	0.06	0.11	0.12	0.00
18	0.64	0.68	0.10	0.10	0.15	0.00
19	0.65	0.69	0.12	0.10	0.19	0.00
20	0.66	0.70	0.00	0.10	0.21	0.00
21	0.68	0.71	0.03	0.12	0.25	0.00
22	0.69	0.72	0.08	0.17	0.27	0.00
23	0.70	0.73	0.11	0.19	0.29	0.00
24	0.71	0.74	0.12	0.21	0.29	0.05
25	0.72	0.75	0.00	0.23	0.32	0.00
26	0.73	0.76	0.02	0.26	0.36	0.01
27	0.74	0.76	0.04	0.27	0.37	0.01
28	0.75	0.77	0.08	0.28	0.41	0.09
29	0.76	0.77	0.10	0.30	0.42	0.10
30	0.76	0.78	0.00	0.31	0.44	0.00
Sum	16.86	18.03	2.79	4.42	5.77	0.71
$B_2(x)$	0.56	0.60	0.09	0.15	0.19	0.02

Chapter 5: Discussion

5.0 Suitability of Sustainability Criteria

5.0.1 Reversibility

Reversibility is a concept that arises primarily from the environmental economics literature. Traditionally reversibility has been considered the extent to which the development of natural resources causes irrevocable change to the natural environment. The key issue is the balancing of social and environmental impacts with the economic benefits of development. Such a comparison is intrinsically difficult because of the different nature of the environmental, social and economic impacts and the degree to which each is measurable. Tietenberg (1994) states that economists have developed several methods for placing a monetary value on environmental amenities. Examples include the contingent valuation method, which uses surveys to determine how much respondents would be willing to pay to preserve the environment, and the hedonic pricing method, which assumes that markets for housing and other commodities inherently consider environmental amenities and that economic values for these environmental goods can be derived from market data. Tietenberg and others, including Eberle and Hayden (1991) and Boyle et al (1993), have noted a variety of problems with such methods. Most of the criticisms of these valuation methods stem from the fact that they attempt to establish a monetary value for a good that is not directly marketed. The reversibility criterion eliminates this sort of criticism because Fanai's model does not attempt to establish a market value for a non-market good. Instead the reversibility criterion measures impacts relative to their best and worst possible values. For some impacts, these values are relatively easy to obtain but for many there is no quantifiable scale on which they can be assessed. As such the reversibility criterion encounters the same problem that the contingent valuation method and others attempt to address. Fanai's solution in developing the criterion is to measure these impacts along a qualitative scale. This opens the criterion up to a different type of criticism, expert opinion in impact and policy assessment.

Expert opinion figures prominently in the reversibility criterion. The simple act of including impacts not measurable in a traditional quantitative sense requires a somewhat more conceptual framework. This sort of framework causes a certain degree of uneasiness with many researchers and decision makers with a background in natural or applied sciences. The very experts whose opinions are sought to fill in the gaps left by quantitative analysis are often reluctant to estimate values which will be blended with traditional scientific information. As Chociolko (1995) observes

> ... expert disagreement is a common, often unavoidable result of legitimately differing interests and perspectives, and ... expert disagreement should be accepted as the norm in environmental deliberations.

This brings the results of the reversibility criterion for the case study under scrutiny because such a large part of the inputs into the model are based on expert opinion. Fanai recommends a sensitivity analysis as one way of reducing the impact of subjective values on the results of the criterion. Recall from the previous chapter that in the ecological category, which consisted of both qualitative and quantitative inputs, the results of the analysis were not compromised even by relatively large changes in the values of individual impacts. The social category, which consisted entirely of qualitative inputs, was considerably more susceptible to different results given modification of individual impacts. This affects the level of confidence a decision maker could have in basing a judgment on that category of the criterion.

However, as noted in Chapter Three, the reversibility criterion is not meant to stand alone as a decision making tool. The reversibility criterion, along with the other sustainability criteria, are meant to form part of a larger multiple criteria analysis. This focus on several different criteria for decision making means that a subjective aspect of one criterion will not be weighted as heavily in the decision making process as it would be if only a single criterion were used. Furthermore, in the case of the reversibility criterion, subjective data is only being used in the absence of more traditional quantitative data. In the author's opinion, this should be considered a strength of the methodology in that it allows impacts which would otherwise not be factored into the decision making process to be considered.

5.0.2 Risk

The risk criterion deals with a subject that has been debated throughout the history of risk assessments, the fact that different people will perceive risks differently. As Whyte and Burton (1982) note, "empirical research on risk perceptions clearly demonstrates that people do not choose the expected value or outcome which is most favourable". This statement indicates that risk evaluation cannot be described by a simple statistical calculation of probability and hazard magnitude. Some risks will be intrinsically more or less acceptable to different individuals. The term often used in the risk assessment literature is "acceptable risk" which indicates what level of risk those who are exposed to the risk are willing to take. The level of acceptable risk cannot be calculated without consulting those who are likely to be impacted. The risk criterion evaluated in this study combines an assessment of the preferences of individuals with the statistical probability of outcomes associated with each alternative. The method of combining stakeholder input with the probability assessments of experts or professionals allows a blend of professional judgement and citizen preferences to be considered in the decision making process. This is a considerable improvement over some traditional risk assessment methodologies which consider only the magnitude and likelihood of risk under different scenarios without taking into account the preferences of those who are most likely to be impacted by the risks.

In practice, the researcher found that the workshop setting was an appropriate way to obtain the necessary participant inputs. The survey administered during the workshop allowed participants to record their preferences while maintaining the opportunity to discuss important issues or concerns in a group setting. This was deemed to be advantageous both to the participants and the researcher. Participants could have any questions about the survey answered while they were responding and could also elaborate upon their responses in a manner that a survey alone would not allow. The researcher was able to gain a better understanding of what issues and concerns motivated the responses and to understand more completely the viewpoints of the respondents.

Despite these merits, the tools used in this study were not without their problems. Several participants commented on the abstractness and bluntness of the question sheet concerning the sustainable development category weights. Others stated that they would reply differently to the question under different circumstances. While the sustainable development category weights are an integral part of the risk criterion, Kroeger never discusses an appropriate method for obtaining these values from the participants.

Perhaps an index could be developed which calculates the category weights for individuals based upon their responses to a series of situational or behavioural questions. This would likely make the workshop process more cumbersome but could alleviate some of the issues associated with the tool used in this study. The risk criterion is also subject to the same criticisms of value judgement and expert opinions as the reversibility criterion.

5.0.3 Equity

Equity, like Risk, is subject to a variety of different interpretations by different people. Any analysis of equity should take this into consideration. Young (1994) discusses a general standard for equity, stating that :

> "Appropriateness is shaped in part by principle and in part by precedent. It expresses what is reasonable and customary in a given distribution situation. To deviate from a rule that is founded on both reason and precedent would violate the stakeholders' legitimate expectations, and this would be inequitable".

If we apply this standard to the case study at hand, we arrive at a quandary. The distribution precedent in Manitoba is the "first in time first in right" standard. Under this policy structure, stakeholders could reasonably expect their access to water rights to be consistent with their license date of application. A change in the policy or legislation surrounding the distribution of water rights would violate this expectation. This idea is supported somewhat by the results of the inter-generational equity analysis performed in the previous chapter. However, if as Lucas (1990) suggests, water licenses convey neither a vested property interest nor a contractual agreement with the Crown, individual users may actually have more secure title under the tradeable water share system, even if the raw amount of water allocated to them decreases.

The purpose of the equity criterion is to measure the distribution of costs or benefits associated with a project or development across different interest groups. Matheson (1997) developed two different equity measures, one that considers distribution for different groups within the same time period (intra-generational) and one that considers distribution for the same group across several time periods (inter-generational). The equity measure takes the form of a matrix that can be expanded to include as many different impacts, stakeholders and time periods as desired. At least three different possible components of equity have been recognized: proportionality, equality and need. However, there are difficulties with defining proportionality and need based measures and as such this study considers only the equality component of equity.

In the case study we are essentially comparing two different allocation structures. The prior allocation model present in the status quo and development scenarios is ranked as less equitable on an intra-generational comparison because once a sub-basin is fully allocated, landowners either have access to water for irrigation or they are denied access. The tradeable water share system present in the conservation scenario allows new users to obtain a water license even after a sub-basin is fully allocated. This results in the conservation scenario being rated as more equitable in an intra-generational setting. However, since the total amount of water available for allocation is the same under each allocation process, the tradeable water share system results in previous users losing some of their allocation as new users request licenses. There are obvious tradeoffs associated with all three systems. An examination of the results of all three of the sustainability criteria in the setting of the larger multiple criteria decision making process will be considered later in this chapter.

Overall, Matheson recognizes the limitations of his equity measure, stating that:

> It should be mentioned that the overall fairness measures developed in this work are a mathematical abstraction of a social system and should not be considered as being precise measures of fairness.

What Matheson does accomplish, however, is the development of a criterion which formalizes the evaluation of equity. As such, Matheson has brought to new light a development issue which is often considered intuitively important, but rarely weighted as heavily in the decision making process as more classical evaluation techniques such as benefit-cost analysis or environmental assessment.

5.1 Importance of Sustainability Criteria as Decision Making Tools

To this point we have examined the role of sustainability criteria in the context of sustainable development, taken them through a practical case study and discussed the strengths and weaknesses of each. From the start of our discussion, however, it was stated that these three sustainability criteria are not meant to replace evaluation techniques such as benefit-cost analysis or environmental assessment. In fact, to consider only the results of the sustainability criteria in a decision making process would be a grave error. For example, the three policy scenarios presented in the case study chapter are not economically neutral, nor are they intended to be. There would be different administrative, monitoring and enforcement costs associated with each one. To exclude a consideration of these costs from the decision making process would be as inappropriate as basing the entire decision on those figures.

Table 5.1 summarizes the results of the three sustainability criteria calculated in the case study chapter. Recall that a lower value for all three criteria is preferred. As we can see, none of the policy scenarios is uniformly preferred by all the criteria. This is expected because there are benefit and cost tradeoffs associated with each of the scenarios. After consideration of all the criteria, the decision is left up to the resource manager. An individual's different value systems would likely lead to different resource decisions.

Table 5.1 Summary of results of the application of the three sustainability criteria to the ADA region case study.

Criteria	Status Quo	Development	Conservation
Reversibility			
environmental	0.30	0.32	0.27
economic	0.05	0.00	0.13
social	0.32	0.39	0.25
Risk			
government managers	0.40	0.36	0.41
irrigators	0.50	0.35	0.55
environmentalists	0.38	0.39	0.37
Equity – intra-generational			
Pine Creek North	0.56	0.60	0.09
Lower Whitemud East	0.15	0.20	0.02
Equity – inter-generational			
Pine Creek North	0.00	0.00	0.25
Lower Whitemud East	0.00	0.00	0.09

For example, an individual who sought to minimize controversy or extreme impacts would likely select the status quo scenario because it is generally ranked in the middle of the three policy scenarios on all aspects of the criteria. However, the sustainability criteria have identified some problems with the status quo scenario. The results of the risk criterion indicate that on average the development scenario is perceived to be less risky than the status quo scenario while the conservation scenario seems to offer improved equitability. Of course, a decision maker would have to have access to the results of other aspects of the multiple criteria decision making model outlined by Simonovic et al. (1997). The scope of this study, however, did not include a benefit cost analysis, consideration of financial implications or an environmental assessment of the three policy scenarios. The researcher is confident, however, that the sustainability criteria analysis conducted in this study has added a valuable dimension to a multiple criteria decision making model for the region.

Chapter 6: Conclusions and Recommendations

6.0 Conclusions

Sustainable development as a development ideal continues to mature a decade after its appearance as a major theme in the Brundtland Commission's final report. Researchers from a variety of disciplines are still examining the theoretical and practical implications of sustainable development and the drive toward sustainability. One of the foremost issues in the sustainable development discussion is the advance of evaluation techniques that incorporate sustainability considerations into the development decision making process. Legislators across Canada are making sustainability issues a priority, and the need for tested, practical measures of sustainability is growing. Traditional evaluation methods such as benefit cost analysis and environmental assessment, although practical and useful, do not provide a complete understanding of the impacts of development.

The four main objectives of this study were listed in Chapter One. The first objective, and part of the second were achieved in Chapter Four. The primary purpose of this study, encompassing objectives two and three, has been to evaluate the practicality of the three sustainability criteria as decision making tools. In order for the three criteria to be considered practical the author feels that it is important that they meet the following standards:

- **Comprehensibility:** The criteria should not be so abstract or intimidating that they are difficult to implement.
- **Flexibility:** Since sustainability must consider environmental, economic and social impacts, the criteria should be able to incorporate qualitative and quantitative data from a variety of sources.

- **Reliability:** The criteria should not produce vastly different results based on slight variations in the input data.
- **Adaptability:** The criteria should be useful under a variety of different conditions.

Each of these standards will be dealt with in turn for all three criteria.

6.0.1 Comprehensibility

In order for the criteria to be considered valuable as decision making tools, they must be practical. The calculations necessary for this study were conducted on standard spreadsheet software and were no more time consuming than calculations for a benefit cost analysis or similar evaluation would be. As Matheson notes, the criteria are "mathematical abstractions of complex social systems and should not be taken as exact representations of those systems". However, the advantage of the criteria is that they provide a testable, replicable index on which to base management decisions.

6.0.2 Flexibility

As we have seen throughout our discussion thus far, sustainability considerations encompass a wide variety of disciplines and impacts. Any metric which purports to evaluate sustainability should recognize that important impacts and concerns may be measurable only in qualitative terms. Decision makers often place great emphasis on impacts which are easily testable or quantifiable. This results in many important impacts or sources of information being excluded from consideration. One of the greatest strengths of the three sustainability criteria is their ability to incorporate a variety of both quantitative and qualitative data.

6.0.3 Reliability

Another important consideration when judging the three sustainability criteria is their reliability. While the inclusion of qualitative data is considered a strength, it brings with it the concern that subjective inputs will have great impact on the outcome of the analysis. If minor changes in some of the qualitative data inputs cause wide variation in the results, then the criteria would not be very useful or viable. The reversibility criterion suggests a sensitivity analysis to determine the impact of such changes on the results of the analysis. This provides a comprehensive way of evaluating the impact of subjective values on the analysis. As we saw in the case study, some aspects of the reversibility criterion were sensitive to changes in the qualitative inputs. The results of the sensitivity analysis should help the decision maker to decide how much weight to assign this aspect of the analysis.

6.0.4 Adaptability

Finally, as has been mentioned throughout this report, sustainability considerations impact every discipline and jurisdiction. In order for a set of criteria to be useful they must anticipate the variety of settings in which they might be used. The authors of the three original theses certainly anticipated the variety of impacts, interest groups and time frames that might be considered. The criteria are well designed in that they can accommodate as many impacts and settings as necessary. Although the criteria were originally designed as project evaluation tools, it has been shown through this study that they are also useful in evaluating policy options. Care must still be taken in the setting of study parameters and in determining the relationship between the policy options and actual changes in the environmental, economic or social condition.

As noted throughout the study, the criteria are not meant to stand alone as decision making tools. The author feels that the sustainability criteria can add a valuable dimension to the multiple criteria decision making process. Although a complete multiple criteria analysis was beyond the scope of this study, the author believes that the sustainability issues brought to light in this research can make a valuable contribution to the design and implementation of groundwater management and policy in the Assiniboine Delta Aquifer (ADA) region.

6.1 Recommendations

This study examined the practicality of implementing the sustainability criteria proposed by Simonovic et al as policy evaluation tools. To this end, the case study of groundwater use in the ADA was examined. The final two objectives of this study were to make recommendations concerning both the criteria themselves, and the future management of the ADA.

6.1.1 Recommendations for improving the sustainability criteria

The first set of recommendations concerns improvements to the sustainability criteria themselves. Some of these recommendations are extensions of those proposed in the work of Fanai (1996), Matheson (1997) and Kroeger (1997):

1. Development of a method to incorporate significant impact thresholds into the reversibility criteria, instead of relying on a straight measure of distance from the ideal impact value.

2. A better method for eliciting the sustainable development category weights for the risk criteria should be developed. The tool used in this study was somewhat obtuse.

3. Further development of the proportionality and need based aspects of the equity criteria.

4. Further research into the issue of expert opinions and input in sustainability and environmental assessment.

6.1.2 Recommendations for future management of the ADA

The final objective of this study was to provide insight into the sustainability of water use from the ADA. The following recommendations concern future management and research directions within the ADA region:

1. Further investigation by WRB into the possibility of a tradeable water entitlement system for the ADA and review of the existing Manitoba Water Rights Act.
2. Continued consultation and involvement of residents from a variety of stakeholder groups in the region.
3. Serious consideration of including the sustainability criteria discussed in this work in the evaluation of future management and policy decisions concerning the ADA.

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APPENDIX A: REVERSIBILITY SENSITIVITY AND REGRESSION ANALYSES

Note:

The regression analysis presented in this appendix was performed comparing stream and water table data with precipitation data for the Carberry region. The purpose of the analysis was to determine if there was a significant relationship between the amount of precipitation and the water table and stream levels for a given period. The analysis was crude and there were holes in the precipitation data. The information presented in this appendix is the raw data used in the analysis with the water table and stream levels presented in metres and the precipitation presented in centimetres for each given time period. The summary outputs of the regression analysis are listed after the raw data. No relationship was found between precipitation and the stream and water table levels.

Carberry4	Carberry 5	ADA 12	ADA 21	Epinnette	Precip
381.84	373.1				50.03333
382.06	373.26				69.1
381.9	373.17				57.4
381.82	373.02				19.23333
382.01	373.16				69.1
381.87	373.04				19.96667
381.73	372.85				32.7
381.73	372.89				61.1
381.58	372.83				56.76667
381.56	372.66				57.6
381.95	373.07				40.46667
381.82	372.97				10.06667
381.61	372.83				56.4
381.78	373.05				76.73333
381.76	373.1				33.36667
381.75	373.06				30.6
382.03	373.41				74.93333
381.88	373.2				1.3
381.63	372.94				49
381.68	373.05				87.36667
381.77	372.96				36.86667
381.75	372.86				57.2
381.87	373.08				55
381.77	372.92				24.16667
381.66	372.71				47.03333
381.95	373.03				29.53333
381.81	373.07				20.43333
381.64	372.88				9.4
381.59	372.82				89.56667
381.52	372.76				29.3
381.47	372.64				12.6
381.43	372.64				99.36667
381.37	372.56				35.13333
381.33	372.49	371.09	359.08		29.83333
381.42	372.56	371.43	359029		98.96667
381.43	372.36	371.17	359.16		22.53333
381.7	372.61	371.52	359.35		50.9
381.58	372.36	371.19	359.19		40.03333
381.41	372.26	371.06	359.19		52
381.51	372.35	371.28	359.37		66.06667
381.34	372.2	371.03	359.29		54.63333
381.27	372.35	371.04	359.35	1.3	23.2
381.38	372.29	371.26	359.61	1.32	77.3
381.47	372.36	371.37	359.54	1.29	48.4
381.53	372.52	371.52	359.84	1.31	59.43333
381.85	372.95	372.01	360.33	1.26	80.4
381.92	372.91	371.77	359.7	1.35	34.86667
380.96	371.98	370.77	359.22	1.29	16.8
380.88	371.98	370.62	359.21	1.12	52.33333
381.04	372.19	370.98	359.55	1.41	90.85

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.05564033
R Square	0.00309585
Adjusted R Square	-0.01324685
Standard Error	0.34621926
Observations	63

ANOVA

	df	SS	MS	F	Sig. F
Regression	1	0.022706919	0.023	0.18943	0.664925022
Residual	61	7.311934351	0.12		
Total	62	7.33464127			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	pper 95%
Intercept	381.552417	0.101145331	3772	2E-165	381.3501641	381.7547
X Variable 1	-0.00082263	0.001890069	-0.44	0.66493	-0.004602059	0.002957

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.04255942
R Square	0.0018113
Adjusted R Square	-0.01455245
Standard Error	0.43532905
Observations	63

ANOVA

	df	SS	MS	F	Significance F
Regression	1	0.020977022	0.021	0.11069	0.740500605
Residual	61	11.56019441	0.19		
Total	62	11.58117143			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	pper 95%
Intercept	372.66008	0.127178081	2930	1E-158	372.4057718	372.9144
X Variable 1	-0.00079068	0.002376534	-0.33	0.7405	-0.00554285	0.003961

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.28739534
R Square	0.08259608
Adjusted R Square	0.04983166
Standard Error	0.2878003
Observations	30

Weight Set 1

Impact Name	Units	Mci	mci	SQ	DE	CO		Wci	Nci SQ	DE	CO		
Woodlot Clearing	Acres/yr	0	2818.2	2562	2818.2	2305.8		0.76	0.630386	0.762768	0.510613		
Water Quality	Scale	10	0	7	7	7		0.91	0.081971	0.081971	0.081971		
Riparian Water Needs	Scale	10	0	6	6	6		0.11	0.018087	0.018087	0.018087	Tcmin	0
Erosion	Scale	10	0	7	6	8		0.39	0.035105	0.062409	0.015602	Tcmax	2.18
							Rc1		0.765549	0.925235	0.626273		
							Scaled		0.351709	0.425071	0.287722		
Irrigated Crop Production	cwt/acre	1746508	0	1587735	1746508	1270188		0.95	0.00785	0	0.070647		
Livestock Population	# anl.	344451	0	328049	344451	321488		0.35	0.00079	0	0.001549	Tcmin	0
Direct Employment-process.	# emp.	451	0	410	451	369		0.67	0.005561	0	0.022243	Tcmax	1.97
							Rc2		0.014201	0	0.094439		
							Scaled		0.007204	0	0.047909		
Water availability - domestic	Scale	10	0	7	6	8		0.2	0.018284	0.032505	0.008126	Tcmin	0
Landscape aesthetics	Scale	10	0	7	7	7		0.4	0.035736	0.035736	0.035736	Tcmax	0.6
							Rc3		0.05402	0.06824	0.043862		
							Scaled		0.09	0.113693	0.073077		

Weight Set 2

Impact Name	Units	Mci	mci	SQ	DE	CO		Wci	Nci SQ	DE	CO		
Woodlot Clearing	Acres/yr	0	2818.2	2562	2818.2	2305.8		0.08	0.062315	0.075401	0.050475		
Water Quality	Scale	10	0	7	7	7		0.35	0.031632	0.031632	0.031632		
Riparian Water Needs	Scale	10	0	6	6	6		0.98	0.156329	0.156329	0.156329	Tcmin	0
Erosion	Scale	10	0	7	6	8		0.86	0.077033	0.136947	0.034237	Tcmax	2.26
							Rc1		0.327308	0.400308	0.272672		
							Scaled		0.144837	0.17714	0.12066		
Irrigated Crop Production	cwt/acre	1746508	0	1587735	1746508	1270188		0.19	0.001564	0	0.01408		
Livestock Population	# ani.	344451	0	328049	344451	321486		0.28	0.000644	0	0.001262	Tcmin	0
Direct Employment-process.	# emp.	451	0	410	451	369		0.02	0.000195	0	0.000781	Tcmax	0.5
							Rc2		0.002404	0	0.016123		
							Scaled		0.004837	0	0.032448		
Water availability - domestic	Scale	10	0	7	6	8		0.18	0.016635	0.029574	0.007394	Tcmin	0
Landscape aesthetics	Scale	10	0	7	7	7		0.51	0.045736	0.045736	0.045736	Tcmax	0.69
							Rc3		0.062372	0.075311	0.05313		
							Scaled		0.09	0.10867	0.076664		

Weight Set 3

Impact Name	Units	Mci	mci	SQ	DE	CO		Wci	Nci SQ	DE	CO		
Woodlot Clearing	Acres/yr	0	2818.2	2562	2818.2	2305.8		0.85	0.702587	0.850131	0.569096		
Water Quality	Scale	10	0	7	7	7		0.72	0.064955	0.064955	0.064955		
Riparian Water Needs	Scale	10	0	6	6	6		0.21	0.034261	0.034261	0.034261	Tcmin	0
Erosion	Scale	10	0	7	6	8		0.22	0.019386	0.034465	0.008616	Tcmax	2
							Rc1		0.82119	0.983812	0.676928		
							Scaled		0.41031	0.491565	0.338229		
Irrigated Crop Production	cwt/acre	1746508	0	1587735	1746508	1270188		0.7	0.005822	0	0.052395		
Livestock Population	# ani.	344451	0	328049	344451	321488		0.32	0.000728	0	0.001428	Tcmin	0
Direct Employment-process.	# emp.	451	0	410	451	369		0	1.86E-05	0	7.44E-05	Tcmax	1.03
							Rc2		0.006569	0	0.053897		
							Scaled		0.00639	0	0.052434		
Water availability - domestic	Scale	10	0	7	6	8		0.3	0.027254	0.048452	0.012113	Tcmin	0
Landscape aesthetics	Scale	10	0	7	7	7		0.24	0.021303	0.021303	0.021303	Tcmax	0.54
							Rc3		0.048557	0.069755	0.033416		
							Scaled		0.09	0.129289	0.061936		

Weight Set 4

Impact Name	Units	Mci	mci	SQ	DE	CO		Wci	Nci SQ	DE	CO		
Woodlot Clearing	Acres/yr	0	2818.2	2562	2818.2	2305.8		0.14	0.114061	0.138014	0.092389		
Water Quality	Scale	10	0	7	7	7		0.34	0.03099	0.03099	0.03099		
Riparian Water Needs	Scale	10	0	6	6	6		0.91	0.145199	0.145199	0.145199	Tcmin	0
Erosion	Scale	10	0	7	6	8		0.71	0.063628	0.113116	0.028279	Tcmax	2.1
							Rc1		0.353877	0.427318	0.296857		
							Scaled		0.168769	0.203794	0.141575		
Irrigated Crop Production	cwt/acre	1746508	0	1587735	1746508	1270188		0.4	0.003282	0	0.029541		
Livestock Population	# ani.	344451	0	328049	344451	321488		0.79	0.001785	0	0.003499	Tcmin	0
Direct Employment-process.	# emp.	451	0	410	451	369		0.83	0.0069	0	0.027599	Tcmax	2.02
							Rc2		0.011967	0	0.060639		
							Scaled		0.005926	0	0.03003		
Water availability - domestic	Scale	10	0	7	6	8		0.33	0.029489	0.052424	0.013106	Tcmin	0
Landscape aesthetics	Scale	10	0	7	7	7		0.08	0.007028	0.007028	0.007028	Tcmax	0.41
							Rc3		0.036517	0.059452	0.020134		
							Scaled		0.09	0.146528	0.049623		

Weight Set 5

Impact Name	Units	Mci	mci	SQ	DE	CO		Wci	Nci SQ	DE	CO		
Woodlot Clearing	Acres/yr	0	2818.2	2562	2818.2	2305.8		0.25	0.208933	0.252809	0.169236		
Water Quality	Scale	10	0	7	7	7		0.64	0.057821	0.057821	0.057821		
Riparian Water Needs	Scale	10	0	6	6	6		0.8	0.127671	0.127671	0.127671	Tcmin	0
Erosion	Scale	10	0	7	6	8		0.8	0.071985	0.127973	0.031993	Tcmax	2.49
							Rc1		0.46641	0.566274	0.386721		
							Scaled		0.187085	0.227142	0.15512		
Irrigated Crop Production	cwt/acre	1746508	0	1587735	1746508	1270188		0.34	0.002838	0	0.025542		
Livestock Population	# ani.	344451	0	328049	344451	321488		0.73	0.001661	0	0.003255	Tcmin	0
Direct Employment-process.	# emp.	451	0	410	451	369		0.39	0.00323	0	0.01292	Tcmax	1.47
							Rc2		0.007729	0	0.041718		
							Scaled		0.00527	0	0.028444		
Water availability - domestic	Scale	10	0	7	6	8		0.69	0.062231	0.110634	0.027658	Tcmin	0
Landscape aesthetics	Scale	10	0	7	7	7		0.05	0.004372	0.004372	0.004372	Tcmax	0.74
							Rc3		0.066603	0.115005	0.03203		
							Scaled		0.09	0.155405	0.043282		

Weight Set 6

Impact Name	Units	Mci	mci	SQ	DE	CO		Wci	Nci SQ	DE	CO		
Woodlot Clearing	Acres/yr	0	2818.2	2562	2818.2	2305.8		0.62	0.511044	0.618363	0.413946		
Water Quality	Scale	10	0	7	7	7		0.05	0.004776	0.004776	0.004776		
Riparian Water Needs	Scale	10	0	6	6	6		0.38	0.060452	0.060452	0.060452	Tcmin	0
Erosion	Scale	10	0	7	6	8		0.84	0.075387	0.134021	0.033505	Tcmax	1.89
							Rc1		0.651659	0.817613	0.512679		
							Scaled		0.345362	0.433313	0.271706		
Irrigated Crop Production	cwt/acre	1746508	0	1587735	1746508	1270188		0.61	0.005032	0	0.04529		
Livestock Population	# ani.	344451	0	328049	344451	321488		0.18	0.000406	0	0.000795	Tcmin	0
Direct Employment-process.	# emp.	451	0	410	451	369		1	0.008246	0	0.032985	Tcmax	1.79
							Rc2		0.013684	0	0.07907		
							Scaled		0.007663	0	0.04428		
Water availability - domestic	Scale	10	0	7	6	8		0.51	0.04634	0.082383	0.020596	Tcmin	0
Landscape aesthetics	Scale	10	0	7	7	7		0.96	0.086595	0.086595	0.086595	Tcmax	1.48
							Rc3		0.132935	0.168977	0.10719		
							Scaled		0.09	0.114402	0.07257		

Weight Set 7

Impact Name	Units	Mci	mci	SQ	DE	CO		Wci	Nci SQ	DE	CO		
Woodlot Clearing	Acres/yr	0	2818.2	2562	2818.2	2305.8		0.63	0.521492	0.631006	0.422409		
Water Quality	Scale	10	0	7	7	7		0.16	0.013986	0.013986	0.013986		
Riparian Water Needs	Scale	10	0	6	6	6		0.41	0.06554	0.06554	0.06554	Tcmin	0
Erosion	Scale	10	0	7	6	8		0.15	0.013112	0.02331	0.005828	Tcmax	1.34
							Rc1		0.614131	0.733842	0.507763		
							Scaled		0.457718	0.546941	0.378441		
Irrigated Crop Production	cwt/acre	1746508	0	1587735	1746508	1270188		0.02	0.000178	0	0.001606		
Livestock Population	# ani.	344451	0	328049	344451	321488		0.33	0.000743	0	0.001456	Tcmin	0
Direct Employment-process.	# emp.	451	0	410	451	369		0.73	0.006061	0	0.024244	Tcmax	1.08
							Rc2		0.006982	0	0.027306		
							Scaled		0.00645	0	0.025225		
Water availability - domestic	Scale	10	0	7	6	8		0.8	0.07185	0.127734	0.031933	Tcmin	0
Landscape aesthetics	Scale	10	0	7	7	7		0.66	0.059818	0.059818	0.059818	Tcmax	1.46
							Rc3		0.131668	0.187551	0.091751		
							Scaled		0.09	0.128199	0.062715		

Weight Set 8

Impact Name	Units	Mci	mci	SQ	DE	CO		Wci	Nci SQ	DE	CO		
Woodlot Clearing	Acres/yr	0	2818.2	2562	2818.2	2305.8		0.67	0.55734	0.674382	0.451446		
Water Quality	Scale	10	0	7	7	7		0.32	0.028737	0.028737	0.028737		
Riparian Water Needs	Scale	10	0	6	6	6		0.04	0.006417	0.006417	0.006417	Tcmin	0
Erosion	Scale	10	0	7	6	8		0.11	0.0099	0.017599	0.0044	Tcmax	1.14
							Rc1		0.602394	0.727135	0.491		
							Scaled		0.526668	0.635728	0.429277		
Irrigated Crop Production	cwt/acre	1746508	0	1587735	1746508	1270188		0.48	0.003975	0	0.035773		
Livestock Population	# ani.	344451	0	328049	344451	321488		0.54	0.00123	0	0.002411	Tcmin.	0
Direct Employment-process.	# emp.	451	0	410	451	369		0.71	0.005856	0	0.023425	Tcmax	1.73
							Rc2		0.011061	0	0.061609		
							Scaled		0.006386	0	0.035569		
Water availability - domestic	Scale	10	0	7	6	8		0.37	0.033704	0.059918	0.01498	Tcmin	0
Landscape aesthetics	Scale	10	0	7	7	7		0.05	0.004806	0.004806	0.004806	Tcmax	0.43
							Rc3		0.03851	0.064724	0.019786		
							Scaled		0.09	0.151264	0.04624		

Weight Set 9

Impact Name	Units	Mci	mci	SQ	DE	CO		Wci	Nci SQ	DE	CO		
Woodlot Clearing	Acres/yr	0	2818.2	2562	2818.2	2305.8		0.61	0.508023	0.614708	0.411499		
Water Quality	Scale	10	0	7	7	7		0.32	0.028369	0.028369	0.028369		
Riparian Water Needs	Scale	10	0	6	6	6		0.88	0.140919	0.140919	0.140919	Tcmin	0
Erosion	Scale	10	0	7	6	8		0.98	0.088406	0.157166	0.039292	Tcmax	2.79
							Rc1		0.765717	0.941162	0.620078		
							Scaled		0.274161	0.336978	0.222016		
Irrigated Crop Production	cwt/acre	1746508	0	1587735	1746508	1270188		0.28	0.002303	0	0.020729		
Livestock Population	# ani.	344451	0	328049	344451	321488		0.24	0.000537	0	0.001052	Tcmin	0
Direct Employment-process.	# emp.	451	0	410	451	369		0.77	0.006335	0	0.025342	Tcmax	1.28
							Rc2		0.009176	0	0.047123		
							Scaled		0.007157	0	0.036755		
Water availability - domestic	Scale	10	0	7	6	8		0.89	0.080116	0.142428	0.035607	Tcmin	0
Landscape aesthetics	Scale	10	0	7	7	7		0.63	0.056958	0.056958	0.056958	Tcmax	1.52
							Rc3		0.137074	0.199386	0.092565		
							Scaled		0.09	0.130913	0.060776		

Weight Set 10

Impact Name	Units	Mci	mci	SQ	DE	CO		Wci	Nci SQ	DE	CO		
Woodlot Clearing	Acres/yr	0	2818.2	2562	2818.2	2305.8		0.14	0.112449	0.136063	0.091083		
Water Quality	Scale	10	0	7	7	7		0.26	0.02352	0.02352	0.02352		
Riparian Water Needs	Scale	10	0	6	6	6		0.81	0.129972	0.129972	0.129972	Tcmin	0
Erosion	Scale	10	0	7	6	8		0.05	0.004459	0.007926	0.001982	Tcmax	1.26
							Rc1		0.2704	0.297482	0.246557		
							Scaled		0.214728	0.236234	0.195795		
Irrigated Crop Production	cwt/acre	1746508	0	1587735	1746508	1270188		0.74	0.006112	0	0.055007		
Livestock Population	# ani.	344451	0	328049	344451	321488		0.26	0.000584	0	0.001144	Tcmin	0
Direct Employment-process.	# emp.	451	0	410	451	369		0.82	0.00678	0	0.027119	Tcmax	1.82
							Rc2		0.013475	0	0.08327		
							Scaled		0.007415	0	0.045822		
Water availability - domestic	Scale	10	0	7	6	8		0.95	0.08564	0.152248	0.038062	Tcmin	0
Landscape aesthetics	Scale	10	0	7	7	7		0.39	0.035437	0.035437	0.035437	Tcmax	1.35
							Rc3		0.121076	0.187685	0.073499		
							Scaled		0.09	0.139512	0.054634		

Appendix B: Workshop Materials

NATURAL RESOURCES INSTITUTE

ETHICS APPROVAL FORM

To be completed by applicant:

Title of Study:
Evaluating Sustainability of Groundwater Resource Use in the Assiniboine Delta Aquifer Region.

Name of Principal Investigator(s) (please print):

Andrew McLaren

Name of Practicum Advisor or Course Instructor (if Principal Investigator is a student) (please print):

Dr. Slobodan Simonovic

I/We, the undersigned, agree to abide by the University of Manitoba's ethical standards and guidelines for research involving human subjects, and agree to carry out the study named above as described in the Ethics Review Application.

Signature of Practicum Advisor or Course Instructor (if required)

Signature(s) of Principal Investigator(s)

To be completed by the Research and Ethics Committee:

This is to certify that the Natural Resources Institute Research and Ethics Committee has reviewed the proposed study named above and has concluded that it conforms with the University of Manitoba's ethical standards and guidelines for research involving human subjects.

John Sinclair

Name of Research and Ethics Committee Chairperson

Date Apr 28/97

Signature of Research and Ethics Committee Chairperson

April 28, 1998

Dear STAKEHOLDER,

I am writing this letter to invite you to a workshop entitled "**Risk Perceptions and Management of the Assiniboine Delta Aquifer**" to be held on **Wednesday, June 10 1998 at 9:00 a.m.** in the Manitoba Crop Diversification Center classroom. The purpose of the workshop is to give stakeholders the opportunity to express their opinions and understandings of different risks associated with managing the aquifer. The study is made possible through a grant from the Prairie Farm Rehabilitation Administration.

Through the course of the workshop you will be asked to consider the environmental, economic and social risks associated with different management strategies for the aquifer. You will have the opportunity to express your opinions and ideas both in open group discussions and on individual forms. The workshop should run for approximately 90 minutes.

You are free to withdraw from any part of the workshop or leave at any time. The information obtained through the workshop will be incorporated into the practicum report for the researcher's Masters degree. Your individual responses and personal information will be kept private. At the conclusion of the workshop there will be a form available for you to request a copy of the results of the study.

If you have any questions regarding this research you can contact me at 204-255-7085 or one of these individuals:

Dr. Slobodan Simonivic
Director and Professor
Natural Resources Institute
University of Manitoba
204-474-8375

Dr. John Sinclair
Chairperson
Research and Ethics Committee
Natural Resources Institute
University of Manitoba
204-474-8374

Your ideas and opinions would be very helpful to me. I hope you can find the time in your schedule to attend the workshop. Once again, feel free to phone me if you have any questions or concerns.

Sincerely,

Andrew McLaren
Candidate, Masters of Natural Resource Management
Natural Resources Institute
University of Manitoba

Workshop Outline

1.0 Introduction (approximately 10 minutes)

- Brief profile of the investigator.
- Study description, research objectives, and purpose of study.
- Ethics discussion, statement that participation is voluntary and individuals may withdraw their participation at any time.
- Outline of workshop format.

2.0 Sustainable Development Discussion (approximately 20 minutes)

- Brundtland Commission definition
- Challenges and Questions about SD
- Introduction of Study Role
- Discussion

3.0 Discussion of Risk (approximately 30 minutes)

- Definition and meanings of Risk
- Importance of public perception
- Discussion

4.0 General Discussion and Concluding Remarks (approximately 30 minutes)

- Opportunity for feedback and re-evaluation of answers if necessary
- General discussion: important issues not covered?
- Administer questionnaires.
- Additional comments or concerns
- Appreciation for participating, mention that copies of the results of thesessions will be made available to anyone who requests one.

Risk Perception Workshop

Data Sheet #1

For this section of the study, it is important to understand how much emphasis different people put on the three aspects of sustainable development: economic, social and environmental. Please consider how important these three components are to you personally and assign each aspect a weight so that the three weights together total 100. For example, if you felt that the economic segment was more important, you might give it a weight of 50 and environmental and social each a weight of 25.

Economic ____________ **Environmental** _____________ **Social** __________

Risk Perception Workshop

Section 1

This section contains a set of positive impacts that may result from implementing different policy or management options. For each impact, please indicate how important it is to you to try to achieve this benefit on a scale from 0 to 10 with 0 being not at all important and 10 being achieve at all costs.

Impact #1: **Increased Agricultural Revenue** which may result from improved crop quality due to irrigation or increases in livestock numbers or crop acreage.

0 1 2 3 4 5 6 7 8 9 10

Not Important	Somewhat Important	Moderately Important	Very Important	Achieve at All Costs

Impact #2: **Increased Employment** either directly, in the form of increased farm or processing jobs or indirectly in the form of transportation, service industries or other sectors.

0 1 2 3 4 5 6 7 8 9 10

Not Important	Somewhat Important	Moderately Important	Very Important	Achieve at All Costs

Impact #3: **Increased Recreation Opportunity or Quality** as a result of more leisure time and disposable income.

0 1 2 3 4 5 6 7 8 9 10

Not Important	Somewhat Important	Moderately Important	Very Important	Achieve at All Costs

Section 2

This section contains a set of negative impacts which may result from implementing different policy or management options. Please indicate how important it is to you to avoid each risk on a scale from 0 to 10 with 0 being not at all important and 10 being avoid at all costs.

Impact #1: **Loss of Wildlife Habitat** related to woodlot clearing for development purposes (municipal, agricultural, infrastructure or other reasons).

0	1	2	3	4	5	6	7	8	9	10
Not Important		Somewhat Important			Moderately Important		Very Important		Avoid at All Costs	

Impact #2: **Increased Erosion** associated with increasing development.

0	1	2	3	4	5	6	7	8	9	10
Not Important		Somewhat Important			Moderately Important		Very Important		Avoid at All Costs	

Impact #3: **Point Source Water Pollution** as a result of fuel, industrial or agricultural chemical spills.

0	1	2	3	4	5	6	7	8	9	10
Not Important		Somewhat Important			Moderately Important		Very Important		Avoid at All Costs	

Impact #4: **Increased Stream Flow Variability** associated with increased use of groundwater reserves.

0	1	2	3	4	5	6	7	8	9	10
Not Important		Somewhat Important			Moderately Important		Very Important		Avoid at All Costs	

Impact #5: **Infrastructure Costs** as a result of increased traffic and development.

0	1	2	3	4	5	6	7	8	9	10

Not Important — Somewhat Important — Moderately Important — Very Important — Avoid at All Costs

Impact #6: **Aesthetic Changes** to the landscape associated with woodlot clearing, erosion or other development related factors.

0	1	2	3	4	5	6	7	8	9	10

Not Important — Somewhat Important — Moderately Important — Very Important — Avoid at All Costs

Appendix C: Sample Equity Calculation Matrix

User #	Allocation	1-n	2-n	3-n	4-n	5-n	6-n	7-n	8-n	9-n
1	150.0	0.0	65.0	50.0	0.0	75.0	75.0	10.0	10.0	10.0
2	85.0	65.0	0.0	15.0	65.0	10.0	10.0	75.0	75.0	75.0
3	100.0	50.0	15.0	0.0	50.0	25.0	25.0	60.0	60.0	60.0
4	150.0	0.0	65.0	50.0	0.0	75.0	75.0	10.0	10.0	10.0
5	75.0	75.0	10.0	25.0	75.0	0.0	0.0	85.0	85.0	85.0
6	75.0	75.0	10.0	25.0	75.0	0.0	0.0	85.0	85.0	85.0
7	160.0	10.0	75.0	60.0	10.0	85.0	85.0	0.0	0.0	0.0
8	160.0	10.0	75.0	60.0	10.0	85.0	85.0	0.0	0.0	0.0
9	160.0	10.0	75.0	60.0	10.0	85.0	85.0	0.0	0.0	0.0
10	160.0	10.0	75.0	60.0	10.0	85.0	85.0	0.0	0.0	0.0
11	160.0	10.0	75.0	60.0	10.0	85.0	85.0	0.0	0.0	0.0
12	80.0	70.0	5.0	20.0	70.0	5.0	5.0	80.0	80.0	80.0
13	80.0	70.0	5.0	20.0	70.0	5.0	5.0	80.0	80.0	80.0
14	150.0	0.0	65.0	50.0	0.0	75.0	75.0	10.0	10.0	10.0
15	140.0	10.0	55.0	40.0	10.0	65.0	65.0	20.0	20.0	20.0
16	100.0	50.0	15.0	0.0	50.0	25.0	25.0	60.0	60.0	60.0
17	125.0	25.0	40.0	25.0	25.0	50.0	50.0	35.0	35.0	35.0
18	135.0	15.0	50.0	35.0	15.0	60.0	60.0	25.0	25.0	25.0
19	120.0	30.0	35.0	20.0	30.0	45.0	45.0	40.0	40.0	40.0
20	160.0	10.0	75.0	60.0	10.0	85.0	85.0	0.0	0.0	0.0
21	160.0	10.0	75.0	60.0	10.0	85.0	85.0	0.0	0.0	0.0
22	65.0	85.0	20.0	35.0	85.0	10.0	10.0	95.0	95.0	95.0
23	160.0	10.0	75.0	60.0	10.0	85.0	85.0	0.0	0.0	0.0
24	111.0	39.0	26.0	11.0	39.0	36.0	36.0	49.0	49.0	49.0
25	100.0	50.0	15.0	0.0	50.0	25.0	25.0	60.0	60.0	60.0
26	85.0	65.0	0.0	15.0	65.0	10.0	10.0	75.0	75.0	75.0
27	115.0	35.0	30.0	15.0	35.0	40.0	40.0	45.0	45.0	45.0
28	119.0	31.0	34.0	19.0	31.0	44.0	44.0	41.0	41.0	41.0
29	122.0	28.0	37.0	22.0	28.0	47.0	47.0	38.0	38.0	38.0
30	122.0	28.0	37.0	22.0	28.0	47.0	47.0	38.0	38.0	38.0
31	122.0	28.0	37.0	22.0	28.0	47.0	47.0	38.0	38.0	38.0
32	160.0	10.0	75.0	60.0	10.0	85.0	85.0	0.0	0.0	0.0
33	88.0	62.0	3.0	12.0	62.0	13.0	13.0	72.0	72.0	72.0
34	160.0	10.0	75.0	60.0	10.0	85.0	85.0	0.0	0.0	0.0
35	80.0	70.0	5.0	20.0	70.0	5.0	5.0	80.0	80.0	80.0
36	85.0	65.0	0.0	15.0	65.0	10.0	10.0	75.0	75.0	75.0
37	88.0	62.0	3.0	12.0	62.0	13.0	13.0	72.0	72.0	72.0
38	88.0	62.0	3.0	12.0	62.0	13.0	13.0	72.0	72.0	72.0
39	85.0	65.0	0.0	15.0	65.0	10.0	10.0	75.0	75.0	75.0
40	115.0	35.0	30.0	15.0	35.0	40.0	40.0	45.0	45.0	45.0
41	85.0	65.0	0.0	15.0	65.0	10.0	10.0	75.0	75.0	75.0

	43	85.0	65.0	0.0	15.0	65.0	10.0	10.0	75.0	75.0	75.0
	44	85.0	65.0	0.0	15.0	65.0	10.0	10.0	75.0	75.0	75.0
	45	85.0	65.0	0.0	15.0	65.0	10.0	10.0	75.0	75.0	75.0
	46	0.0	150.0	85.0	100.0	150.0	75.0	75.0	160.0	160.0	160.0
	47	0.0	150.0	85.0	100.0	150.0	75.0	75.0	160.0	160.0	160.0
	48	0.0	150.0	85.0	100.0	150.0	75.0	75.0	160.0	160.0	160.0
E-average		107.9 Column Totals	2220.0	1720.0	1612.0	2220.0	2050.0	2050.0	2500.0	2500.0	2500.0

Grand total 103512.0

0.208156371

10-n	11-n	12-n	13-n	14-n	15-n	16-n	17-n	18-n	19-n	20-n	21-n	22-n
10.0	10.0	70.0	70.0	0.0	10.0	50.0	25.0	15.0	30.0	10.0	10.0	85.0
75.0	75.0	5.0	5.0	65.0	55.0	15.0	40.0	50.0	35.0	75.0	75.0	20.0
60.0	60.0	20.0	20.0	50.0	40.0	0.0	25.0	35.0	20.0	60.0	60.0	35.0
10.0	10.0	70.0	70.0	0.0	10.0	50.0	25.0	15.0	30.0	10.0	10.0	85.0
85.0	85.0	5.0	5.0	75.0	65.0	25.0	50.0	60.0	45.0	85.0	85.0	10.0
85.0	85.0	5.0	5.0	75.0	65.0	25.0	50.0	60.0	45.0	85.0	85.0	10.0
0.0	0.0	80.0	80.0	10.0	20.0	60.0	35.0	25.0	40.0	0.0	0.0	95.0
0.0	0.0	80.0	80.0	10.0	20.0	60.0	35.0	25.0	40.0	0.0	0.0	95.0
0.0	0.0	80.0	80.0	10.0	20.0	60.0	35.0	25.0	40.0	0.0	0.0	95.0
0.0	0.0	80.0	80.0	10.0	20.0	60.0	35.0	25.0	40.0	0.0	0.0	95.0
0.0	0.0	80.0	80.0	10.0	20.0	60.0	35.0	25.0	40.0	0.0	0.0	95.0
80.0	80.0	0.0	0.0	70.0	60.0	20.0	45.0	55.0	40.0	80.0	80.0	15.0
80.0	80.0	0.0	0.0	70.0	60.0	20.0	45.0	55.0	40.0	80.0	80.0	15.0
10.0	10.0	70.0	70.0	0.0	10.0	50.0	25.0	15.0	30.0	10.0	10.0	85.0
20.0	20.0	60.0	60.0	10.0	0.0	40.0	15.0	5.0	20.0	20.0	20.0	75.0
60.0	60.0	20.0	20.0	50.0	40.0	0.0	25.0	35.0	20.0	60.0	60.0	35.0
35.0	35.0	45.0	45.0	25.0	15.0	25.0	0.0	10.0	5.0	35.0	35.0	60.0
25.0	25.0	55.0	55.0	15.0	5.0	35.0	10.0	0.0	15.0	25.0	25.0	70.0
40.0	40.0	40.0	40.0	30.0	20.0	20.0	5.0	15.0	0.0	40.0	40.0	55.0
0.0	0.0	80.0	80.0	10.0	20.0	60.0	35.0	25.0	40.0	0.0	0.0	95.0
0.0	0.0	80.0	80.0	10.0	20.0	60.0	35.0	25.0	40.0	0.0	0.0	95.0
95.0	95.0	15.0	15.0	85.0	75.0	35.0	60.0	70.0	55.0	95.0	95.0	0.0
0.0	0.0	80.0	80.0	10.0	20.0	60.0	35.0	25.0	40.0	0.0	0.0	95.0
49.0	49.0	31.0	31.0	39.0	29.0	11.0	14.0	24.0	9.0	49.0	49.0	46.0
60.0	60.0	20.0	20.0	50.0	40.0	0.0	25.0	35.0	20.0	60.0	60.0	35.0
75.0	75.0	5.0	5.0	65.0	55.0	15.0	40.0	50.0	35.0	75.0	75.0	20.0
45.0	45.0	35.0	35.0	35.0	25.0	15.0	10.0	20.0	5.0	45.0	45.0	50.0
41.0	41.0	39.0	39.0	31.0	21.0	19.0	6.0	16.0	1.0	41.0	41.0	54.0
38.0	38.0	42.0	42.0	28.0	18.0	22.0	3.0	13.0	2.0	38.0	38.0	57.0
38.0	38.0	42.0	42.0	28.0	18.0	22.0	3.0	13.0	2.0	38.0	38.0	57.0
38.0	38.0	42.0	42.0	28.0	18.0	22.0	3.0	13.0	2.0	38.0	38.0	57.0
0.0	0.0	80.0	80.0	10.0	20.0	60.0	35.0	25.0	40.0	0.0	0.0	95.0
72.0	72.0	8.0	8.0	62.0	52.0	12.0	37.0	47.0	32.0	72.0	72.0	23.0
0.0	0.0	80.0	80.0	10.0	20.0	60.0	35.0	25.0	40.0	0.0	0.0	95.0
80.0	80.0	0.0	0.0	70.0	60.0	20.0	45.0	55.0	40.0	80.0	80.0	15.0
75.0	75.0	5.0	5.0	65.0	55.0	15.0	40.0	50.0	35.0	75.0	75.0	20.0
72.0	72.0	8.0	8.0	62.0	52.0	12.0	37.0	47.0	32.0	72.0	72.0	23.0
72.0	72.0	8.0	8.0	62.0	52.0	12.0	37.0	47.0	32.0	72.0	72.0	23.0
75.0	75.0	5.0	5.0	65.0	55.0	15.0	40.0	50.0	35.0	75.0	75.0	20.0
45.0	45.0	35.0	35.0	35.0	25.0	15.0	10.0	20.0	5.0	45.0	45.0	50.0
75.0	75.0	5.0	5.0	65.0	55.0	15.0	40.0	50.0	35.0	75.0	75.0	20.0

75.0	75.0	5.0	5.0	65.0	55.0	15.0	40.0	50.0	35.0	75.0	75.0	20.0
75.0	75.0	5.0	5.0	65.0	55.0	15.0	40.0	50.0	35.0	75.0	75.0	20.0
75.0	75.0	5.0	5.0	65.0	55.0	15.0	40.0	50.0	35.0	75.0	75.0	20.0
160.0	160.0	80.0	80.0	150.0	140.0	100.0	125.0	135.0	120.0	160.0	160.0	65.0
160.0	160.0	80.0	80.0	150.0	140.0	100.0	125.0	135.0	120.0	160.0	160.0	65.0
160.0	160.0	80.0	80.0	150.0	140.0	100.0	125.0	135.0	120.0	160.0	160.0	65.0
2500.0	2500.0	1870.0	1870.0	2220.0	2000.0	1612.0	1720.0	1900.0	1652.0	2500.0	2500.0	2450.0

23-n	24-n	25-n	26-n	27-n	28-n	29-n	30-n	31-n	32-n	33-n	34-n	35-n
10,0	39,0	50,0	65,0	35,0	31,0	28,0	28,0	28,0	10,0	62,0	10,0	70,0
75,0	26,0	15,0	0,0	30,0	34,0	37,0	37,0	37,0	75,0	3,0	75,0	5,0
60,0	11,0	0,0	15,0	15,0	19,0	22,0	22,0	22,0	60,0	12,0	60,0	20,0
10,0	39,0	50,0	65,0	35,0	31,0	28,0	28,0	28,0	10,0	62,0	10,0	70,0
85,0	36,0	25,0	10,0	40,0	44,0	47,0	47,0	47,0	85,0	13,0	85,0	5,0
85,0	36,0	25,0	10,0	40,0	44,0	47,0	47,0	47,0	85,0	13,0	85,0	5,0
0,0	49,0	60,0	75,0	45,0	41,0	38,0	38,0	38,0	0,0	72,0	0,0	80,0
0,0	49,0	60,0	75,0	45,0	41,0	38,0	38,0	38,0	0,0	72,0	0,0	80,0
0,0	49,0	60,0	75,0	45,0	41,0	38,0	38,0	38,0	0,0	72,0	0,0	80,0
0,0	49,0	60,0	75,0	45,0	41,0	38,0	38,0	38,0	0,0	72,0	0,0	80,0
0,0	49,0	60,0	75,0	45,0	41,0	38,0	38,0	38,0	0,0	72,0	0,0	80,0
80,0	31,0	20,0	5,0	35,0	39,0	42,0	42,0	42,0	80,0	8,0	80,0	0,0
80,0	31,0	20,0	5,0	35,0	39,0	42,0	42,0	42,0	80,0	8,0	80,0	0,0
10,0	39,0	50,0	65,0	35,0	31,0	28,0	28,0	28,0	10,0	62,0	10,0	70,0
20,0	29,0	40,0	55,0	25,0	21,0	18,0	18,0	18,0	20,0	52,0	20,0	60,0
60,0	11,0	0,0	15,0	15,0	19,0	22,0	22,0	22,0	60,0	12,0	60,0	20,0
35,0	14,0	25,0	40,0	10,0	6,0	3,0	3,0	3,0	35,0	37,0	35,0	45,0
25,0	24,0	35,0	50,0	20,0	16,0	13,0	13,0	13,0	25,0	47,0	25,0	55,0
40,0	9,0	20,0	35,0	5,0	1,0	2,0	2,0	2,0	40,0	32,0	40,0	40,0
0,0	49,0	60,0	75,0	45,0	41,0	38,0	38,0	38,0	0,0	72,0	0,0	80,0
0,0	49,0	60,0	75,0	45,0	41,0	38,0	38,0	38,0	0,0	72,0	0,0	80,0
95,0	46,0	35,0	20,0	50,0	54,0	57,0	57,0	57,0	95,0	23,0	95,0	15,0
0,0	49,0	60,0	75,0	45,0	41,0	38,0	38,0	38,0	0,0	72,0	0,0	80,0
49,0	0,0	11,0	26,0	4,0	8,0	11,0	11,0	11,0	49,0	23,0	49,0	31,0
60,0	11,0	0,0	15,0	15,0	19,0	22,0	22,0	22,0	60,0	12,0	60,0	20,0
75,0	26,0	15,0	0,0	30,0	34,0	37,0	37,0	37,0	75,0	3,0	75,0	5,0
45,0	4,0	15,0	30,0	0,0	4,0	7,0	7,0	7,0	45,0	27,0	45,0	35,0
41,0	8,0	19,0	34,0	4,0	0,0	3,0	3,0	3,0	41,0	31,0	41,0	39,0
38,0	11,0	22,0	37,0	7,0	3,0	0,0	0,0	0,0	38,0	34,0	38,0	42,0
38,0	11,0	22,0	37,0	7,0	3,0	0,0	0,0	0,0	38,0	34,0	38,0	42,0
38,0	11,0	22,0	37,0	7,0	3,0	0,0	0,0	0,0	38,0	34,0	38,0	42,0
0,0	49,0	60,0	75,0	45,0	41,0	38,0	38,0	38,0	0,0	72,0	0,0	80,0
72,0	23,0	12,0	3,0	27,0	31,0	34,0	34,0	34,0	72,0	0,0	72,0	8,0
0,0	49,0	60,0	75,0	45,0	41,0	38,0	38,0	38,0	0,0	72,0	0,0	80,0
80,0	31,0	20,0	5,0	35,0	39,0	42,0	42,0	42,0	80,0	8,0	80,0	0,0
75,0	26,0	15,0	0,0	30,0	34,0	37,0	37,0	37,0	75,0	3,0	75,0	5,0
72,0	23,0	12,0	3,0	27,0	31,0	34,0	34,0	34,0	72,0	0,0	72,0	8,0
72,0	23,0	12,0	3,0	27,0	31,0	34,0	34,0	34,0	72,0	0,0	72,0	8,0
75,0	26,0	15,0	0,0	30,0	34,0	37,0	37,0	37,0	75,0	3,0	75,0	5,0
45,0	4,0	15,0	30,0	0,0	4,0	7,0	7,0	7,0	45,0	27,0	45,0	35,0
75,0	26,0	15,0	0,0	30,0	34,0	37,0	37,0	37,0	75,0	3,0	75,0	5,0

75.0	26.0	15.0	0.0	30.0	34.0	37.0	37.0	37.0	75.0	3.0	75.0	5.0
75.0	26.0	15.0	0.0	30.0	34.0	37.0	37.0	37.0	75.0	3.0	75.0	5.0
75.0	26.0	15.0	0.0	30.0	34.0	37.0	37.0	37.0	75.0	3.0	75.0	5.0
160.0	111.0	100.0	85.0	115.0	119.0	122.0	122.0	122.0	160.0	88.0	160.0	80.0
160.0	111.0	100.0	85.0	115.0	119.0	122.0	122.0	122.0	160.0	88.0	160.0	80.0
160.0	111.0	100.0	85.0	115.0	119.0	122.0	122.0	122.0	160.0	88.0	160.0	80.0
2500.0	1612.0	1612.0	1720.0	1620.0	1644.0	1672.0	1672.0	1672.0	2500.0	1684.0	2500.0	1870.0

36-n	37-n	38-n	39-n	40-n	41-n	42-n	43-n	44-n	45-n	46-n	47-n	48-n
65,0	62,0	62,0	65,0	35,0	65,0	65,0	65,0	65,0	65,0	150,0	150,0	150,0
0,0	3,0	3,0	0,0	30,0	0,0	0,0	0,0	0,0	0,0	85,0	85,0	85,0
15,0	12,0	12,0	15,0	15,0	15,0	15,0	15,0	15,0	15,0	100,0	100,0	100,0
65,0	62,0	62,0	65,0	35,0	65,0	65,0	65,0	65,0	65,0	150,0	150,0	150,0
10,0	13,0	13,0	10,0	40,0	10,0	10,0	10,0	10,0	10,0	75,0	75,0	75,0
10,0	13,0	13,0	10,0	40,0	10,0	10,0	10,0	10,0	10,0	75,0	75,0	75,0
75,0	72,0	72,0	75,0	45,0	75,0	75,0	75,0	75,0	75,0	160,0	160,0	160,0
75,0	72,0	72,0	75,0	45,0	75,0	75,0	75,0	75,0	75,0	160,0	160,0	160,0
75,0	72,0	72,0	75,0	45,0	75,0	75,0	75,0	75,0	75,0	160,0	160,0	160,0
75,0	72,0	72,0	75,0	45,0	75,0	75,0	75,0	75,0	75,0	160,0	160,0	160,0
75,0	72,0	72,0	75,0	45,0	75,0	75,0	75,0	75,0	75,0	160,0	160,0	160,0
5,0	8,0	8,0	5,0	35,0	5,0	5,0	5,0	5,0	5,0	80,0	80,0	80,0
5,0	8,0	8,0	5,0	35,0	5,0	5,0	5,0	5,0	5,0	80,0	80,0	80,0
65,0	62,0	62,0	65,0	35,0	65,0	65,0	65,0	65,0	65,0	150,0	150,0	150,0
55,0	52,0	52,0	55,0	25,0	55,0	55,0	55,0	55,0	55,0	140,0	140,0	140,0
15,0	12,0	12,0	15,0	15,0	15,0	15,0	15,0	15,0	15,0	100,0	100,0	100,0
40,0	37,0	37,0	40,0	10,0	40,0	40,0	40,0	40,0	40,0	125,0	125,0	125,0
50,0	47,0	47,0	50,0	20,0	50,0	50,0	50,0	50,0	50,0	135,0	135,0	135,0
35,0	32,0	32,0	35,0	5,0	35,0	35,0	35,0	35,0	35,0	120,0	120,0	120,0
75,0	72,0	72,0	75,0	45,0	75,0	75,0	75,0	75,0	75,0	160,0	160,0	160,0
75,0	72,0	72,0	75,0	45,0	75,0	75,0	75,0	75,0	75,0	160,0	160,0	160,0
20,0	23,0	23,0	20,0	50,0	20,0	20,0	20,0	20,0	20,0	65,0	65,0	65,0
75,0	72,0	72,0	75,0	45,0	75,0	75,0	75,0	75,0	75,0	160,0	160,0	160,0
26,0	23,0	23,0	26,0	4,0	26,0	26,0	26,0	26,0	26,0	111,0	111,0	111,0
15,0	12,0	12,0	15,0	15,0	15,0	15,0	15,0	15,0	15,0	100,0	100,0	100,0
0,0	3,0	3,0	0,0	30,0	0,0	0,0	0,0	0,0	0,0	85,0	85,0	85,0
30,0	27,0	27,0	30,0	0,0	30,0	30,0	30,0	30,0	30,0	115,0	115,0	115,0
34,0	31,0	31,0	34,0	4,0	34,0	34,0	34,0	34,0	34,0	119,0	119,0	119,0
37,0	34,0	34,0	37,0	7,0	37,0	37,0	37,0	37,0	37,0	122,0	122,0	122,0
37,0	34,0	34,0	37,0	7,0	37,0	37,0	37,0	37,0	37,0	122,0	122,0	122,0
37,0	34,0	34,0	37,0	7,0	37,0	37,0	37,0	37,0	37,0	122,0	122,0	122,0
75,0	72,0	72,0	75,0	45,0	75,0	75,0	75,0	75,0	75,0	160,0	160,0	160,0
3,0	0,0	0,0	3,0	27,0	3,0	3,0	3,0	3,0	3,0	88,0	88,0	88,0
75,0	72,0	72,0	75,0	45,0	75,0	75,0	75,0	75,0	75,0	160,0	160,0	160,0
5,0	8,0	8,0	5,0	35,0	5,0	5,0	5,0	5,0	5,0	80,0	80,0	80,0
0,0	3,0	3,0	0,0	30,0	0,0	0,0	0,0	0,0	0,0	85,0	85,0	85,0
3,0	0,0	0,0	3,0	27,0	3,0	3,0	3,0	3,0	3,0	88,0	88,0	88,0
3,0	0,0	0,0	3,0	27,0	3,0	3,0	3,0	3,0	3,0	88,0	88,0	88,0
0,0	3,0	3,0	0,0	30,0	0,0	0,0	0,0	0,0	0,0	85,0	85,0	85,0
30,0	27,0	27,0	30,0	0,0	30,0	30,0	30,0	30,0	30,0	115,0	115,0	115,0
0,0	3,0	3,0	0,0	30,0	0,0	0,0	0,0	0,0	0,0	85,0	85,0	85,0
[illegible]	[illegible]	[illegible]										

0.0	3.0	3.0	0.0	30.0	0.0	0.0	0.0	0.0	0.0	85.0	85.0	85.0
0.0	3.0	3.0	0.0	30.0	0.0	0.0	0.0	0.0	0.0	85.0	85.0	85.0
0.0	3.0	3.0	0.0	30.0	0.0	0.0	0.0	0.0	0.0	85.0	85.0	85.0
85.0	88.0	88.0	85.0	115.0	85.0	85.0	85.0	85.0	85.0	0.0	0.0	0.0
85.0	88.0	88.0	85.0	115.0	85.0	85.0	85.0	85.0	85.0	0.0	0.0	0.0
85.0	88.0	88.0	85.0	115.0	85.0	85.0	85.0	85.0	85.0	0.0	0.0	0.0
1720.0	1684.0	1684.0	1720.0	1620.0	1720.0	1720.0	1720.0	1720.0	1720.0	5180.0	5180.0	5180.0