University of Alberta

Valuation of Irrigation Water in Southern Alberta: A Stated Preference Approach

by

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Abstract

The research presented in this thesis focuses on determining the value of irrigation water in southern Alberta. Utilizing a stated preference method, the research represents a successful attempt at applying contingent behavior scenarios to estimate irrigation water supply and demand, and thus irrigators' willingness to pay/accept (WTP/WTA) for water through a hypothetical water market during droughts. The research also aims to assess the effectiveness of water markets in conserving water and promoting water productivity and efficiency. The findings reveal that irrigators' WTP during droughts is within the range of \$1.22-4.90/acre-inch (\$0.012-\$0.048/m^3), varying over various levels of water scarcity. It is found that the presence of water markets plays a crucial role in water reallocation and improves water productivity and efficiency, the extent of which depends on how active are water markets.

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List of Abbreviations

Abbreviation	*Definition*
AAFRD	Alberta Agriculture, Food and Rural Development
AENV	Alberta Environment
AID	Aetna Irrigation District
BLUE	Best Linear Unbiased Estimator
CAIS	The Canadian Agricultural Income Stabilization program
CB	Contingent Behaviour
CVM	Contingent Valuation Method
DC	Dichotomous Choice approach
EID	Eastern Irrigation District
IWE	Initial Water Endowment
LID	Leavitt Irrigation District
LM	Lagrange Multiplier
LNID	Lethbridge Northern Irrigation District
MID	Magrath Irrigation District
ML	Maximum Likelihood
MNL	Multinomial Logit model
MVID	Mountain View Irrigation District
OE	Open-ended question approach
OLS	Ordinary Least Square Model
PC	Payment Card approach
RCID	Ross Creek Irrigation District
RP	Revealed Preference
SMRID	St. Mary River Irrigation District
SP	Stated Preference
SSRB	South Saskatchewan River Basin
WTA	Willingness to Accept
WTP	Willingness to Pay

Chapter 1

Introduction

1.1 Background

Irrigated agriculture in Alberta is a significant economic driver and contributes to the worldwide need for food and fibre. Irrigation has become essential to the functioning of the southern Alberta economy, consuming a significant amount of water. However, the geographical imbalance between water supply and demand in Alberta, combined with persistently increasing water demand arising from population, industrial and agricultural growth, indicates that water management challenges will intensify over time. In addition, global climate change that we are witnessing is expected to alter weather patterns in the near future. Among the predicted impacts for southern Alberta is an increase in the intensity, duration and frequency of extreme weather events such as severe droughts.

Irrigation water management will be pivotal in the long-term water management strategy in southern Alberta. Alberta Environment's *Water for Life: Alberta's Strategy for Sustainability* (2003) identifies water conservation as a "key direction". Economic instruments are under consideration to target greater water conservation, higher water productivity and efficiency. One instrument that has already been implemented is the ability to trade irrigation water rights within specified districts through water markets. Specifically, temporary water trading has been highlighted in efforts to mitigate water scarcity in the agriculture sector. However, the water trading approach to the reallocation of irrigation water within the agriculture sector is still under development in Alberta. The water market remains rare and the information about farmers' market behaviour is therefore inadequate. It is important for policy makers to better understand the underlying economic causes of inefficient water allocations and farmers' responses to water trading and their valuation of irrigation water so that water management can be adequately addressed. This understanding could be achieved by using stated preference approaches to first observe irrigators' contingent market behaviour and thus to determine the value of irrigation water and to assess the effectiveness of a water trading approach in promoting water productivity and efficiency, which is the focus of this study.

1.2 Objectives of the Study and Research Questions

The overall objective of this research is to determine the value of irrigation water in southern Alberta. The findings should help assess the effectiveness of a water trading approach to conserving water and promoting water productivity and efficiency during severe droughts. The more specific objectives of this research are:

1) to determine the value of irrigation water in southern Alberta;
2) to identify the determinants of irrigators choosing to participate in water markets and their levels of participation;
3) to assess the effectiveness of water trading approach in water reallocation and water conservation;
4) to determine the extent to which the use of water markets in southern Alberta assist in promoting water productivity and water efficiency in the agriculture sector.

The main research questions are as follows:

1) What are the demand and supply of irrigation water during droughts?
2) How much are irrigators in southern Alberta willing to pay/accept for irrigation water during droughts?
3) What are the demographics of water market participants?
   a) What are the specific demographics of irrigators playing different roles in water markets, namely, water sellers, buyers and market non-participants?
4) What are the determinants of an irrigator's choice of participating in water markets or not?

    a) What are the specific determinants of an irrigator participating as a seller or a buyer and the level of participation in water markets?

5) What are the implications for the potential contribution of water trading as one of the future water conservation policies in Alberta, given the results of this study?

1.3 Organization of the Thesis

The thesis is organized as follows. Chapter Two presents a broad context of irrigation water management in Alberta, including details about Alberta's irrigation water resources and irrigation developments, Alberta's current irrigation legislation and policy framework, and a short overview of the economics of irrigation water management. A review of economic valuation of water resources is presented in Chapter Three, in order to provide a theoretical background for this study. The definitions of economic values of water and economic valuation techniques are explored, with stated preference methods highlighted. In this chapter, the related econometric models are also presented. Chapter Four explains the data collection procedure and presents a summary of the survey dataset as well as the model specifications used in this study. Chapter Five presents a summary and discussion of the results of the models specified in Chapter Four, as well as the estimates of the value of irrigation water. Some econometric issues such as multicollinearity, heteroscedasticity and heterogeneity are also discussed in this chapter. Finally, Chapter Six summarizes the conclusions drawn from this study and presents limitations of this study and suggestions for further research.

Chapter 2

Irrigation in Southern Alberta

2.1 Introduction

Irrigation has a long history in Alberta, dating back to the late 1800s. The majority of irrigation activity takes place in the South Saskatchewan River Basin. As a result of irrigation technology developments, irrigation activity has moved towards higher water use efficiency with the majority of gravity systems having been replaced by sprinkler irrigation systems. However, southern Alberta still faces challenges in managing intensified strain on its irrigation water supply and demand. This chapter provides the context of irrigation in southern Alberta. It starts with details about southern Alberta's water resources and irrigation districts in the next section. Section Three focuses specifically on southern Alberta's irrigation developments, including its irrigation systems in particular. Section Four summarizes current legislative and policy instruments applied in irrigation water management: the *Water Act* of 1999, the *Irrigation Districts Act* of 2000, and the *Water for Life Strategy* of 2003 and its *Renewal* in 2008. This is followed by a short review of economics of irrigation water management in Section Five, with market-based instruments highlighted. Section Six draws a short conclusion.

2.2 Irrigation Water Resources and Irrigation Districts

Alberta holds only 2.2% of Canada's fresh water supply. 80% of this water supply comes from the northern part of the province, while 80% of demand originates in the southern part (AENV, 2002b). 97.5% of water consumed in the province comes from surface water, while only 2.5% comes from groundwater. The two main surface water uses in Alberta are irrigation (71%) and commercial/industrial operations (15%), while municipal demand accounts for only 5% of use (AENV, 2002b).

In Alberta, there exist seven major river systems or basins: the Peace/Slave River, Athabasca River, Hay River, North Saskatchewan River, South Saskatchewan River, Beaver River and Milk River. Except for the Beaver River Basin, all the other basins originate from glacier melt (AENV, 2002b). These are depicted in Figure 2.1.

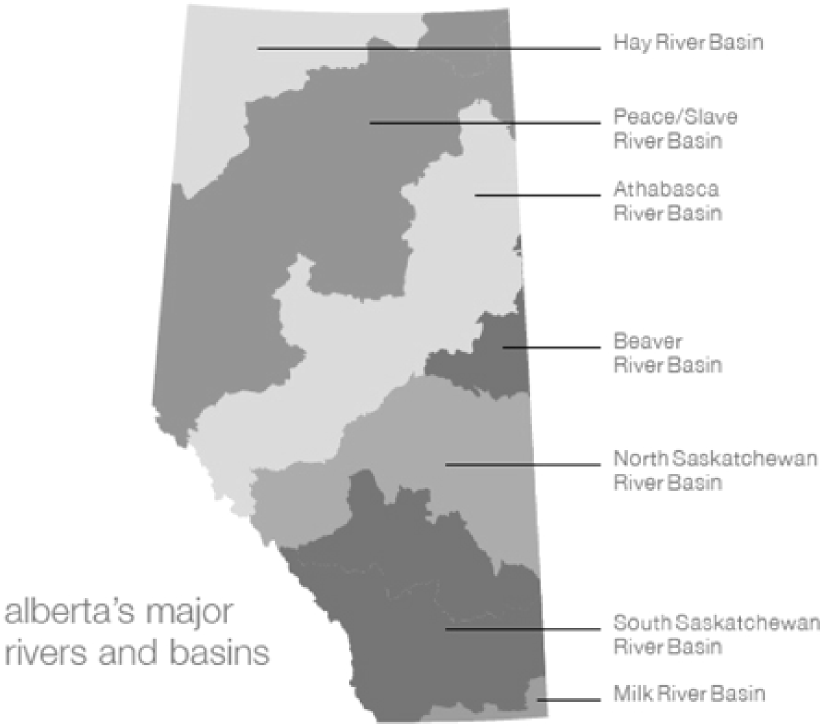

Figure 2.1 Alberta's Major River Basins

Source: http://www.waterforlife.gov.ab.ca/docs/infobook.pdf

There are 13 irrigation districts in southern Alberta, providing water to 1,359,153 assessed acres of farmland (AAFRD, 2009). The South Saskatchewan River Basin (SSRB) is the most important in terms of irrigation. All of the province's 13 irrigation districts are located in this basin and all of the water used by these irrigation districts comes from rivers in this basin, such as the Bow River, Oldman River, and South Saskatchewan River. The irrigable lands within these districts are used for the cultivation of major crops such as forages (38.0%), cereals (33.6%), oil seeds (14.4%), specialty crops (11.3%) and others (2.6%) (AAFRD, 2009). In addition to irrigation districts, there are 2,929 individual irrigation projects, irrigating approximately 310,272 acres (AAFRD, 2009).

Table 2.1 and Figure 2.2 provide general information about these irrigation districts and their locations.

Table 2.1 Alberta's 13 Irrigation Districts

Alberta's Irrigation Districts	***Length of Distribution System** (km)*	***Assessment Roll Acres***
Aetna (AID)	27	3,699
Bow River (BRID)	1,058	233,869
Eastern (EID)	1,784	285,086
Leavitt (LID)	56	5,126
Lethbridge Northern (LNID)	650	176,069
Magrath (MID)	106	18,300
Mountain View (MVID)	35	3,700
Ross Creek (RCID)	20	1,101
Raymond (RID)	247	46,293
St. Mary River (SMRID)	1,719	373,162
Taber (TID)	364	82,600
United (UID)	227	34,069
Western (WID)	1,077	96,079
Private Licenses	--	310,272
Total Assessed for Irrigation: 1,669,425 acres		

Source: AAFRD (2009).

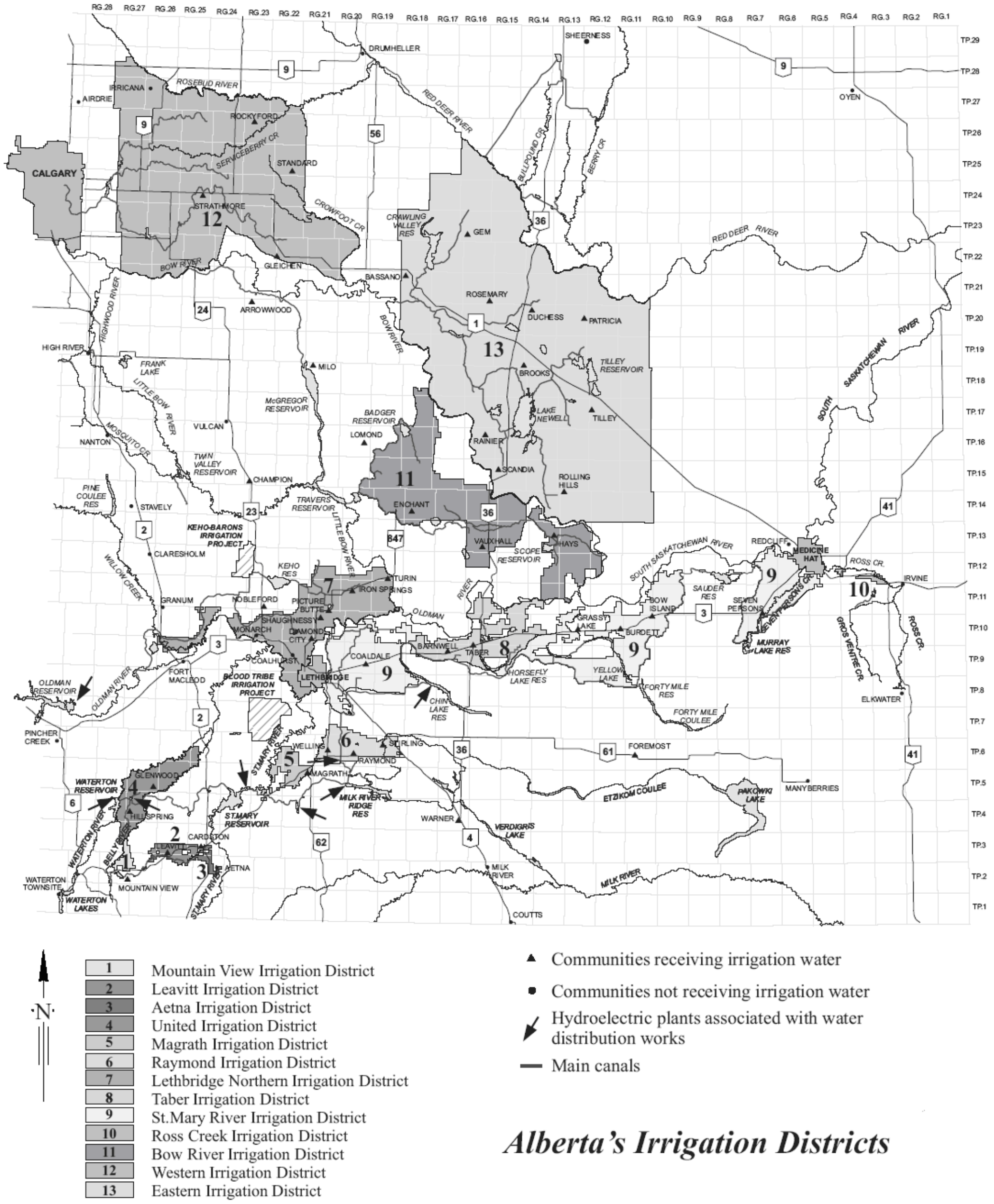

Figure 2.2 Alberta's 13 Irrigation Districts

Source: AAFRD (2009).

The irrigation districts can be categorized into three groups based on irrigation water sources, irrigated area, farm size, and crop production (Bjornlund et al., 2007; 2008). First, the "Bow River" group, generally located between Calgary and Medicine Hat, consists of the Western (WID), Eastern (EID), and Bow River (BRID) irrigation districts. Districts in this group derive irrigation water solely from the Bow River and have never experienced restrictions in water use. In this group, specialty crops and cereals are cropped as well as forage production in support of significant beef production. In addition, EID and BRID are among the largest of the 13 districts with more than 50% of farms greater than 65 hectares (160.6 acres). These two irrigation districts also benefit from the largest non-irrigation incomes from oil, dryland rental and other businesses. The WID provides services to urban dwellers and lifestyle farmers due to its proximity to the city of Calgary (Bjornlund et al., 2008).

Second, the "Central" group consisting of Lethbridge Northern (LNID), St. Mary River (SMRID), Taber (TID) and Ross Creek (RCID) irrigation districts, is located generally between Lethbridge and Medicine Hat. Irrigation water for these districts is primarily drawn from the St. Mary River and the Oldman River. Irrigation districts in this group have suffered from water constraints during exceptional drought years. Except for RCID, these districts are relatively large with 30-40% of farms greater than 65 hectares. In LNID, there is a high concentration of feedlot operations; in SMRID and TID, farmers provide raw materials such as sugar beets and potatoes to the vegetable processing industry under contract, which results in the greatest crop diversity among these regions.

Third, the "Southern Tributary" group, generally located in the southwest of the province, consists of Aetna (AID), Leavitt (LID), Mount View (MVID), United (UID), Raymond (RID), and Magrath (MID) irrigation districts. The southern tributaries of the Oldman River, such as the Belly River, St. Mary River and Waterton River, are the main source of irrigation water in this group. Districts in this group traditionally have suffered from the most frequent and most severe water constraints. Moreover, they are among the smallest in terms of assessed area with the majority of farms having less than 65 hectares and using the least efficient irrigation equipment of all regions. Forage production is common in this group in support of cow-calf operations.

Bjornlund et al (2007; 2008) argue that water reliability, soil type, growing days, frost free days, and precipitation vary significantly across groups of irrigation districts. Generally, as one moves from the Bow River group to the Southern Tributary group, water reliability from the river, water storage capacity and precipitation diminishes, and soil types change from primarily brown soils to higher quality black soils (Bjornlund et al., 2007; 2008). In terms of crop growing conditions, such as frost-free days and heat units, the Central group has the most favourable conditions for specialty crops. It therefore is not surprising that the greatest concentration of specialty crop production is found in this group where vegetable processing industries are concentrated and where contract growing is possible. The growing conditions are less favourable in the Bow River group and least favourable in the Southern Tributaries group. Low-value forages and cereals, which require less water and heat, comprise almost the entire crop production in the Southern Tributaries group (Bjornlund et al., 2007; 2008).

2.3 Irrigation Development

Agriculture is considered to be one of Alberta's largest economic sectors and irrigation is one of the primary methods of improving agricultural productivity and diversifying the range of crops grown in the province. Land has been successfully irrigated in Alberta since the 1890s. The total area irrigated has gradually increased over the years. In southern Alberta, around 1,359,153 acres of land are serviced by 13 irrigation districts. There are 2,929 individual irrigation projects, outside of the 13 irrigation districts, irrigating approximately 310,272 acres (AAFRD, 2009). In addition, irrigated land produces about 16% of the province's gross agricultural output from only 4% of the total agricultural land (AAFRD, 2009).

Though Alberta has abundant water resources, precipitation is scarcest where the agricultural potential consumption is greatest. The southern part of the province, with a growing season of about 150 days, receives only 300-450 mm of precipitation annually. Less than half falls during May through August, the growing season. Precipitation can only provide up to 50% of total crop water needs. The combination of abundant sunshine, warm temperatures and a long growing season results in an average net water deficit of 380 mm a year for crops grown in the southeast corner of the province (AAFRD, 2000a).

Defined as a semi-arid region, much of southern Alberta's land would not be viable for production of crops and forages without irrigation. Irrigation diversifies the range of crops that can be grown in the warmer, more arid regions of the province while improving agricultural productivity as well. With irrigation, crop yields increase substantially and the range of crops than can be successfully grown in this region also expands considerably (Nicol and Klein, 2006).

In Alberta, technology has changed the way irrigation water is applied, helping to ensure long-term sustainability of irrigation. Sprinkler irrigation methods have replaced the majority of gravity irrigation systems used previously, resulting in improved irrigation water efficiency. Hand-move systems, used in the 1960s, have been exchanged for wheel roll and center pivot irrigation systems. Sprinkler systems have also been updated. Advancement in the design of sprinkler nozzles has reduced water losses through evaporation and wind drift, reduced energy consumption and improved water application efficiency. Figures 2.3 and 2.4 show the development of irrigation systems in Alberta over time.

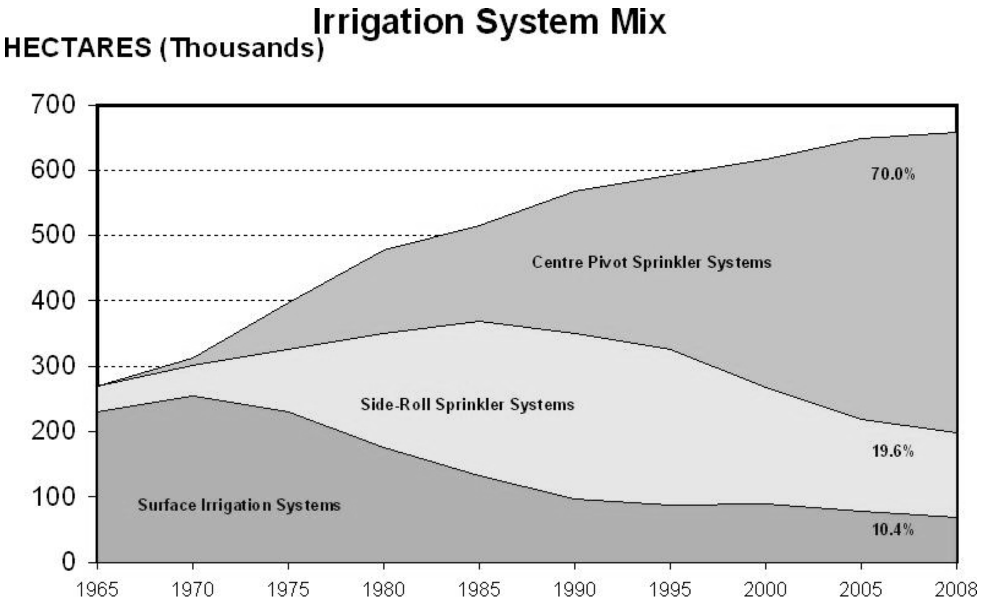

Figure 2.3 Irrigation System Methods in Alberta
Source: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/irr4478.

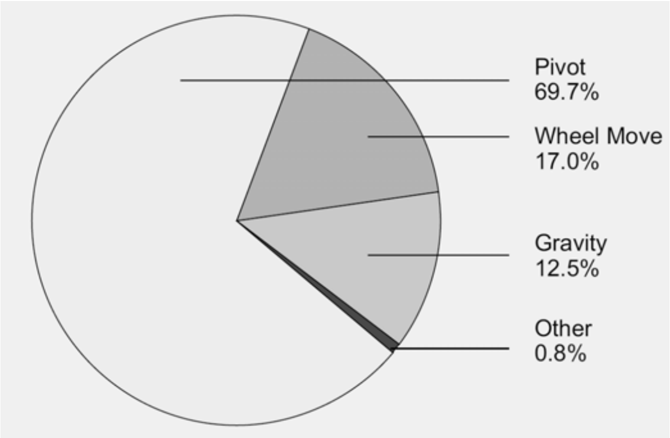

Figure 2.4 On-farm Irrigation Methods within the 13 Irrigation Districts in 2008
Source: AAFRD (2009).

2.4 Current Irrigation Legislation and Policies

Since 1930, water management in Alberta has primarily been the responsibility of the provincial government. The Government of Alberta owns the rights to all water within its borders, and, through legislation, regulates all developments and activities that might impact rivers, lakes, wetlands and groundwater. Specifically, water within Alberta is managed jointly by provincial government policy and law makers, administrators within irrigation districts, and farmers themselves (Nicol and Klein, 2006). At the provincial level, licensed water use for irrigation purposes is managed along with domestic, industrial, recreational and environmental uses.

Irrigation water license holders, as well as other licensees such as municipalities and industries, are provided limited water rights with the "first-in-time, first-in-right" principle that has been in place since 1894. The underlying principle is that this protects an existing user's rights from those who come after and is the best way to allow for orderly development. Water is allocated on a year-by-year basis based on supply and the seniority of license holders. Licenses are held by private irrigators individually or by irrigation districts which hold water licenses and manage water on behalf of farmers within the district. Water is transferred to farmers based on acreage on the assessment roll.[1]

Since increased water demand associated with population and economic growth puts a strain on Alberta's water supply, the previous *Water Resources Act* of 1931 could not provide the tools to cope with water management challenges. This led to a government review of water management policy, legislation and also the prospect of legislating tradable water rights by the early 1990s. This review "culminated in the passage of *Water Act* in 1999 and *Irrigation Districts Act* in 2000" (Nicol and Klein, 2006). The *Water Act* of 1999 allows for the transfer of water rights among all water license holders. The *Irrigation Districts Act* of 2000 allows for the transfer of water rights among irrigation users within irrigation districts. Transfers can be permanent or temporary in both cases. The Alberta government's *Water for Life Strategy* of 2003 establishes the foundation for the government's water management plan for the future, which encourages the development of market-based instruments in managing water issues.

The *Water Act* of 1999 gives a much broader authorization to water license holders than under the former *Water Resources Act*. The purpose of the *Water Act* is to support water conservation and management, to sustain the

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[1] Acres approved for irrigation by the irrigation district and for which an annual water rate is paid to the district.

environment and support economic growth. Under the *Water Act*, water can be permanently or temporarily transferred among vastly different users (e.g. irrigation districts to industries), with more extensive water movement involved than off-stream re-allocation. It also provides the government with the ability to withhold up to 10% of the water transferred to meet the needs of the aquatic environment, which is applicable to both permanent and temporary water transfers.

The *Irrigation Districts Act* of 2000 allows irrigators greater autonomy and independence, but with greater accountability. Under the *Irrigation Districts Act*, irrigators can transfer water licenses to other irrigators within the same irrigation district. Transfers of all or a portion of a district's water license outside the district is possible only if a plebiscite is held and a majority of irrigators agree (*Irrigation Districts Act*, 2000). Unlike transfers under the *Water Act* of 1999, transfers within irrigation districts do not involve more extensive water movement than off-stream reallocation. This helps to significantly simplify the approval process of individual transfer within the same district under the *Irrigation Districts Act*.

Water for Life: Alberta's Strategy for Sustainability of 2003 is the Alberta government's comprehensive strategy for addressing water management issues for the future, as a response to the increasing pressures on its water resources. It promotes water conservation as a "key direction" (AENV, 2003c). Water conservation efforts focus on using water effectively and efficiently, improving water use productivity and finding effective ways to manage water demand and supply (AENV, 2003c). By 2007, the province would "complete an evaluation and make recommendations on the merit of economic instruments to meet water conservation and productivity objectives" and "implement economic instruments as necessary to meet water conservation and productivity objectives" in the medium term (from 2007/08 to 2009/10) (AENV, 2003c, pp.21-22).

Water for Life: A Renewal in 2008 reviews the achievements by the Alberta government in implementing the *Water for Life Strategy* over the past five years and “recognizes the need to continuously improve and strengthen water policy to ensure sustainability for the future” (AENV, 2008, pp.6). The use of market-based instruments is highlighted to maintain flexible and adaptive water management. In addition, the renewed strategy accelerates actions to safeguard Alberta’s water resources, ensuring better resource management integration of watershed planning with other environmental policies and plans, such as Land-use Framework planning in Alberta.

As discussed above, irrigation districts mange water infrastructure and administration on behalf of farmers within districts. Each irrigation district operates independently in a manner that may vary significantly due to their varied sizes and physical characteristics (Southeast Alberta Regional Planning Commission, 1982). The sizes of irrigation districts, in terms of acreage, range from 1,101 acres in the RCID to 373,162 acres in the SMRID (AAFRD, 2009). Irrigators pay a flat fee for administrative and maintenance services, and to cover 25% of the cost of repairing and upgrading the infrastructure, with the remainder paid by the provincial government. The flat fee varies from as high as $21.00 per acre per year in the RCID to as low as $0.00 per acre per year in the EID, and is not meant to pay for the water itself (AAFRD, 2009). This large variation in rates is reflective of whether or not irrigators have piped and pressurized water supply and whether irrigation districts have alternative sources of funding (some districts also supply water to municipalities, feedlots, oil and gas firms, and other industries).

Of particular importance is the fact that the charges made for irrigation water fail to signal the scarcity of water to farmers. These low charges can have an adverse impact on the effectiveness of irrigation systems and water use (Rosegrant et al., 2002), which may result in poor maintenance and consequent inefficient operation of existing irrigation systems, limited capacity for improvements or investment in new infrastructure, and waste of water at the farm level.

2.5 Economics of Irrigation Water Management

In recent years, a significant amount of literature has focused on the effectiveness of various water allocation instruments. It is not surprising since humans, nationally and globally, are under pressure to reform water allocation methods because of intensifying water competition for urban, industrial and environmental purposes. Since water used for irrigation consumes by far the largest amount of water world-wide, irrigation water management is the main object of reform (Abu-Zeid, 2001; Varela-Ortega et al., 1998). For example, the Alberta government is interested in making wider use of economic instruments to explore their potential in the management of irrigation water (AENV, 2003c).

Economic instruments have two main categories: regulation as control mechanisms and economic incentives (i.e. market-based instruments in forms of informal and formal markets). Market-based instruments, such as water rights trading, have been successfully implemented in irrigation water management in some countries such as Australia and United States. The markets for permanent and temporary trades in water rights are commonly referred to as formal and informal markets in the literature. One key feature to distinguish the two is that: in the formal market, the longer-term entitlement to the water is transferred; while in the informal market, only the right to use a specified volume of water over a specified period of time is traded (Bjornlund, 2003). The informal market with temporary water right trades is the basis of this study.

One of the main conclusions of the Coase Theorem (Coase, 1960) states that, if the transaction costs associated with the transfer of property right from one individual to another are sufficiently low, then an efficient outcome can be achieved irrespective of the initial allocation. Although externalities are common in water use, the Coase theorem states that externalities will be internalized when the property rights are established and exchange of the rights will achieve efficiency if transaction costs are zero (Hyman and Strick, 2001).

Water right trading provides much more flexibility of water reallocation and encourages water to move from low to higher value uses, thus increasing water productivity and enhancing economic growth. Conservation efforts can also be enhanced since users, with the freedom to sell or buy any excess water, are provided with an incentive to conserve by using water more efficiently and effectively. Studies by Bjornlund and McKay (1998) and Bjornlund (2002) show that efficiency gains can be realized through water transfers from sellers who use relatively inefficient irrigation equipment to buyers who use more efficient technologies. Trade in water also allows irrigators to manage the risks of wet and dry years (Watson, 2005). Low flexibility users, such as those with perennial plantings, will be buyers in dry years and sellers in wet years. Higher flexibility users with annual crops will be sellers in dry years and buyers in wet years. In addition, water trading can ultimately increase policy options by expanding the number of alternatives through market-based solutions (Haddad, 2000). For unprofitable producers, markets provide them an option to sell their water rights and facilitate exit from the industry if needed.

However, water markets are still controversial for several reasons. Though the potential benefits include greater efficiency and flexibility of water use and less government intervention, there are also some drawbacks. These include social and environmental externalities, vulnerability to high transaction costs, and other common examples of “market failure” (Bauer, 1997). Livingston (1998) notes that transaction costs can be significant in both formal and informal markets, which may need the governments’ regulatory power to some degree to mitigate the problems associated with water markets. Water markets need institutional and organizational arrangements to function as efficiently as possible (Easter et al., 1997). These water organizations and institutions can be either private (e.g. irrigation companies) or public (municipalities, regional water districts or government departments) (Livingston, 1998).

Transaction costs include the time, effort and expenditures involved in locating someone to trade with, negotiating terms of trade, drawing contracts, and assuming risks associated with the contracts (Hyman and Strick, 2001). These costs are likely to vary over the lifetime of a program, decreasing over time due to learning and the presence of fixed costs which are incurred primarily at the beginning of a program (Falconer et al., 2001). Water prices are observed to be related to transaction costs - the higher the volume of water traded the lower the transaction costs on a per unit basis. Hence, it is expected that there will be a willingness to pay higher prices for larger volumes of water (Bjornlund, 2002; Howe et al., 1990; Nicol and Klein, 2006).

Relative to formal water markets, informal water markets are much more put into practice because of their simplicity and low implementation and transaction costs. They are usually limited in scope (within the same district and among similar users), and the sales are not likely to be anonymous so the enforcement of contracts is based on reputation and personal trust rather than by the legal system (Easter et al., 1999). Experience in other countries (such as Australia) shows that informal markets have succeeded in moving water to higher valued uses (Bjornlund, 2003; 2005). Transaction costs are low and legal challenges are rare in informal markets (Nicol and Klein, 2006).

In addition, the transfer of a water entitlement can result in third-party effects (Etchells et al., 2006; Brennan and Scoccimarro, 1999; Heaney et al., 2005). Specifically, the third-party effects are: volumetric reliability, delivery reliability and change in water quality. Brennan and Scoccimarro (1999) discuss several ways in which trade can have an impact on third parties, including the addition or removal of return flows used by other irrigators, salinity damage, overburdening of delivery systems, in-stream flows and sharing of infrastructure costs. Overall, the underlying cause of water market failure emerges as a problem of trading private goods where their value depends upon the usage of public goods.

The main features of the early stages of informal water markets are that they tend to be “thin” and water prices erratic (Bjornlund, 2003), which was also confirmed in the practice of water trading in southern Alberta (Nicol and Klein, 2006). Based on the principle of declining marginal returns, studies predict that water prices per unit will decline with the volume of the transfer (Bjornlund and McKay, 1998). Similar to the Australian water market, the water trading practice in southern Alberta reveals that buyers' main reason for buying water has been to manage droughts and sellers' main rationale for selling water has been due to excess supply and the income opportunity available to them (Bjornlund, 2003; Bjornlund and McKay, 2000; Nicol and Klein, 2006).

The Alberta government's objectives of increasing productivity and efficiency of water use have been supported through informal water market activities which mainly occurred in 2001 (Nicol and Klein, 2006). Water moved from low-value crops (e.g. barley and forage) to higher-value production (e.g. potatoes and sugar beets), thus increasing productivity. Water also moved from relatively low to relatively high efficiency irrigation equipment.

However, water markets are not a panacea for all water problems. Market mechanisms are driven by economic profits and do not automatically protect specific sectors of the economy, society or geographic regions. According to Haddad (2000), they do not protect specific uses of water that promote general rather than individual welfare, and they can move a society's "relationship" with water in a direction that is not preferred by the society.

2.6 Summary

Irrigated agriculture in Alberta is a significant economic driver and contributes to the worldwide need for food and fibre. Unfortunately, the geographic imbalance between water supply and demand in Alberta, combined with persistently increasing water demand, indicates that water management challenges will intensify over time. New legislative tools that provide irrigators with economic instruments for managing water establish a foundation for water markets in Alberta. Water trading has proved to be successful in increasing water efficiency, productivity and conservation by providing producers with greater flexibility in water management. As a consequence, the provincial government's objective, which is greater water productivity, efficiency and conservation derived from the *Water for Life Strategy*, could be supported to an extent by the implementation of water markets.

Chapter 3

Economic Valuation of Irrigation Water: Theoretical Background

3.1 Introduction

In recent decades, stated preference (SP) methods, in particular contingent valuation (CV) and contingent behaviour (CB), have gained widespread use in measuring economic values of nonmarket environmental commodities. This review is intended to draw together the main streams of the literature relating to the SP studies on nonmarket environmental commodities, particularly water resources in agriculture. There are ten sections starting with definitions of economic values of water in Section Two and economic valuation techniques in Section Three, with stated preference methods highlighted. The disparity between willingness-to-pay and willingness-to-accept measures are explored in Section Four. This is followed by an enumeration of limitations of the SP in conducting evaluations of nonmarket environmental commodities in Section Five. In Section Six, the censored nature of the data collected from SP survey is highlighted and several econometric models are explored that can be used to model censored survey data. Section Seven explores the approaches of conducting SP surveys, with mail surveys highlighted. Section Eight provides a short review of recent agricultural water valuation studies done in Canada. Section Nine draws a short summary of this chapter.

3.2 Economic Value of Water Resources

Economic value, in monetary terms, refers to the maximum amount an individual is willing to pay (WTP) for a good from a set of resources or the minimum amount an individual would accept (WTA) in exchange for the good (Adamowicz, 1991). According to Brown (1984), the basic premise of economic value is that the value of a commodity is not intrinsic but depends on individuals' preference systems. Therefore, economic value for a particular good may vary over time and across individuals.

The economic value of water to a user is the maximum amount the user would be willing to pay for the use of the resource (Briscoe, 1996; Renzetti and Dupont, 2007). The benefits that accrue from water resources vary by both uses and users, and can be divided into use values and non-use values (or passive values). The use values of water include: (i) direct use values, which refer to the benefits derived when water is directly used in a production process, farming operation or household consumption; (ii) indirect use values, which refer to the benefits derived from activities that occur alongside or in proximity to water such as recreational fishing or swimming (Dupont and Renzetti, 2008). On the other hand, the non-use values of water include: (i) preservation values: the benefits that individuals place on ensuring the opportunity of access to clean water for their offspring; (ii) existence values: the benefits that individuals attach to the knowledge of the existence of some specific environmental assets; (iii) option values: the premium or value that individuals place on ensuring that the possibility for their future use of this asset is preserved (Dupont and Renzetti, 2008).

The economic value of water depends on several factors, including how the water is used, the quality and quantity of water, the time and location at which it is available, its relative scarcity, and other attributes (Dupont and Renzetti, 2008). Particularly, the value of irrigation water depends on crop type, irrigation technique, irrigation delivery efficiency, crop price, and weather conditions.

3.3 Economic Valuation Techniques

There are a number of techniques that can be used for economic valuations. These can be grouped into two categories depending on whether the techniques rely on observed market behaviour to elicit the value of water resource functions (*revealed preference methods*), or on whether they use survey methods to obtain valuation information directly from respondents (*stated preference methods*) (Turner et al., 2004; Renzetti, 2002). More specifically, revealed preference (RP) approaches include market-based transactions, derived demand functions, travel cost methods, and hedonic pricing approaches, etc. Stated preference (SP) approaches, on the other hand, include contingent valuation (CV) methods, contingent behaviour (CB), contingent ranking and conjoint analysis (Table 3.1 presents a summary of these economic valuation techniques). The SP approach's appeal lies in its flexibility and ability to mitigate the difficulties found in the RP approach. Of particular importance is the flexibility of the hypothetical methods. Mitchell and Carson (1989) point out that SP researcher can easily specify different scenarios of the good to be valued and the conditions of its provision within the constraint of being plausible to respondents. Moreover, without the limitation of current institutional arrangements, the hypothetical character of the SP, which allows it to obtain ex-ante judgments, allows it to estimate existence values as well. This is exactly what is needed to help policy makers in southern Alberta better understand irrigators' responses to a hypothetical water market design. Second, SP can avoid measurement error and collinearity effects common in RP data (Adamowicz et al, 1994).

In CV, respondents are asked to make statements about their willingness to pay (WTP) or willingness to accept (WTA) for changes in environmental quality. In contrast, the CB approach asks respondents directly for the changes in their behaviour contingent to the quality change. Whereas CV questions elicit hypothetical value statements, CB questions focus on hypothetical behaviour changes (Englin and Cameron, 1996). A recent trend in recreation demand modeling is to use CB trip data to value changes in consumer welfare under hypothetical scenarios, such as changes in management rules or environmental quality. Commonly, CB data are also combined with revealed preference (RP) data on past use levels (Englin and Cameron, 1996; Adamowicz et al., 1994; Cameron, 1992; Alberini et al., 2007).

In many cases, the value of irrigation water cannot be captured through its market price, either because there is no market price associated with water, or the price does not reflect its economic value. Therefore, stated preference methods are more appropriate in estimating the value of water in agriculture. Of particular importance, the CV method is commonly used in estimating economic values for a variety of ecosystem and environmental goods and services. As an extension of CV, CB questions focus on hypothetical behaviour rather than hypothetical values.

In this study, the CB approach is developed to identify irrigators' market behaviour as well as their valuation of irrigation water. To the best of our knowledge, this study is the first that attempts to estimate the value of water using the CB approach. In contrast to CV, the CB approach has its particular strengths in the reduction of the possibility of hypothetical bias and the decreased likelihood of payment vehicle bias (Kuperis, 1997). The payment vehicle is embodied in the prices of the product in a scenario where the valuation questions do not directly ask the respondent to state a value on the product. Furthermore, it is possible that people are better able to predict what they would do in a hypothetical situation than whether they would pay some hypothetical price or how much they would like to pay, as in a CV survey (Englin and Cameron, 1996). Thus, it may be easier for respondents to predict prospective behaviour than to estimate their total willingness-to-pay for a resource.

Table 3.1 Summary of Economic Valuation Techniques for Water Resources

	Valuation Method	***Description***	***Use Value***	***Non-use Value***
Revealed Preference Approaches	Market-based transactions	Used where market prices of outputs (and inputs) are available. Can also be approximated using market prices of close substitutes. Can not measure values of larger scale changes that affect the supply or demand for a good/service. May not fully reflect the true economic value of a good/service due to market imperfections and/or policy failures.	√	
	Derived demand functions	Derive value from the household's or individual's inverse demand function based on observations on water use behaviour.	√	
	Travel cost method	Costs incurred in accessing a recreation site as a proxy for the value of recreation. Expenses differ between sites (or for the same site over time) with different environmental attributes.	√	
	Hedonic price method	Derive an implicit price for an environmental good/service from analysis of goods for which markets exist and which incorporate particular environmental characteristics.	√	

	Residual imputation and variants	Use budget analysis to estimate return attributable to water. Water treated as one input in a production process. Calculate the total returns and subtract all non-water expenses then the value of water is obtained.	√	
	Damage costs avoided	The costs that would be incurred if a catchment function were not present e.g. flood prevention.	√	
	Avertive behaviour & defensive expenditures	Costs incurred in mitigating the effects of reduced environmental quality. Represents a minimum value for the environmental commodity/service.	√	
	Replacement/cost savings	Potential expenditures incurred in replacing/restoring the function that is lost; e.g. by the use of substitute facilities or "shadow projects".	√	√
Stated Preference Approaches	Contingent valuation method	Construction of a hypothetical market in surveys for a sample of individuals, asking them to directly state their preferences. Problems of potential biases.	√	√
	Contingent behaviour	Construction of a hypothetical scenario in surveys for a sample of individuals, asking them to directly state their behaviour changes.	√	√
	Contingent ranking	Individuals are asked to rank several alternatives in surveys that comprise various combinations of environmental goods and prices.	√	√
	Conjoint analysis	Ask people to make choices based on a hypothetical scenario in surveys. Values are inferred from the hypothetical choices or tradeoffs that people make.	√	√

Source: Turner et al (2004); Renzetti (2002); Young and Gray (1972).

3.4 Willingness-to-Pay versus Willingness-to-Accept Measures

The disparity between the WTP (the maximum price one wants to pay for an object) and the WTA (the least price one is willing to accept to forgo an owned object) measures is a well established result. CV researchers have consistently confirmed that WTA values are considerably larger than WTP values for the same amenity (Mitchell and Carson, 1989). In other words, individuals ask for a substantially higher price to forgo an object in their possession than they are willing to pay to obtain it (Knetsch and Sinden, 1984). As well, another difference is revealed in the way respondents react to the WTP/WTA questions asked.

Respondents are more likely to give protest responses or infinite values when how much they would accept to forgo an amenity than when asked how much they would pay to receive it (Mitchell and Carson, 1989).

This phenomenon was first attributed to endowment effects by Thaler (1980), and is often explained in terms of loss aversion. According to the principle of loss aversion, "the aggravation that one experiences in losing a sum of money appears to be greater than the pleasure associated with gaining the same amount" (Kahneman and Tversky, 1979, pp.279). As a result, people are prone to value possessions more than alternatives of similar objective values (Kahneman and Tversky, 1979; Tversky and Kahneman, 1991).

A second explanation is due to Hanemann (1991): based on the analysis of Randall and Stoll (1980), he argues that the difference between the WTP and WTA depends not only on income effects but also on substitution effects. More specifically, the lack of substitutes can generate large divergences between compensating variation and equivalent variation, and thus between the WTP and WTA.

3.5 Limitations of Stated Preference Methods

Stated preference methods are widely used to value environmental goods. Of particular importance is the flexibility of these hypothetical methods in specifying different scenarios for the good to be valued and the conditions of its provision without constraints of current institutional arrangements. However, the SP method is subject to some potential biases, such as hypothetical bias and sample-related bias. Similar to CV methods, the use of CB still remains controversial due to its inherent hypothetical nature. There are tradeoffs between the benefits of using a particular technique and the costs imposed by its associated biases when a SP study is conducted.

3.5.1 Hypothetical Bias

Hypothetical bias arises easily in SP studies due to the hypothetical nature of contingent valuation markets in SP questionnaires (Cummings et al., 1986). It is defined by Cummings et al (1986) as the potential divergence between the real and hypothetical payments for the provided goods/services, and is most likely to occur where respondents are very unfamiliar with the scenarios presented to them. It has been shown in many CV studies that the hypothetical WTP values are found to be greater than the real WTP values (Brown et al., 1996; Neill et al., 1994; Kealy et al., 1990; Bishop and Heberlein, 1979).

To counter such problems, an effective approach is to incorporate "cheap talk" in questionnaire designs, involving an explicit discussion of the hypothetical bias problem (Cummings and Taylor, 1999). The premise behind this technique is that one might be able to reduce or eliminate hypothetical bias by simply making respondents aware of it regardless of its underlying causes (Brummett et al., 2007). Cheap talk describes the hypothetical bias phenomena, discusses possible explanations for this phenomenon and then asks respondents to vote in the upcoming hypothetical referendum as if it were a real one (Cummings and Taylor, 1999). However, finding the appropriate length of the cheap talk script required to achieve desired corrections on the part of subjects in the SP remains a challenge.

3.5.2 Sample-Related Bias

Since SP studies often rely on survey instruments as a means of collecting data, regardless of the strengths and weaknesses of elicitation techniques, the survey process may introduce potential problems of its own. Among the most troubling of these problems is the potential of sample non-response bias or sample selection bias, which are referred to as sample-related biases (Messonnier et al., 2000). These sample-related biases may occur when the realized sample (the final dataset available to the researcher) differs from the surveyed sample, introducing the potential of misrepresentation of the target population. There are two sources for the difference. Unit non-response occurs when a recipient randomly does not return the questionnaire; item non-response arises when the recipient returns the questionnaire without answering all of the key questions (Messonnier et al., 2000). As a consequence, both types of non-response invalidate these observations and remove them from the realized sample, resulting in sample non-response bias.

Solutions to the problem of sample non-response bias vary with its source. In case of unit non-response, the available complete responses may be weighted so that the weighted sample remains representative of the target population (Anderson et al., 1983; Brox et al., 2003). For item non-response, the information available on item non-respondents could be used to calculate missing WTP values (David et al., 1986). The missing WTP values could be obtained through regressions or imputed on the basis of the similarity in socio-economic characteristics between item non-response observations and other observations (Orchard and Woodbury, 1972).

The other source of sample-related bias is sample selection bias. Specifically, survey recipients who have a greater interest in the commodity under question are more likely to respond and thus will be over-represented in the realized sample. Therefore, it is essential to examine response rates within subgroups rather than between them as in the case of sample non-response bias and to find out whether there is a systematic reason for some recipients of the surveyed sample to respond while others do not.

To sum up, sample-related bias is one of the most troubling problems in CV studies, especially when mail-administered surveys are used. Random failure on part of survey recipients to respond is a passive potential source of bias while the systematic, interest-induced responses to questionnaires are potential active sources (Messonnier et al., 2000). Sample-related bias may lead to a realized sample that is not representative of the target population and as a consequence, an aggregation bias may arise when an aggregate welfare estimate is developed for a community or region.

3.6 Censored Survey Data and Possible Econometric Models

The SP studies involve directly asking respondents to state their preference via survey techniques as a means of collecting data. The survey data collected could be censored. For example, a payment card lists a series of values, from which respondents choose an amount that best represents their maximum

WTP or minimum WTA for the good under consideration (Haab and McConnell, 2002). It provides value responses in the form of intervals rather than point valuations. To deal with the censored survey data, several econometric analysis models could be conducted to model part or all of the information elicited from the data.

3.6.1 Ordinary Least Square (OLS) Regression

A simple way to deal with interval data collected from payment card methods is to assign to each interval a value equal to the interval midpoint, which could be taken as approximations to the true unobserved values. This allows fitting a univariate distribution of values or the use of a continuous dependent variable in a regression (Cameron and Huppert, 1989). Such a model could be estimated via Ordinary Least Square (OLS) Regression under certain assumptions.

In the OLS regression, suppose the dependent variable can be represented as an additive linear function of the regressors and an error term ε_i:

$$y_i = \alpha + x_{1i}\beta_1 + x_{2i}\beta_2 + ... + x_{ki}\beta_k + \varepsilon_i$$

where it is assumed that

$$E(\varepsilon_i | x_{1i}, x_{2i}, ..., x_{ki}) = 0 \text{ , } E(\varepsilon_i^2) = \sigma^2 \text{ and } E(\varepsilon_i \, \varepsilon_j) = 0 \;\; for \; i \neq j \text{ .}$$

The OLS estimator chooses β coefficients to minimize the sum of squared residuals which is to solve

$$\underset{(\beta_1,\beta_2,...,\beta_k)}{Min} \sum_{i=1}^{n} (y_i - \alpha - x_{1i}\beta_1 - x_{2i}\beta_2 - ... - x_{ki}\beta_k)^2$$

However, the midpoint method doesn't take into account the fact that expected values within the intervals are not necessarily equal to the interval midpoints and thus involves a biased average valuation or biased regression coefficients (Cameron and Huppert, 1989). In addition, it only takes into account the non-zero responses which may lead to an overrepresentation of non-zero bidders in the sample.

3.6.1.1 The Estimations for Panel Data

One type of the panel estimations assumes constant coefficients in intercepts and slopes across observations. In this case, the data can be pooled and conventional OLS regression methods can be considered.

However, panel data may have group effects, time effects, or both. These effects can be analyzed by fixed effects and random effects models (Park, 2008). The fixed effects model examines group differences in intercepts by including dummies as a part of intercepts, assuming the same slopes and constant variance across groups; the random effects model estimates variance components for groups and error with dummies considered as an error term, assuming the same intercept and slopes. The former examines if intercepts vary across groups or time periods, whereas the latter explores differences in error variances (see Table 3.2).

Table 3.2 Fixed Effects and Random Effects Models

	Fixed Effects Model	***Random Effects Model***
Functional form	$y_{it} = (\alpha + \mu_i) + X'_{it}\beta + \upsilon_{it}$ *	$y_{it} = \alpha + X'_{it}\beta + (\mu_i + \upsilon_{it})$ **
Intercepts	Varying across groups and/or times	Constant
Error variances	Constant	Varying across groups and/or time
Slopes	Constant	Constant
Hypothesis test	Incremental F test	Breusch-Pagan LM test
Comparison test	Hausman specification test	

Notes: * $\upsilon_{it} \sim IID(0, \sigma_\upsilon^2)$; ** $\mu_i \sim IID(0, \sigma_\mu^2), \upsilon_{it} \sim IID(0, \sigma_\upsilon^2)$.

Source: Park (2008).

3.6.2 Tobit Model

It is possible that in some situations we do not observe the true response for our dependent variable. All that is known is that the true response, if it had been observed, would have been above (or below) some threshold. In that case, the OLS estimation will produce biased and inconsistent estimates of parameters because the dependent variable is no longer continuous and unbounded. In contrast, the Tobit model, which can be estimated with maximum likelihood, produces consistent estimates of parameters (Tobin, 1958). It is a standard tool to account for censoring in the linear regression models.

The Tobit model, initially proposed by James Tobin (1958), is used to describe the relationship between a non-negative dependent variable and a set of independent variables. Tobin proposes a hybrid of a probit model and OLS estimation as a solution to the problem where there is a large concentration of observations at zero.

A more general version can be right or left censored at some value C. In the right censored regression model, for example, all values at or above a certain value are given that value in the observed sample. The Tobit model is generally represented as follows. First, there is a latent model where the dependent variable is y^*, and is a function of a set of explanatory variables X along with a disturbance term that is normally distributed with a mean of zero. Since the data are right censored at the value C, the response y equals y^* if the value of y^* is less than C, but equals C if the value of the unobserved y^* is above or equal to C.

The latent model: $y_i^* = X_i^{'}\beta + \upsilon_i^*$

The data are right censored at C: $y_i = y_i^* \text{ if } \mathrm{y}_\mathrm{i}^* < C;$
$y_i = C \text{ if } \mathrm{y}_\mathrm{i}^* \geq C.$

So, the observed model: $y_i = X_i^{'}\beta + \upsilon_i \text{ if } y_\mathrm{i} < C;$
$y_i = C \text{ otherwise.}$

The full sample consists of two different types of observations. The first set contains the observations for which the value of y equals C. For those observations we know only the values of the X variables and the fact that y^* is greater than or equal to C. The second set consists of all observations for which the values of both X and y^* are known.

3.6.3 Interval Censored Regression

Through an overview of a considerable statistical literature, Cameron and Huppert (1989) suggest that maximum likelihood (ML) estimation is appropriate for models based on interval censored data. The following is an overview of a method that can be used to deal with interval data, using the ML estimation (Haab and McConnell, 2002).

Suppose that there are K quantities, $q_1, \ldots, q_K$, arranged in ascending order so that $q_k > q_{k-1}$. When a respondent picks the quantity q_k, the probability that a respondent picks this quantity is the probability that the true quantity (Q) lies between q_k and q_{k+1}:

$$Pr(choose \;\; q_k) = Pr(q_k \le Q < q_{k+1})$$

Responses to the payment card can be treated in a parametric model by specifying $\mathrm{Q} = \mu + \varepsilon$, where $\mu = f(X\beta)$. We assume linearity here for simplicity but results can be generalized to many of the models. Let $\varepsilon \sim \mathrm{N}(0, \sigma^2)$, then

$$Pr(choose \;\; q_k) = \Phi((q_{k+1} - \mu)/\sigma) - \Phi((q_k - \mu)/\sigma)$$

where $\Phi((q_{k+1} - \mu)/\sigma)$ is the standard normal cumulative distribution function (CDF) evaluated at $(q_{k+1} - \mu)/\sigma$. We can then form the log-likelihood function for the responses as:

$$\ln \mathrm{L} = \sum_{i=1}^{\mathrm{T}} \ln(\Phi((q_{k+1}(i) - \mu)/\sigma) - \Phi((q_k(i) - \mu)/\sigma))$$

where individual i picks the quantity $q_k(i)$. This is a form of an interval model, in which every individual picks some quantity.

If the question is "pick the range that describes the amount you are willing to choose", we would use the lower and upper bound of the range that is picked for the value of $q_k(i)$ and $q_{k+1}(i)$ in the likelihood function.

3.6.4 Double Hurdle Model

A Hurdle model is "a modified count model in which the two processes generating the zeros and the positives are not constrained to be the same" (Cameron and Trivedi, 1998, pp.124). The fundamental idea underlying this model is that a binomial probability model determines the binary outcome of whether the observation is zero or positive (Mullahy, 1986). If the observation is positive, the "hurdle is crossed", and the conditional distribution of the positives is determined by a truncated-at-zero count data model (Mullahy, 1986). Further, the Double Hurdle model allows for the possibility that two decisions may be affected by a different set of variables, while the Tobit model fails to analyze the factors that determine the individuals' first decision about whether to participate in the proposed market.

The Double Hurdle model allows for two kinds of zero values for the dependent variable, in other words, two types of respondents who choose the "zero" bid. The desired consumption or participation is non-positive because the respondent does not get over the first hurdle; or, if it is positive, an additional hurdle still can prevent participation since the respondent does not cross the second hurdle.

In the Double Hurdle model, the two decisions, whether to participate in the market and the level of participation, are determined by two separate stochastic processes. According to Martínez-Espiñeira (2006), the Double Hurdle model has a participation equation (D):

$$\begin{aligned} D_{\mathrm{i}} &= 1 \text{ if } D_{\mathrm{i}}^{*} > 0; \\ D_{\mathrm{i}} &= 0 \text{ if } D_{\mathrm{i}}^{*} \leq 0; \\ D_{\mathrm{i}}^{*} &= \alpha' Z_i + \mu_i \end{aligned}$$

where D^* is a latent participation variable which takes the value 1 if the respondent is willing to participate in the market, and 0 otherwise; Z is a vector of individual characteristics and α a vector of parameters. The level of participation (Y) equation:

$$\begin{cases} Y_i = Y_i^{*} \text{ if } Y_i^{*} > 0 \text{ and } D_{\mathrm{i}}^{*} > 0 \\ Y_i = 0 \text{ otherwise} \\ Y_i^{*} = \beta' X_i + \upsilon_i \end{cases}$$

where Y_i is the observed responses to the valuation question, X is a vector of the individual's characteristics and β a vector of parameters.

The decisions of whether to participate in the market and the size of Y can be jointly modelled, if they are made simultaneously by the individual;

independently, if they are made separately; or sequentially, if one decision is made first and affects the other one.

The Cragg model (Cragg, 1971) is a special case of the Double Hurdle model under the assumption of independence between the error terms μ_i and υ_i of the two hurdles, which is originally proposed by Cragg (1971) to model recreation demand behaviours. It is a two-stage model that is equivalent to a combination of a dichotomous choice model and a truncated regression model. In the first stage, a dichotomous choice model is estimated to determine whether the individual participates in the activity at the site. In the second stage, a truncated model is estimated, conditional on the first decision that the individual decides to participate. The Cragg model allows separate stochastic processes for the participation and consumption decisions (Cragg, 1971).

3.7 Conducting SP Surveys

Survey techniques are often used in SP studies as a means of collecting data. There are basically three components of any SP survey (Winpenny, 1991; Bateman et al., 2002). First, general questions are asked to determine the respondent's previous knowledge and understanding of the good or service under consideration. The hypothetical scenario is presented in the following section, as well as valuation/behaviour questions to solicit the WTP/WTA response as in CV or behaviour changes in response as in CB. The final section comprises questions about the respondent’s socio-economic characteristics. It reveals how well the survey realized sample represents the target population and therefore enables model analysis and verification of the validity of responses collected.

Surveys in SP studies may be conducted by in-person interviews, telephone interviews or mail surveys. Mitchell and Carson (1989) point out that in-person survey is the choice for most SP studies, as the physical presence of the interviewer offers the greatest opportunity to motivate the respondent to cooperate fully with the interview and allows the interviewer to probe unclear responses and to provide observational data. Compared with in-person interviews, telephone surveys limit the ability of the interviewer to motivate the participant due to the absence of the interviewer and the use of visual aids is precluded (Mitchell and Carson, 1989).

Mail surveys, which are applied in this study, are the least expensive means of collecting data. The major advantage of mail surveys over the other two approaches is the ability of avoiding the possibility of interviewer bias (Mitchell and Carson, 1989) while providing a level of anonymity. However, mail surveys do suffer the highest unit non-response rates (Schuman, 1996). As a consequence, they are more vulnerable to sample selection bias and sample non-response bias, which leads to the potential of being unrepresentative of the target population and aggregation bias when inferring aggregate welfare changes for the community (Mitchell and Carson, 1989). In addition, Mitchell and Carson (1989) argue that there is little opportunity to correct these biases due to the absence of information about the respondents who fail to return the questionnaires. Mail surveys are also limited by the literacy level of respondents as they require the respondent to first understand the description given in the scenarios. (See Appendix F for a summary of Advantages and Disadvantages of Mail Surveys).

3.8 Review of Water Valuation Studies

There have been a number of water valuation studies conducted over the past three decades, which indicate that valuation techniques have been applied extensively to a large variety of water resource functions. However, to the best of our knowledge, the CB approach was never used to estimate the value of water, in particular the value of irrigation water. Early surveys were undertaken by Young and Gray (1972) and Gibbons (1986), while more recent work includes Young (1996), Frederick et al (1997), Raucher et al (2005) and Dupont and Renzetti (2008). Renzetti (2002) provides an overview of water demands for all types of beneficial uses. There have also been a number of specific studies of the value of water in specific uses. In general, most of these studies focus on estimating values of water for recreation functions (Bateman et al., 1995; Bergstrom et al., 1990; Haener et al., 2001; Shaw and Shonkwiler, 2000), while only a few are attached to estimating the value of water in agriculture (Michelsen and Young, 1993; Veeman and Freeman, 1993; Bogess et al., 1993; Kulshreshtha and Grant, 2005).

In their review of water valuation studies, a wide variation was found by Frederick et al (1997) in estimated values across water use sectors. While not the lowest, values in the irrigation water sector tend to be much lower than those in domestic and industrial uses. A similar picture emerges from the analysis undertaken by Briscoe (1996), which reveals that the value of water used for low-value crops, such as food grains and fodder, is universally low while the value of water used on high-value crops can be higher. In addition, the value of water for household and industrial purposes is usually much higher than the value for irrigation. The value of water for environmental and ecological purposes varies widely but usually falls between the agricultural and municipal values (Briscoe, 1996).

Several valuation studies have been conducted to assess the efficiency of water allocation and estimate the value of irrigation water in the SSRB (Alberta) with work being done by Muller (1985), Kulshreshtha and Tewari (1991), Freeman (1996), Mahan (1997), Royer (1997), Horbulyk and Adamowicz (1997), Veeman et al (1997), Gheblawi (2004), Nicol and Klein (2006), Bruneau (2007), Dupont and Renzetti (2008), and Samarawickrema and Kulshreshtha (2008a, 2008b). Most of the studies involve some form of residual imputation or rent valuation approaches. Royer (1995) estimates the value of water rights within agriculture in southern Alberta using a hedonic pricing analysis and a linear programming model. Royer's model relates land sale prices to land attributes as explanatory variables. According to his study, the implicit marginal value of irrigation water is \$126/acre foot (\$0.102/ m^3), based on land transaction data between 1993 and early 1994 in southern Alberta. Royer's case study of the EID shows that overall values of water vary widely, ranging from \$8 to \$250/acre foot (\$0.006-0.203/ m^3), depending on the enterprise mix of the farm. More precisely, he argues that irrigation water values are approximately \$100 to \$350/acre foot (\$0.081-0.284/ m^3) for specialty crop farms and \$10 to \$68/acre foot (\$0.008-0.055/ m^3) for traditional farms. Nicol and Klein (2006) examine the characteristics of the temporary market for water allocations within the SMRID in southern Alberta during the 2001 drought. In their study, the prices for water transferred are found to be highly variable, ranging from \$20 to \$140/acre foot (\$0.016-0.114/m^3) with the average price \$79.06/acre foot (\$0.064/m^3). Bruneau (2007) focuses mainly on the Alberta portion of the SSRB to provide value estimates of water applied to different crops using a derived demand method. The results show that the average value of water varies from a low of \$3.24/acre foot (\$0.026/m^3) for dry beans to a high of \$922.59/acre foot (\$0.748/m^3) for potatoes, in accordance with the expectation that water is more valuable in specialty crops and less valuable in grains.

Table 3.3 provides an overview of estimated water values for agricultural functions in Canada. It is to note that few SP methods have been applied to valuate irrigation water, particularly in southern Alberta, which makes more relevant the attempt to apply a SP method in estimating irrigators' WTP/WTA of irrigation water in this region.

Table 3.3 Literature Reviews of Water Values in the Agricultural Sector

Author(s)	*Estimated Value ($/acre foot)*	*Valuation Technique*	*Region*	*Unit*	*Additional Information*
Kulshreshtha and Tewari (1991)	Short run: 62.44-127.82; Long run: 0-1.59	Derived demand function & linear programming	SSRB	1986$	Imputation based on different levels of product prices.
Royer (1995)	Marginal value: 126; Range from 8 to 250	Hedonic pricing approach & linear programming model	Alberta SSRB (EID)	1993$	Hedonic pricing analysis based on land transaction data; linear programming model used in the case study of EID.
Mahan (1997)	Range from 17.82 to 74.52	Non-linear programming model	Alberta SSRB	1995$	Three scenarios are considered in this study: no water trade, intra-regional trade and inter-regional trade.
Gheblawi (2004)	Deterministic values: 576-1632; Stochastic values: 467-1579	Discrete sequential stochastic programming model	Alberta SSRB (EID)	1997$	High estimates are attributed to overrepresentation of potatoes in the optimal crop mix of this study.
Gardner Pinfold et al (2006)	Short run: 2.43-102.87; Long run: 0-40.5	N/A	Alberta SSRB	2005$	Report prepared for the Government of Alberta, not released to the public. The value estimates presented here come from Dupont and Renzetti (2008).
Nicol and Klein (2006)	Range from 20 to 140 with average 79.06	Market-based transactions approach	Alberta SSRB (SMRID)	2001$	This study explores water market activities in southern Alberta, focusing on the temporary transfer of irrigation water allocations by surveys.
Bruneau (2007)	Range from 3.24 and 922.59 with average 156.33	Residual imputation approach	Alberta SSRB	1996$	Measures the shadow price of water delivered to the farm, not the value of raw water.
Samarawickrema and Kulshreshtha (2008a)	Range from 29.97 to 34.02 with average 32.91	Residual imputation approach	Alberta SSRB	2007$	Measures the benefits from irrigation as the difference between producer surpluses from irrigated and dryland production in a drought year, excluding the value of water for irrigated crop production in a non-drought year.
Samarawickrema and Kulshreshtha (2008b)	Short run: 31.59-42.93 with average 38.48; Long run: 13.77-20.25 with average 16.81	Derived demand functions	Alberta SSRB	2007$	The value of irrigation water is estimated as the difference between the weighted irrigated producer surplus and the weighted dryland producer surplus, divided by the volume of water used.

3.9 Summary

Among the economic valuation techniques available to value nonmarket goods and services, stated preference methods have gained popularity, especially in evaluating environmental amenities and natural resources. However, it is also the most controversial method since a variety of biases and errors could potentially affect the SP results. The fact that the SP is based on individual's "stated preference", as opposed to "revealed preference", is the source of its greatest strengths and its greatest weaknesses. More specifically, the SP is subject to a number of potential biases such as hypothetical bias and sample-related bias. In contrast to CV, CB questions focus on hypothetical behaviour rather than hypothetical values. In addition, CB has its particular strengths in the reduction of the possibility of hypothetical bias and the decreased likelihood of payment vehicle bias. The data collected from SP surveys could be censored and require more sophisticated models and econometric techniques. In the review of agricultural water valuation studies most recently undertaken in Canada, few SP studies have been applied to evaluate irrigation water, particularly in southern Alberta, which makes it more meaningful the attempt to apply a SP in estimating irrigators' WTP/WTA of irrigation water in this region.

Chapter 4

Methodology and Model Specifications

4.1 Introduction

In this chapter, the procedure of data collection and brief summaries of the dataset are first outlined. The potentially biased responses are identified and survey response rates are also presented in this section, as well as a socio-economic profile of the survey respondents. Prior to any model specifications, the characteristics of the dataset are described and a simple statistical summary is provided as a preliminary to check of whether the expected relationship between water price and water supply/demand are reflected in the data. Section Three addresses the specifications of two models used in this study: the Ordinary Least Squares (OLS) estimations and the Cragg model. Section Four draws a short summary.

4.2 Data Collection

4.2.1 Study Area

The study focuses on six irrigation districts in southern Alberta, which are Lethbridge Northern Irrigation District (LNID), Ross Creek Irrigation District (RCID), Aetna Irrigation District (AID), Leavitt Irrigation District (LID), Magrath Irrigation District (MID) and Mountain View Irrigation District (MVID).

As discussed in Chapter 2, both LNID and RCID are part of the Central group of irrigation districts in Alberta, while the other four districts are in the Southern Tributary group. Relative to the Southern Tributary group, the Central group has higher water reliability and more favourable conditions for specialty crop production. More specifically, according to Bjornlund et al (2007), it has experienced restrictions in water use during years when annual precipitation is low; while the Southern Tributary group traditionally has experienced the most frequent and the most severe restrictions to water use. LNID has contributed to the production of predominately forages (including silage barley) and cereal grains (mainly barley and wheat), and has the highest concentration of livestock in Alberta (AAFC, 2000; Rodvang et al., 2004). Part of LNID is located within the "feedlot alley" in the southern part of the province, primarily between Calgary and Lethbridge where a lot of beef cattle development has occurred (Price, 2003; Acharya, 2007).

In LNID, water allocation to irrigators is 17.5 inches per acre in a regular year (Gary Burke, LNID, personal communication, November 26, 2008). In AID, there are no water allocation restrictions to irrigators in regular years. This is also the case in LID and MID (Ralph Price, AID, personal communication, February 02, 2009). Irrigators in these districts could use as much water as they need without limitation for irrigation use individually in regular years. In 2001, irrigators in AID suffered from water scarcity and used only 11-12 inches per acre of irrigation water during the drought which was much less than the amount in a regular year (Ralph Price, AID, personal communication, February 02, 2009). In LID, irrigators used 12 inches per acre of water due to the severe water restriction in 2001 (Jason Comin, LID, personal communication, February 02, 2009).

Table 4.1 presents general information for these irrigation districts, including water source, district size, annual water allocation and water rates.

Table 4.1 Water Allocation in Study Areas in 2008

	Southern Tributary Group				*Central Group*	
	AID	LID	MVID	MID	LNID	RCID
Water Source	Belly River	Belly River	Belly River	SMRID main canal	Oldman River	Gros Ck. & Ross Ck.
Percentage of Farms Smaller than 65 ha	95	95	80	74	63	N/A
Assessment Roll Acres (Acre)	3,699	5,126	3,700	18,300	176,069	1,101
Acres Actually Irrigated (Acre)	2,361	4,763	3,509	13,420	175,886	0
Water License Allocation (Acre-foot)	9,000	12,000	8,000	34,000	334,450	3,000
Volume of Water Diverted (Acre-foot)	3,584	6,389	2,609	12,659	178,750	200
Annual Water Rate ($ per acre per year)	10.00	11.50	12.00	9.00	14.00	21.00
No. of Water Users*	95	90	37	138	664	7
Average Water Allocation (Acre-inch)**	29.20	28.09	25.95	22.30	22.79	32.70
Actual Water Use (Acre-inch)***	18.22	16.10	8.92	11.32	12.20	N/A
Regular Water Allocation (Acre-inch)****	No limit	No limit	N/A	No limit	17.5	N/A

Notes: *From the contact lists offered by the district administrations;
**Average Water Allocation (Acre-inch) =
Water License Allocation (Acre-foot)*12/Assessment Roll Acres;
***Actual Water Use (Acre-inch) =
Volume of Water Diverted (Acre-foot) *12/Acres Actually Irrigated;
****Personal communications.

Source: AAFRD (2009); Bjornlund et al (2007).

Table 4.2 identifies main crop groups grown within the study areas and in aggregate for Alberta's irrigation districts in 2008, showing a concentration of cereals and forages in these districts.

Table 4.2 Crop Mix Distribution in Study Areas in 2008

Irrigation District	*Cereals*	*Forages*	*Oilseeds*	*Specialty Crops*	*Others*
AID	5.9%	57.9%	0.0%	0.0%	36.2%
LID	8.5%	82.2%	0.0%	0.0%	9.4%
LNID	23.0%	61.4%	6.6%	4.4%	4.6%
MID	34.7%	48.6%	13.9%	2.8%	0.0%
MVID	13.0%	82.0%	0.0%	0.0%	5.1%
RCID	0.0%	100%	0.0%	0.0%	0.0%
Alberta	**33.6%**	**38.0%**	**14.4%**	**11.3%**	**2.6%**

Source: AAFRD (2009).

Irrigation growth has been accompanied by a transition of irrigation systems to more efficient, lower energy low-pressure centre pivot sprinkler systems. Table 4.3 lists the proportional distribution of on-farm irrigation systems in 2008, by irrigation districts, as well as the overall average distribution of systems for Alberta's irrigation districts.

Table 4.3 On-Farm Irrigation Systems within Study Areas in 2008

Irrigation District	***Pivot Sprinkler***	***Wheel-Move***	***Gravity***	***Other***
AID	15.8%	49.0%	20.1%	15.1%
LID	19.5%	35.2%	41.8%	3.6%
LNID	68.1%	29.6%	1.3%	1.0%
MID	45.4%	35.1%	18.4%	1.1%
MVID	0.0%	11.9%	88.1%	0.0%
RCID	3.6%	0.0%	96.4%	0.0%
Alberta	**66.8%**	**18.8%**	**13.5%**	**0.9%**

Source: AAFRD (2009).

Table 4.4 lists the historical annual water allocation in selected years (2000, 2001 and 2008), in terms of irrigation districts, which shows the variations in water allocations between irrigation districts in the same years. It reveals that irrigators in LNID and MVID did not experience restrictions in water use since their actual water use slightly increased in the drought year of 2001; while irrigators' water use decreased to approximately half of the regular use in AID, LID and MID in the same year.

Table 4.4 Water Use in Study Areas in 2001, 2002 and 2008

	Year	***AID***	***LID***	***LNID***	***MID***	***MVID***	***RCID***
Volume of Water Diverted (Acre-foot)	2000	6,000	11,240	245,976	35,375	6,700	0
	2001	3,952	7,593	275,475	21,173	6,814	0
	2008	3,584	6,389	2,609	12,659	178,750	200
Acres Actually Irrigated (Acre)	2000	2,361	4,763	154,300	15,427	3,510	0
	2001	3,155	4,763	160,657	17,520	3,510	0
	2008	2,361	4,763	3,509	13,420	175,886	0
Actual Water Use (Acre-inch)	2000	30.50	28.32	19.13	27.52	22.91	N/A
	2001	15.03	19.13	20.58	14.50	23.30	N/A
	2008	18.22	16.10	8.92	11.32	12.20	N/A
Water Restriction in 2001	--	Yes	Yes	No	Yes	No	N/A

Source: AAFRD (2009).

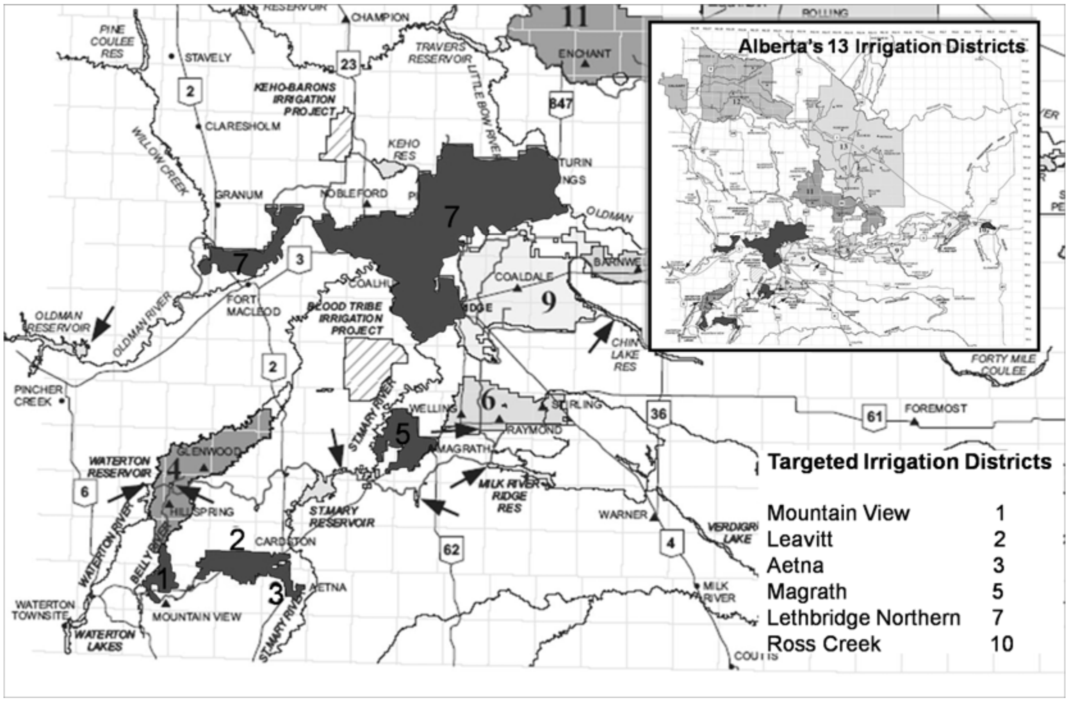


Figure 4.1 The Study Areas in Southern Alberta

Source:http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/irr4475/$FILE/irrbase.gif.

4.2.2 Survey Administration

A survey of irrigators in AID, LID, LNID, MID, MVID and RCID was conducted in the spring of 2009. The district offices in these irrigation districts were approached and asked to provide contact lists of potential participants (see Table 4.6 for details). A total of 1031 survey packages were sent out, including a one-page Information sheet, a one-page Individualized Result sheet (double sided) and one copy of the survey questionnaire (18 pages, double sided) (see Appendix A). Approximately two or three weeks after the initial mail-out, 997 reminder letters were sent to the same potential participants, excluding 34 participants who had already returned their completed surveys or responded with the notice that they did not qualify for the survey. The reminder letter served to thank all those who had already returned completed questionnaires and to encourage those who had not done so.

The survey questionnaire was developed in contingent behaviour (CB) scenarios, to elicit information relating to temporary irrigation water trade over a growing season during a hypothetical drought. The valuation question was designed as transaction cards in a format similar to payment cards which represented a contingent water market that has three dimensions: a contingent level of water scarcity, a set of water prices and, for each price, a series of water quantities. Given a drought scenario, at each water price, the respondent was asked to check their choice of market participation (whether to sell, to buy, or not to trade any water) and then circle the appropriate amount of water they would be willing to trade, conditional on their first decision. Each respondent was presented with four scenarios, each with a different water price in an increasing order. Furthermore, they were asked to consider each scenario independently of the others.

Hence, rather than directly asking one to place a value on irrigation water, the respondents was allowed to choose whether to participate in the water market or not, giving a water shortage level and water price; if choosing participating in the market, the respondent was given the opportunity to mitigate water shortage or to dispose excess water for additional income as needed. This allowed the respondent to indicate by their behaviour the value they placed on irrigation water during droughts.

The survey questionnaire was designed as a double-sided booklet of 18 pages with a design and title on the front cover and an open-ended comment section on the back. The survey was divided into 3 sections:

1. The first section solicited information regarding current farming patterns, on-farm irrigation system mix and the crop mix intended for sale in 2008.

2. The second section, beginning with a short cheap talk, solicited information about irrigation water values by asking people to participate in a temporary water market during a hypothetical drought.

3. The third and final section solicited information on the respondent's socio-economic characteristics and a set of farm specifics (e.g. gender, age, education, household size, employment status, farming operation roles, etc.), followed by an open-ended question where respondents were free to express any opinions or comments about the survey.

In the Information sheet, a short introduction about our study was provided informing the participant of the purpose for soliciting the information and the importance of providing a completed questionnaire. In the Individualized Result sheet, participants had the option to provide their address and request an individualized result related to their decision to trade. This was to ensure that they understood the contribution they made towards the evaluations of irrigation water resource in their district, and to provide them added incentive to complete and return the survey.

Table 4.5 Survey Administration Procedure

	AID	*LID*	*LNID*	*MID*	*MVID*	*RCID*	*Total*
Initial Sample Size	95	90	664	138	37	7	1031
Survey Mail-out (D/M/Y)	17/02/09	17/02/09	18/02/09	22/04/09	03/04/09	26/03/09	1031
Reminder Letter Mail-out (D/M/Y)	12/03/09	12/03/09	12/03/09	14/05/09	14/05/09	14/05/09	997

4.2.3 The Contingent Behaviour Question

The second section of the survey questionnaire presented four transaction cards, intended to assess irrigators' willingness to trade water in response to a hypothetical drought that required water rationing. Within each transaction card, a hypothetical drought scenario and the going rate of water were described and participants were asked to consider trading options based on their farming experience and farming operation.

Under the assumption of a significant drought in the region, three trading options were available to each irrigator: (i) Sell some (or all) of the irrigation water the individual has to another irrigator within the district; (ii) Buy additional inches for every irrigable acre that the individual farms from another irrigator within the district; (iii) Choose not to trade. Under the given water endowment and each going rate of water, participants were asked to first check the trading option they chose and then circle the appropriate water quantity they would like to trade in the column under the corresponding trading option, conditional on their first decision.

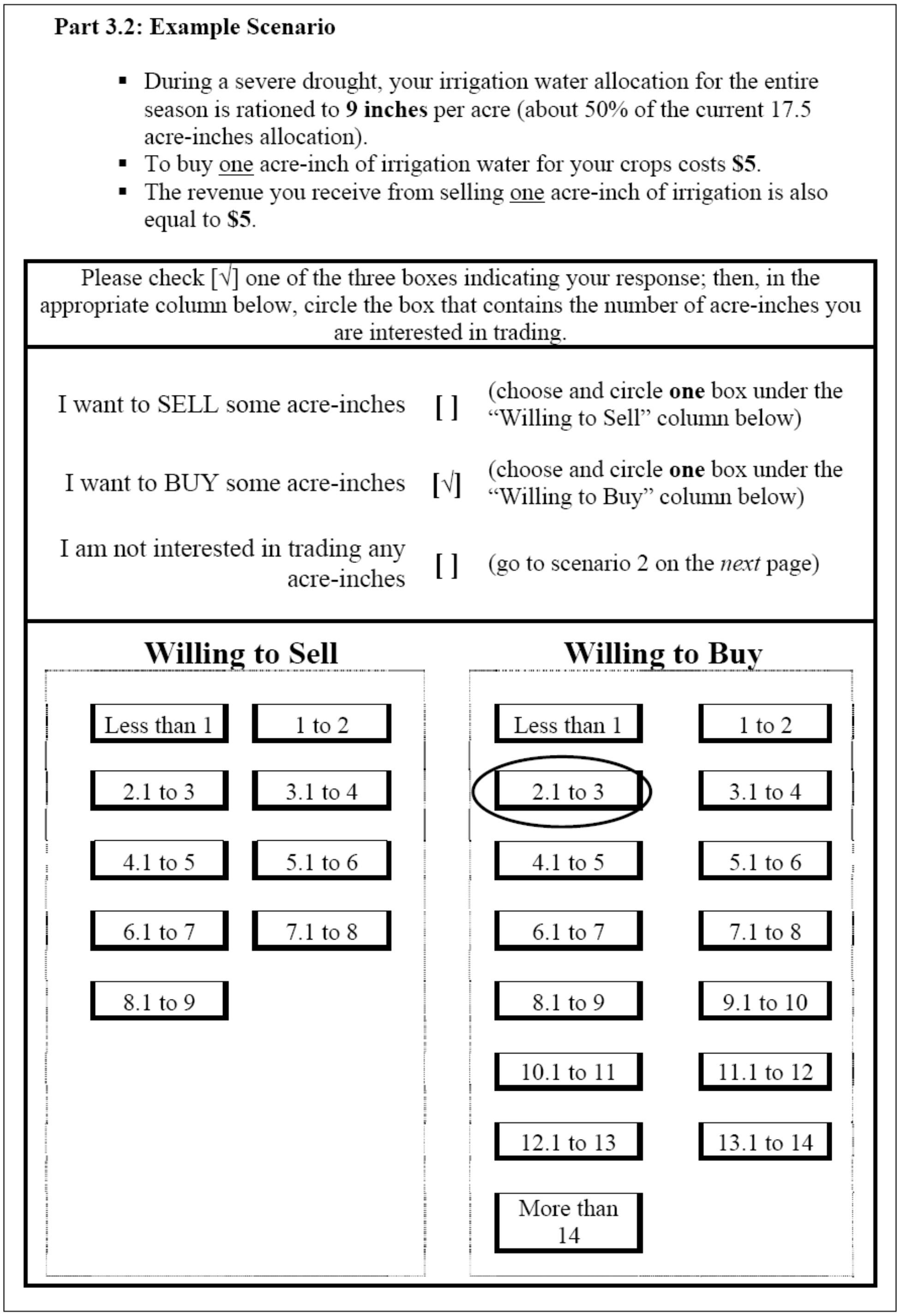
Each participant was given four transaction cards with a fixed water endowment and four slightly increasing water prices. Each transaction card was presented on a single page with an accompanying scenario at the top of the page. Respondents were asked to carefully read the scenarios to ensure they were fully aware of the severity of the hypothetical drought before they started to fill in the transaction cards. Furthermore, they were asked to consider each scenario independently of the others, taking into account the irrigable acres they were currently farming as well as all their relevant crop needs. It was clearly stated that the trade would only last for one growing season.

Three versions of the questionnaire were developed with different initial water endowments in order to identify varied willingness to trade water under different severities of droughts, as well as to make the hypothetical drought scenarios more realistic: (i) High severity of drought scenarios in which initial irrigation water allocations in the district were rationed to 6 acre-inches; (ii) Median severity of drought scenarios with irrigation water rationed to 9 acre-inches; and (iii) Low severity of drought scenarios with water rationed to 12 acre-inches. Each irrigation district was assigned up to three versions of the questionnaire. The range of water quantity and water price used on the transaction cards in our application was designed to cover the likely range of responses, based on a literature review and personal communications with professionals.

Table 4.6 Design and Distribution of Drought Scenarios in Questionnaires

Drought Severity	***Water Endowment*** *(Acre-inch)*	***Irrigation District***	***Water Price*** *($ per acre-inch)*				***Sample Size***
Low	12	LNID	2	4	6	8	222
Median	9	AID	4	6	8	10	475
		LID	5	7	9	11	
		LNID	3	5	7	9	
		MID	4	6	8	10	
High	6	LNID	9	11	14	18	334
		MID	9	11	14	18	
		MVID	9	11	14	18	
		RCID	9	11	14	18	

To avoid confusion, an example of transaction cards was presented to familiarize participants with this type of question before presenting the hypothetical drought scenarios.



Part 3.2: Example Scenario

- During a severe drought, your irrigation water allocation for the entire season is rationed to **9 inches** per acre (about 50% of the current 17.5 acre-inches allocation).
- To buy one acre-inch of irrigation water for your crops costs **$5**.
- The revenue you receive from selling one acre-inch of irrigation is also equal to **$5**.

Please check [√] one of the three boxes indicating your response; then, in the appropriate column below, circle the box that contains the number of acre-inches you are interested in trading.

I want to SELL some acre-inches [ ] (choose and circle **one** box under the "Willing to Sell" column below)

I want to BUY some acre-inches [√] (choose and circle **one** box under the "Willing to Buy" column below)

I am not interested in trading any acre-inches [ ] (go to scenario 2 on the *next* page)

Willing to Sell

Less than 1
1 to 2
2.1 to 3
3.1 to 4
4.1 to 5
5.1 to 6
6.1 to 7
7.1 to 8
8.1 to 9

Willing to Buy

Less than 1
1 to 2
[✓ 2.1 to 3]
3.1 to 4
4.1 to 5
5.1 to 6
6.1 to 7
7.1 to 8
8.1 to 9
9.1 to 10
10.1 to 11
11.1 to 12
12.1 to 13
13.1 to 14
More than 14

4.2.4 Protest Zero Responses

Protest zero response occurs when respondents reject some aspect of the contingent market scenario by reporting a zero value even though they place a positive value on the amenity or resource being valued (Freeman, 1936). Desvousges et al (1987) argue that the logic of the traditional utility maximization model suggests two types of zero bidders should be classified as protest bidders: the respondents who consciously reject the contingent market setting and will not search their preferences and those who lack the capacity to respond (due to education, language barriers, etc.). The suggested way to identify true zero responses and protest zeros is to include follow-up questions in the survey. The approach is to ask every respondent who gives a zero value to indicate a reason for doing so. Responses of those who choose a specific statement would be classified as protest zeros and deleted from the analysis data, while responses of those choosing the other statements would be considered valid zeros.

In this study, the follow-up question is:

Please answer this question ***only if you chose not to trade*** *in any of the above scenarios.*

Which statement best expresses your reason for choosing not to trade?

[ ] I. I can get by with my ration of water.

[ ] II. I cannot afford to pay more than I already do to have access to the extra water.

[ ] III. It is unfair or immoral to expect irrigators to pay more money for access to the extra water during droughts.

[ ] IV. I would not be able to easily find another member within my district to trade water with.

[ ] V. I would rather leave the surplus in the canals and rivers for conservation reasons than sell it.

[ ] VI. I don't believe that this type of trading regime will exist.

[ ] VII. None of the above, *please specify* ______________________________

Responses of those choosing Statement (III) were classified as protest zeros and excluded from the sample, while responses of those choosing any of the other statements were considered valid zeros.

More specifically, respondents who gave "NOT TRADING" responses to all of the four transaction questions were excluded from the sample for valuation analysis if they (a) indicated they did not understand the valuation question well (e.g. provided confusing responses to the transaction cards), (b) indicated they were no longer farming any land (e.g. rent out all the land to other farmers or just using water to gardening), (c) did not fill in the transaction cards, or (d) protested the concept of water rights trading by choosing Statement (III) to the follow-up question. This last group was excluded because they could not be defined as true zero bidders. Respondents who gave NO responses are included in this analysis if they chose any of the reasons from the follow-up question but Statement (III) or they (a) indicated the initial offer was too high but they did have some value for irrigation water, (b) indicated a zero value for irrigation water trading, or (c) said they did not know how much irrigation water would be worth to them. Thus, 30.3% of the total 66 NO respondents were excluded. More specifically, 20 protest responses in total were excluded from the sample, with 2, 3, 13 and 2 responses from the district AID, LID, LNID and MID, respectively.

4.2.5 Response Rates

Mitchell and Carson (1989) identify the proper way to calculate response rate for a mail survey as dividing the number of returned questionnaires[2] by the initial sample size. This approach shows how well one has done in reaching all potential respondents (Dillman, 1978), by including in the non-responses both the sample members who no longer live at the address listed as well as those who received the questionnaire but failed to return it. Another approach frequently used for determining the response rate is to calculate the percentage of valid

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[2] Includes questionnaires that are mostly completed, but which are missing responses to the CV elicitation questions. The number of questionnaires usable for directly estimating the WTP is therefore often lower than the number given.

contacts with eligible respondents that result in completed questionnaires (Dillman, 1978).

In this study, response rates are calculated in both ways, namely, the general and the effective response rates. The latter is calculated by dividing the number of completed questionnaires valid for valuation analysis by the valid sample size. The formulas for the response rates are as follows:

$$\text{General Response Rate} = \frac{\text{number returned}}{\text{number in initial sample}} \times 100\%$$

$$\text{Effective Response Rate} = \frac{\text{number valid for valuation}}{\text{number in initial sample - (noneligible + nonreachable)}} \times 100\%$$

Of the 1031 surveys sent to irrigators within the six targeted irrigation districts in southern Alberta, 10 were returned because of inappropriate addresses which reduced the total sample size to 1021 individuals. 155 individuals responded either by returning their completed or partially completed questionnaires or by call and email, giving a general response rate of 15.0%. More specifically, 19 individuals responded by call or email and 14 individuals responded by mail, indicating the reason that they did not participate in the survey: they were no longer farming any land, or they were not able to participate. 122 individuals returned their completed or partially completed questionnaires, which provided the dataset for the analysis of irrigators' farming patterns, irrigation system mix, crop mix, and socio-economic characteristics. No responses were removed because of incompleteness or suspicion of bias effects, because such effects are a concern only for the modeling of irrigation water valuation. Each returned survey was assigned an identification number in the dataset to ensure confidentiality.

For the valuation analysis, the dataset was subject to inspection for completeness (item non-response) and potential bias sources. As a result, 10 responses out of 122 returned surveys were removed from the dataset due to suspected bias effects, of which 8 respondents were no longer farming land and 2 respondents provided confusing transaction card responses; 2 responses were removed since they did not fill in the transaction cards; 20 responses were removed after being defined as protest zeros. As a result, 90 returned surveys were selected for the valuation modeling with an effective response rate of 8.8%.

Table 4.7 Summary of Survey Response Rates in Terms of Irrigation Districts

	Southern Tributary Group				***Central Group***		***Total***
	AID	LID	MID	MVID	LNID	RCID*	
Initial Sample Size	95	90	138	37	664	7	1031
Valid Sample Size	92	90	137	37	658	7	1021
Responses for General Analysis	13	13	14	2	80	0	122
Responses for Valuation Analysis	11	8	10	2	59	0	90
Response Rate for General Analysis	14.1%	14.4%	10.2%	5.4%	12.2%	0.0%	11.9%
Response Rate for Valuation Analysis	12.0%	8.9%	7.3%	5.4%	9.0%	0.0%	8.8%
Total Responses				155			
General Response Rate				15.03%			
Effective Response Rate				8.8%			

Note: *RCID is excluded from the sample in the following studies since no responses were received from this district.

4.2.6 Respondents' Demographics and Farm Characteristics

The third and final section of the survey questionnaire was designed to collect information on the respondents' socio-economic and farm characteristics including gender, age, education, household size and income, off-farm employment status, their roles in farming operations, farm size, crop mix and irrigation techniques. Therefore, it was possible to construct a socio-economic profile of the survey respondents and to examine the sample's representation of the targeted population.

Table 4.8 presents the characteristics of the respondents, the number of responses and the percentage of each characteristic as well as the sample mean for that characteristic. Table 4.9 lists the general characteristics of the respondents' farms, including the percentage and sample mean for each farm characteristic.

In this study, the majority of survey respondents (94%) were males. While the provincial average age of farm operators is 52.2 years (Statistic Canada, 2008), the participants were slightly older in age with an average of 57 years. Over a half of the respondents are 55 years old or over (58%) while 38% of them are between

35 and 54 years. The majority were farm owners (91%) as half were operators (50%). The educational level of farmers varied from junior high school education to professional post-graduate degrees. The majority of the respondents (68%) had at least a technical diploma or a university degree while the others had a junior high or high school education. Most respondents (65%) were living within a household of fewer than 4 persons. The majority (86%) had been involved in irrigated farming for more than 10 years. 46% reported their 2007 annual gross household income over \$100,000, followed by 29% between \$60,000 and 99,999, and 25% under \$60,000. Over a half of the individuals (59%) reported their households were involved in some off-farm work as another important source of income. In addition, 83% of the respondents had no household members who had ever taken any formal irrigation training offered by the Alberta government[3] and 90% had never been involved in any water trading transactions since 2000[4]. 70.7% of the respondents were affiliated with some environmental organizations, agricultural clubs or watershed groups.

In addition to the demographics of the respondents, the characteristics of their farms were also reported in the survey. Geographically, in terms of irrigation districts, 66% of the respondents came from the LNID (the Central group). Farm sizes varied widely in acres from less than 10 acres to over 1,600 acres with an average of 288.4 acres in total. Additional land rental was reported by 22 individuals out of 155, rented lands varied in size from less than 10 acres to over 1,000 acres with an average of 289 acres. The majority (77%) of rented lands were between 10 and 499 acres. Over a half of the respondents (59%) raised some livestock on farm while 71% raised crops for sale in 2008. Unsurprisingly, most of the respondents raised more than one crop and adopted more than one irrigation technology. The majority (90%) did hold some irrigable land in 2001.

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[3] Any irrigation training programs (e.g. Alberta Irrigation Management Program given by the Irrigation Branch of AAFRD).

[4] This excluded the water transfers between 2 parcels that belong to the same household.

About 47% participated in the CAIS[5] program and only 11% had a local food process contract in 2008 and 2009.

To determine the specific demographics of irrigators that played different roles in water markets, the breakdown of respondents by trading decisions[6] is also explored (see Appendix F). It indicates that among the respondents selected for valuation analysis, the buyers are slightly younger than the sellers, have a larger household size and a higher level of education on average. 84.4% of the buyers have a technical diploma or a higher degree, compared to 68.7% for the sellers. Besides, the buyers are slightly more experienced in farming operations and less engaged in off-farm employment. They usually operate larger farms in scale with an average of 395.4 acres and have a much larger scale of rented land. A larger proportion of the buyers are involved in the CAIS program as well. Both the buyers and the sellers have a very small proportion of people holding food processing contract in 2008 and 2009. The majority of them have no experience in water trading.

In addition, it also indicates that there is a tendency that water markets induce the transfer of water from less productive to more productive users and from less efficient to more efficient irrigation systems. More specifically, in terms of crops, the buyers in the survey raised more specialty crops and oilseeds while the sellers raised more forage, indicating that water would be transferred from lower to higher valued crops. Furthermore, a greater proportion of the buyers raised livestock on farm than did the sellers. In terms of irrigation technologies, the buyers operated more efficient irrigation systems than did the sellers, indicating that water moves from less efficient to more efficient irrigation equipment. Thus, water use efficiency and productivity may be enhanced by water trading.

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[5] The Canadian Agricultural Income Stabilization (CAIS) program, which is designed to provide Canadian agricultural producers with an on-going whole-farm risk management tool that provides protection against large drops in farming income (AFSC).

[6] In this case, the participant is identified as a buyer/ seller/ zero bidder if he/she chose to buy/sell/not trade water at least in one transaction card in the survey without taking into account of switches among different roles.

Table 4.8 General Characteristics of the Respondents (n=122)

Characteristics	*N*	*%*	*Sample Mean*	*Characteristics*	*N*	*%*	*Sample Mean*
Age				**Farming Experience**			
Under 35 Years	5	4.3%					
35-54 Years	45	38.1%	56.7	≤ 10 Years	16	14.2%	28.1
55 Years and Over	68	57.6%		≥ 11 Years	97	85.8%	
Gender				**Off-farm Work**			
Male	111	94.1%		Yes	69	59.0%	
Female	7	5.9%		No	48	41.0%	
Household Size				**2007 Annual Gross Household Income**			
Under 4 Persons	76	65.0%	3.29	Under $60,000	28	25.2%	$86,599
4 Persons and Over	41	35.0%		$60,000-99,999	32	28.8%	
				$100,000 and Over	51	45.9%	
Education				**Farming Operation Role**	**117**		
High School and Under	38	31.7%		Owner	106	90.6%	
Technical Diploma and Over	82	68.3%		Operator	58	49.6%	
				Manager	46	39.3%	
Irrigation Training				**Trade Experience**			
Yes	20	16.8%		Yes	12	10.1%	
No	99	83.2%		No	107	89.9%	
Membership							
Yes	53	70.7%					
No	22	29.3%					

Table 4.9 General Farm Characteristics of the Respondents (n=122)

Characteristics	*N*	*%*	*Sample Mean*	*Characteristics*	*N*	*%*
Farm Size (Acres)						
Under 10	3	2.5%		**Crops for Sale 2008**		
10-69	31	26.3%				
70-129	16	13.6%		Yes	85	70.8%
130-239	20	16.9%	288.4 Acres	No	35	29.2%
240-399	18	15.3%				
400-559	12	10.2%		**Crop Mix**		
560-759	7	5.9%		Cereal	58	66.7%
760-1,119	6	5.1%		Oilseed	23	26.4%
1,120-1,599	4	3.4%		Specialty	18	20.7%
1,600 and Over	1	0.8%		Forage	58	66.7%
Rent Acres				**Irrigation Technology**		
Under 10	1	4.5%				
10-99	6	27.3%		Low-pressure Pivot	46	38.7%
100-299	7	31.8%	289 Acres	Wheel Move	79	66.4%
300-499	4	18.2%		Gravity	25	21.0%
500-699	1	4.5%		Others	31	26.1%
700-999	2	9.1%		More than One Technology	56	47.1%
1000 and Over	1	4.5%				
Irrigation District						
AID	13	10.7%		**CAIS Participation**		
LID	13	10.7%				
LNID	80	65.6%		Yes	53	46.5%
MID	14	11.5%		No	61	53.5%
MVID	2	1.6%				
Holding land in 2001				**Food Contract in 2008**		
Yes	107	89.9%		Yes	13	11.3%
No	12	10.1%		No	102	88.7%
Livestock in 2008				**Food Contract in 2009**		
Yes	70	58.8%		Yes	13	11.6%
No	49	41.2%		No	99	88.4%

4.2.6.1 Sample Representivity

Whether or not the sample of individuals obtained through the random survey procedure is representative of the larger targeted population, (in this case, the population of irrigators in southern Alberta), is essential if we are going to generalize the findings from the survey sample. A series of *t*-tests are explored here to assess the survey sample's representivity of the targeted population. Sample means are compared to the population means for selected major characteristics. Table 4.10 presents the results of the *t*-tests with the significance of the sample *t*-tests displayed in the final column. Taking the characteristic of education as an example, the null hypothesis that the sample mean and population mean are equal would be rejected at the 0.1 but not 0.05 level of confidence. Depending on the desired level of confidence (0.05 for example), the null hypothesis could not be rejected for the characteristics of household size, education and off-farm work but would be rejected for age, gender, household income and average farm size. Therefore, one could conclude that in general, the sample and population means are significantly different in our study.

Table 4.10 T-tests for Sample Population Representivity

Characteristic	*N*	*Degree of Freedom**	*Sample Mean*	*Population Mean***	*T-Test Statistic*	*Significance (2 tailed)*
Age	118	117	56.7	52.2	3.763899	0.000
Gender	118	117	0.94	0.70	10.98943	0.000
Household Size	117	116	3.29	3.1	0.794213	0.500
Education (≤High school)	120	119	31.7%	50%	-1.78006	0.100
Annual Gross Household Income (CAD$)	111	110	86,599	61,942	70231.43	0.000
Average Farm Size (Acres)	118	117	288.4	1,055	-24.3734	0.000
Off-farm Work	117	116	0.59	0.546	0.963434	0.400

Notes: *The variation in the degrees of freedom (N-1) is reflective of item non-response;
**Data for the population of farmers in the province of Alberta, obtained from *2006 Census of Agriculture*, Statistics Canada.

Therefore, the analysis of sample representivity indicates that the survey respondents, though randomly sampled, are not well representative of the population of irrigators in the province of Alberta. This may be a direct consequence of non-response bias in the survey.

4.2.7 Data Characteristics

Since each participant was presented four different drought scenarios and was asked to complete four transaction cards, four water transactions were observed for each individual at varying water prices within the same time frame. Therefore, the data collected from the survey have a structure similar to panel data but not exactly in terms of the time series dimension. Panel data are cross sectional and time series; but in this case, the data are cross sectional with each individual providing four observations at four different prices.

In addition, the data have a substantial proportion of zero observations. Over a half of the respondents stated zero bids, i.e. chose not to trade water at all in four transaction cards, which indicates that a large number of responses are clustered around the value zero. This could be because those respondents did not accept the provided prices to sell or buy any water, or because they lacked the ability to participate in the water market.

Furthermore, the transaction card was designed in a similar format of payment card, in which the respondent was asked to pick a range of water quantity if he/she was willing to trade. Therefore, the responses collected in this study provided information on the upper and lower bound of the amount that the individual was willing to trade, but not the exact amount, in other words, the dataset provides the water quantity in the form of intervals other than point values.

4.2.8 Determination of Price Change Effect on Water Supply and Demand

Generally, out of the 90 surveys finally selected for the valuation modeling analysis, 42 (46.7%) are from the median severity of drought scenarios while 27 (30%) and 21 (23.3%) are from the high and the low severity scenarios, respectively. 43 respondents chose to participate in the market as sellers or buyers at least once out of four transaction scenarios, while the other 47 bid zeros in all transactions. Some respondents played different roles in the market, switching among water buyers, sellers and zero bidders as the price of water changed.

More specifically, there are 9 pure sellers in the hypothetical market who were water sellers in all scenarios, of which 8 respondents even fixed their amounts of water supply to the market regardless of price changes. Of the 9 pure sellers, in terms of drought severities, 6 are from the median severity of drought scenario while 2 from the high severity and 1 from the low severity.

17 respondents are pure water buyers in all transactions. 3 of these chose to fix their demand regardless of price changes, while the other 14 responded to price changes in an expected way with the demand for water decreases when the price goes up. In terms of drought severities, 8 respondents are from the median severity of drought while 8 from the high severity and 1 from the low severity.

In addition, 17 respondents chose to play different roles in the market along with increasing water prices in the transactions. More specifically, 10 respondents first chose to buy some water at low prices and then quit the market (as zero bidders) when the price increased, while 5 respondents switched from being buyers at low prices to sellers at higher prices and the other 2 switched from zero bidders to sellers as prices went up. Of these 17 respondents, 7 are from the median severity of drought while 6 are from the high severity and the other 4 are from the low severity.

It is expected in this study that changes in water prices will probably affect the amount of water traded as well as the trading choice. This is evident in the survey responses. Where water prices changed, some irrigators responded by altering their water supply and/or demand and some even switched their roles in the market. However, the data also reveal that there is little flexibility between water prices and supply on the supply side. On the demand side, the demand for water is more elastic to prices in our sample. This is evident in Table 4.11, where the correlation coefficient between water price and water quantity traded is positive but weak for supply and negative and stronger for demand. In total only 3 out of 16 sellers (18.8%) responded to price changes; while 19 out of 32 buyers (59.4%) responded to price changes in an expected way.

Table 4.11 Correlation Matrix of Price and Quantity of Water Traded

Initial Water Endowment	***12 acre-inches***		***9 acre-inches***		***6 acre-inches***	
	Water Quantity					
	Demand	Supply	Demand	Supply	Demand	Supply
Price	-0.25654	0.04044	-0.10316	0.03418	-0.13921	0.15633

Furthermore, based on experience from other countries like Australia, market activity has tended to increase as water supply constraints intensify. In our study, out of 43 market participators, 21 respondents are from the median severity of drought, 16 from the high severity and 6 from the low severity. Therefore, 59.3% of the respondents in the high severity of drought and 50% in the median severity chose to participate in the water market compared to 28.6% in the low severity. This is consistent with our expectation that when water scarcity is getting worse, water markets become more active. In terms of irrigation districts, 26 irrigators (44.1% of the respondents from LNID) from the Central group participated in the market while 17 (54.8%) from the Southern Tributary group chose to participate. In the Central group, 7 respondents (11.9%) were sellers and 22 (37.3%) were buyers; in the Southern Tributary group, 9 respondents (29.0%) were sellers and 10 (32.3%) were buyers.

The distributions of responses on both supply and demand sides for water regarding levels of water scarcity are summarized in Appendix G.

4.3 Model Specifications

Using the midpoints of the intervals provides a simple way to deal with the interval censored data. However, this would not reflect the uncertainty regarding exact values within each interval, nor would it deal adequately with the left- and right-censoring issues in the data.

The Double-Hurdle Cragg model and the Tobit model could be used to deal with the censored survey data. Both models propose a hybrid of a discrete choice model and a censored regression model. The Cragg model allows for the possibility that two decisions may be affected by different sets of determinants. Therefore, it allows that the decisions to participate in the market and the levels of participation are determined by two separate stochastic processes. In contrast, the Tobit model fails to analyze the factors that determine the individuals' first decision about whether to participate in the market.

Therefore, the OLS estimations with midpoints replacing intervals and the Double-Hurdle Cragg model were chosen and estimated based on the dataset to estimate irrigation water supply and demand in this study. Each model has its own pros and cons which were already discussed in Chapter 3.

4.3.1 Determinants of Irrigation Water Supply and Demand

In the study of water trading practices in SMRID in 2001, Nicol and Klein (2006) summarize that the basis for trading water allocations in SMRID depends on the range of crops grown, the differences in their water requirements, and their values in terms of crop prices as well as water prices and the severity of water scarcity. The severity of water scarcity gives farmers their initial water endowments, which determine their water demand and supply in the water market. Intensifications in the severity of droughts, i.e. decreases in initial water endowments, are expected to have significant effects on market activities. On the demand side, the demand for water is expected to increase, while on the supply side, the supply of extra water to decrease. In this study, different levels of severity of a hypothetical drought (expressed as water *Allocation*) were designed and presented in the survey questionnaires, along with various water prices, to examine irrigators' market activity responses to varied initial water endowments and water prices.

Increases in water *Price* have two effects. On the demand side, a reduction in purchase of extra water, provided that the purchase of water is positive, and a reduction in participation in water markets as buyers. On the supply side, price increases lead to an increase in selling surplus water, provided that the supply of water is positive, and an increase in participation in the market as sellers.

To identify different effects of varied water endowments on market activities and further on water values, three intercept dummy variables (*Dum1, Dum2, Dum3*), representing three levels of initial water endowments (6, 9 and 12 acre-inches, respectively), and three slope dummies (*Dum1_p, Dum2_p, Dum3_p*), representing the corresponding products of intercept dummies with water prices, are created in the models to capture the effects of water endowments on water trading through parallel shifts and slope changes on the demand/supply curves. As a consequence, the net effect of price on water supply and demand at different water scarcities would be captured by the coefficient estimation of the variable *Price* at the initial endowment of 12 inches/acre, the coefficient add-up of the variables *Price* and *Dum1_p* at 6 inches/acre and the coefficient add-up of *Price* and *Dum2_p* at 9 inches/acre, respectively.

Water requirements of crops vary widely among crop types. Crops such as potatoes and sugar beets require more water for optimal production than do others (AAFRD, 2001). Crops with higher water consumptions also yield higher net returns (AAFRD, 2001), which provides a strong incentive for growers of these crops to ensure that they have adequate water. Generally, specialty crops require the most consumptive water and yield the highest net returns to water, which produce the strongest incentive for growers to participate in water markets. Hence, crops raised in 2008 were reported in the survey and classified into four major categories: cereals, oilseeds, forages and specialty crops. This enables the proportion of acreage devoted to each crop to be specified and that of *Specialty Crops* is highlighted in this case.

Farm Size, in terms of irrigable acreages, also affects market activities as well as farming activities. Nicol (2005) confirmed in her study that water sellers in SMRID in 2001 had fewer irrigated acres than buyers. Besides, if farmers rent some irrigable land (expressed as *Rent Acres*) from other farmers for cropping businesses, they may have more of an incentive to participate in the water market to ensure adequate water for crop requirements.

The location of a farm determines some of its natural resource endowments for irrigated farming, such as soil types, climates and water supply reliability. As discussed above, the surveyed irrigation districts can be grouped into the *Central* (LNID) and Southern Tributary (expressed as *South*) (AID, LID, MID and MVID) groups due to geographic distributions and similar natural resource endowments. Natural resource endowments such as water supply reliabilities vary widely across the two groups.

In addition, on-farm water use efficiency, which relates to the fraction of water delivered to the farm that actually reaches the root zone of crops (Bjornlund et al., 2007), determines the total water demand on a farm and thus relates to the decision of trading water allocations. The greater the efficiency, the less water is lost to evaporation, surface run-off and seepage. Therefore less applied water is needed for crops. There are several ways for farmers to increase on-farm water use efficiency, including the replacement of on-farm irrigation systems by more efficient ones, improved scheduling knowledge of water irrigation, and other improved management techniques (Bjornlund et al., 2007).

The water delivery efficiency of on-farm *Irrigation Systems* varies widely with gravity systems the lowest and low-pressure pivot systems the highest. Hence, efficiency gains can be made by shifting from gravity to wheel move and further to pivot irrigation systems. Nicol and Klein (2006) summarize that water tends to be transferred from sellers using relatively inefficient irrigation systems to buyers using relatively more efficient systems. Therefore, one might expect that water may move from lower to higher efficiency irrigation systems and from low to high value uses.

Moreover, water use efficiency is also related to farmers' operational and/or other management techniques which have a significant influence on the profitability of crops and efficiency of water use (AIPA, 2002). Irrigators are found to benefit from having knowledge about water holding characteristics of their soils, as well as operational parameters of their irrigation systems through formal *Education* and irrigation *Training*. Yields are increased when the crop is properly irrigated, and water use efficiency can be improved when water is not lost to evaporation, surface relocation, surface runoff, etc. (AIPA, 2002). With evidence provided by AIPA (2002), irrigation management training has been shown to be beneficial to irrigators, particularly those using center pivot irrigation systems. Poor management or design of the on-farm irrigation network may offset gains from conversions of irrigation systems.

Farmers face various uncertainties in terms of weather, yields, prices, government policies, global markets, and other factors, which may cause fluctuations in farm incomes. Farm risk management plays an essential role in farming business and farm-level production decisions. There are several available strategies for farmers to manage farm risks such as enterprise diversification, financial leverage, production contracting, crop yield insurance and household off-farm employment or investment (Harwood et al., 1999). Most producers have used a variety of these farm risk management strategies, which may affect farmers' decisions about water market participations as well.

Raising *Livestock* may intensify water scarcity on the farm during droughts. However, as one possible enterprise diversification strategy, it also offers a way to increase household income in terms of returns from livestock operations. Farms with irrigated cropping activities frequently engage in livestock production (58.8% of the respondents in the survey), relying in part on forages and feeds produced on the same farm. Hence, additional irrigation water supplies could produces more feeds and forages for the livestock and may provide a better way to raise income through farm livestock operations than in the crop market. As a consequence, raising livestock on farms is expected to play a significant role in farmers' water market participation decisions.

As one form of on-farm risk managements, half of the respondents in the survey participated in the Canadian Agricultural Income Stabilization (*CAIS*) Program, which is delivered provincially in Alberta by Agriculture Financial Services Corporation (AFSC). Introduced in 2003, the CAIS program is designed to provide Canadian agricultural producers with an on-going risk management tool that provides assistance in dealing with short-term income fluctuations. It incorporates a whole-farm stabilization and disaster mitigation approach in which producers and governments share the costs. As a consequence, farmers participating in the CAIS program undertake less income fluctuation risks from crop operations and thus may have more incentive to sell water for additional income and less incentive to purchase any water.

Water markets provide irrigators with more flexibility to manage their water. More specifically, sellers may consider the market as an opportunity to earn additional income by selling excess water, while buyers could manage a short-term water shortage by temporarily purchasing water allocations. Holding *Food Processing Contracts* in a drought year could play as a powerful incentive for crop producers to participate in water markets, which is an effective way to ensure adequate water for higher valued crops during droughts.

Furthermore, socio-economic characteristics of farmers may play an important role in farming operations and market participation as well. Previous research (Bakshi and Chen, 1994; Riley and Chow, 1992; Knight et al., 2003) shows that there may be a significant relationship between risk aversion and individual characteristics such as age, gender and other characteristics. There is heterogeneity of risk aversion among individuals with different demographics.

Age has long been hypothesized to affect an individual's degree of risk aversion. It has been confirmed in many studies that risk aversion will increase over the lifecycle (Bakshi and Chen, 1994). Older farmers are considered to be more risk averse than younger farmers. Nicol (2005) found that on average, water buyers during the drought in SMRID in 2001 were 7 years younger than sellers. Furthermore, age is expected to have different effects on water demand and supply. Regarding selling water in the market, age is hypothesized to be positively associated with the selling decision and the quantity of water supply; on the other hand, age may have negative effects on farmers purchasing water in the market. Besides, age is usually expected to positively correlated with farmers' education and farming experience.

Evidence in previous research indicates that there is a significant *Gender* difference in risk taking with women being more risk averse than men (Riley and Chow, 1992). On average, as farm owners or managers, women may make more conservative decisions than men in farming operations. Hence, it is reasonable to expect that women are prone to sell excess water for generating additional income and less incentive to purchase additional water to bear more risks in crop operations.

Based on previous research, risk aversion is positively correlated to *Household Size* in financial decisions (Brunello, 2002). However, this may be controversial in farming operations. Two opposing interpretations can be given to the relationship between the degrees of risk aversion and household size (Ajetomobi and Binuomote, 2006). On one hand, the larger the size of the family, the higher are the subsistence consumption needs and the more risk averse are the farmers. On the other hand, family size might determine the labour capacity of the household on the farm, in which case a larger family implies greater availability of labour and a greater capacity to generate off-farm income and thus a greater risk tolerance.

In terms of gross household *Income*, previous studies have confirmed that farmers' risk aversion decrease with income (Knight et al., 2003), i.e. farmers with higher household income have a greater capacity for risk tolerance. Moreover, household income determines the capacity of flexibility in farming operations in which case, the higher the household income, the larger the flexibility in dealing with risks and the less the vulnerability to income fluctuations. As a significant component of household income, *Off-farm Income* provides a more stable income source for the household during a drought year and has been confirmed to significantly decrease risk aversions (Knight et al., 2003).

Education of farmers is found to decrease risk aversion. On one hand, irrigators benefit from having knowledge about characteristics of their soils and irrigation systems on the farm through formal education and specific irrigation training. Therefore, farmers with a higher level of education and irrigation training are hypothesized to have stronger abilities to manage their farms appropriately and promote their farm productivity and on-farm water use efficiency. They are also prone to try new things and incorporate new advances in research and development into their production practices, and to participate in water markets. On the other hand, education helps increase farmers' access to various sources of household income, indicating that farmers with higher education can more easily become involved in off-farm business or employment.

Farming Experience measures the number of years that a farmer has been involved in irrigated farming operations. It is expected to be correlated with a greater intensity of participation in water markets, as sellers in particular, because more experienced farmers are expected to be more knowledgeable about irrigated farming and their farms' water demand in general. Like the effects of education and irrigation training, more experienced farmers are hypothesized to have stronger management abilities and are more capable of handling situations of droughts, e.g. managing irrigation schedule more appropriately to mitigate water scarcity.

Water Trading Experience also helps farmers have a better understanding of the concepts and procedures of trading water in the market. Farmers would benefit from such experience and become more sophisticated when facing similar situations of droughts. Besides, such experience would highlight the benefits of improving on-farm water productivity in which irrigators are more motivated to promote water use efficiency and to prepare themselves for market participation.

Irrigators who have *Membership* in agricultural and environmental associations or institutions may have broader information sources and have easier access to other services. Specifically, it reduces transaction costs in terms of information seeking, encouraging irrigators to participate in water markets.

The *Ownership* of a farm may also affect its farming operations. Farmers who own their farms usually play a decision making role in their farm operations. Tavernier et al (1997) has confirmed that ownership even plays a significant role in farm operators' off-farm employment decisions. Therefore, the ownership of farms is expected to play a significant role in the decisions regarding water market participation during a severe drought.

4.3.2 Description of Variables

According to the specification of determinants of irrigation water supply and demand, the explanatory variables in this study are classified into three groups, namely, “drought and market conditions”, “farm characteristics” and “farmer characteristics”. The first group of the variables include water rationing (initial water endowment) and water price as well as six dummy variables. Farm characteristics include farm size, rental land acres, farm locations, crop pattern, adopted irrigation systems and other information; farmer characteristics contain age, gender, education, household size, farming experience, trading experience, membership, income, off-farm income, etc.

Unfortunately, the data collected in the survey did not have much variation for some of the determinants discussed above, partly because of low response rates. For example, among the 90 respondents selected for valuation analysis, 98.9% were males (with only 1 female respondent), 92.2% held land in 2001 and did not have any water trading experience and 90% were owners of their farms. In addition, although 17.8% of these respondents had participated in some formal irrigation training, none of them elected to sell water in the survey, preventing us from estimating the effect of irrigation training on the decision to sell water.

Among those who chose to sell water in the survey, only 1 respondent had rented some land from others which also made the estimation of the effect of rental land on the decision to participate in water trading impossible.

In addition, to avoid exact collinearity, 4 variables were dropped from the models. For example, the variable “*Gravity*” was excluded as well as “*Central*”. As a consequence, for regression analysis 23 explanatory variables were selected out of a potential 32, based on data and the category of variables. Table 4.12 displays a list of the subset of these selected variables used in the models, along with their definitions and descriptive statistics.

Table 4.12 Variables and Descriptions

Variables	*Description*	*Mean*	*S.D.*
Dependent Variables			
Trade	The quantity of water willing to trade (mid-point values of the interval) (acre-inches)	--	--
Choice	Y=0, 1, 2 (representing zero bidders, sellers and buyers, respectively)	--	--
Category	The category code from 1 up to 15 for each interval	--	--
Explanatory Variables			
Hypothetical Drought and Market Conditions			
Allocation	Initial water allocation (inch/acre)	8.80	2.185
Price	Water price (CAD$/acre-inch)	8.21	4.191
Dum1	=1 if the initial water allocation is 6 inches/acre and 0 otherwise	0.30	0.459
Dum2	=1 if the initial water allocation is 9 inches/acre and 0 otherwise	0.467	0.499
Dum3	=1 if the initial water allocation is 12 inches/acre and 0 otherwise (the reference group in the model)	0.233	0.423
Dum1_p	Product of Dum1 and Price	3.90	6.249
Dum2_p	Product of Dum2 and Price	3.144	3.733
Dum3_p	Product of Dum3 and Price (the reference group)	1.167	2.378
Farm Characteristics			
Farm Size	Current irrigable acreages of farm (1,000 acres)	0.314	0.002
South	=1 if farm located in LID, MVID, MID and AID, and 0 otherwise	0.344	0.476
Pspecialty	Proportion of acreage devoted to specialty crops intended for sale in 2008	0.0484	0.166
Specialty	=1 if raising specialty crops and 0 otherwise	0.144	0.352
Low Pivot	Proportion of acreage using low-pressure pivot system	0.298	0.391
Gravity	Proportion of acreage using gravity system (the reference group in the model)	0.118	0.314
Other Irrigation	Proportion of acreage using other irrigation systems (e.g. medium and high-pressure pivots, etc.)	0.413	0.406
Livestock08	=1 if raising any livestock intended for sale in 2008 and 0 otherwise	0.584	0.494
CAIS	=1 if participating in the Canadian Agriculture Income Stabilization (CAIS) program in 2007 and 0 otherwise	0.529	0.499
Contract08	=1 if holding a local food processing contract in 2008 and 0 otherwise	0.116	0.321
Farmer Characteristics			
Age	The age of the respondent (years)	56.0	11.52
Household Size	The number of people living in the household	3.45	2.19
Income	2007 annual gross household income (10,000 CAD$)	7.99	3.69
Off-farm Income	=1 if anyone in the household performs off-farm work and 0 otherwise	0.614	0.487
Education	=1 if the respondent has post-high school education and 0 otherwise	0.68	0.468
Farming Experience	The number of years involved in farming	27.7	13.46
Membership	=1 if affiliated to any agricultural/environmental associations or institutions and 0 otherwise	0.478	0.500

4.3.3 Explanatory Variable Selection for Models

Choosing which variables to include in the second-hurdle models of irrigation water supply and demand is made easier using LIMDEP's forward stepwise regression method that we used along what economic theory suggests. In this study, the explanatory variables in both supply and demand equations were selected via a mix of economic theory and forward stepwise regression from the set of potential contributing variables in Table 4.12. According to the literature, the determinants *water price, farm size, household income, crop type* and *farming experience* may have essential impacts on water supply and demand, which were selected before starting the statistic regression selection. As a result, slightly different sets of explanatory variables were selected to describe irrigation water supply and demand depending on the data characteristics, literature review and the statistical evaluation process, which means water supply and demand are determined by different variables.

Table 4.13 Explanatory Variables Chosen for Supply and Demand Equations

Explanatory Variables	***Supply Equation***	***Demand Equation***
Price	√	√
Dum1_p	√	√
Dum2_p	√	√
Farm Size	√	√
Pspecialty	√	√
Income	√	√
Farming Experience	√	√
Other Irrigation	√	√
Dum2	√	
Livestock08	√	
CAIS	√	
Low Pivot		√
Contract08		√
Off-farm Income		√
South		√

4.3.4 Ordinary Least Squares (OLS) Estimations

A constant coefficients OLS regression and a random effects OLS regression were specified for both supply and demand equations. In these models, midpoints of the intervals are used with the dependent variable TRADE.

The general model: $y_{it} = \alpha + X_{it}^{'}\beta + \varepsilon_{it}$

where i indicates the individual and t indicates the price offered to the individual on the transaction card and $\varepsilon_{it} \sim IID(0, \sigma_{\varepsilon}^{2})$.

4.3.4.1 The Constant Coefficients Regressions

In the constant coefficients or pooled regressions, both intercepts and slopes of the explanatory variables (α and βs) are set constant across individuals. The data were pooled to run the OLS estimations using midpoint values for the dependent variable.

So the specifications in this case are:

$$\begin{aligned}
&\text{Supply Equation:}\\
&\text{TRADE}_{\text{it}} = \alpha + \beta_1 \Pr ice + \beta_2 Dum1\_p + \beta_3 Dum2\_p + \beta_3 Dum2 + \beta_4 Farmsize + \beta_5 Pspecialty\\
&\qquad + \beta_6 Otherirrigation + \beta_7 livestock08 + \beta_8 CAIS + \beta_9 Income + \beta_{10} Far\min g\exp erience\\
&\qquad + \varepsilon_{it}\\
&\text{Demand Equation:}\\
&\text{TRADE}_{\text{it}} = \alpha + \beta_1 \Pr ice + \beta_2 Dum1\_p + \beta_3 Dum2\_p + \beta_3 Farmsize + \beta_4 Pspecialty + \beta_5 Lowpivot\\
&\qquad + \beta_6 Otherirrigation + \beta_7 Contract08 + \beta_8 Income + \beta_9 Far\min g\exp erience\\
&\qquad + \beta_{10} \text{Off\_farm income} + \beta_{11} South + \varepsilon_{it}
\end{aligned}$$

4.3.4.2 The Random Effects Regressions

In this case, the data were composed by 90 respondents with each individual providing four observations. There may be heterogeneity across individuals which could be analyzed by random effects regressions. The random effects regressions explore differences in error variances for individuals, assuming the same intercept and slopes across individuals.

So the general models become $y_{it} = \alpha + X_{it}^{'}\beta + (\mu_i + \upsilon_{it})$

where $\mu_i \sim IID(0, \sigma_{\mu}^{2}), \upsilon_{it} \sim IID(0, \sigma_{\upsilon}^{2})$ and the μ_i are independent of the υ_{it}.

The major differences between the constant coefficients estimations and the random effects estimations are the specification of the error term and whether the data are pooled or not.

4.3.5 The Cragg Model

One of the particularities of this dataset is that there are a substantial proportion of zero observations. When using the OLS estimations (in Section 4.3.4) to analyze the data, non-participants are excluded from the dataset. This would exaggerate participation rates and result in the loss of potentially useful information about the participation decision (Martínez-Espiñeira, 2006). The Cragg model, as one special case of double hurdle models, can be introduced to deal with survey data that are characterized by a cluster of zero observations on a continuous dependent variable.

A hurdle mechanism is introduced to explain the decision to enter the water market. The underlying assumption in this model is that irrigators make two decisions with regard to their willingness to trade irrigation water in the temporary water market. The first decision is whether they will participate in the water market. The second is about the amounts of water they are willing to trade, either to sell or to buy, conditional on the first decision. The Cragg model allows for the possibility that two decisions may be affected by different sets of variables. Therefore, the decisions to participate in the market (to buy or sell irrigation water) and the levels of participation (stated amounts of water for trading) could be determined by two separate stochastic processes.

The model allows for two kinds of zero values for the dependent variable, or two types of individuals for whom $y = 0$. Some irrigators may not participate in the market under any water rations and prices and never get over the first hurdle. Others do trade their water under other market conditions (they are participators in the market) but for some reason optimally choose not to trade at the given water price and initial water allocation. These irrigators do not get over the second hurdle.

The Cragg model is explored in which case the multinomial logit (MNL) choice model in the first hurdle and interval censored regressions in the second hurdle, are combined and jointly estimated for total seasonal demand/supply of irrigation water during a hypothetical drought. The MNL model is used to examine decisions to allocate among three trading options simultaneously while the interval censored regression approach can easily handle estimates of amounts for each option (to sell/buy).

4.3.5.1 First Hurdle: Multinomial Logit Model

The Multinomial Logit (MNL) model is first developed to estimate the probabilities of participation in the water market, i.e., whether an irrigator chooses to sell, buy or not trade water.

The general form of the choice probabilities in the model is

$$\text{MLOGIT:} \qquad P_{ij} = \frac{\exp(\beta_j^{'} x_i)}{\sum_{m=0}^{J} \exp(\beta_m^{'} x_i)}, j = 0, ..., J$$

where i indicates the individual, j and m indicate the choices, and P_{ij} is the probability of individual i choosing alternative j. The x_i stands for the characteristics of individual i, β and α denote for the corresponding parameter vectors, respectively. J is the number of alternatives and j=0 is the benchmark category ("not interested in trading any water" in this case). A convenient normalization is $\beta_0 = 0$.

$$\text{MLOGIT:} \qquad P_{ij} = \frac{\exp(\beta_j^{'} x_i)}{1 + \sum_{m=1}^{J} \exp(\beta_m^{'} x_i)}, j = 0, ..., J, \beta_0 = 0$$

The estimated coefficients (βs) show the effect of the x variables on the probability of choosing each alternative (to sell/buy) relative to one alternative that serves as a benchmark (not to trade any water). For the benchmark category, the corresponding probability is $1 \big/ \sum_{\mathrm{m=1}}^{\mathrm{J}} \exp(\beta_m^{'} \mathrm{x}_{\mathrm{mi}})$, since $\beta = 0$ and $\exp(0) = 1$. The model is based on the assumption that the error terms follow an extreme value distribution and are independent across alternatives (independence of irrelevant alternatives, IIA).

The dependent variable in our application is CHOICE which takes a value of 1 if the respondent is willing to sell some water, 2 if willing to buy, and 0 otherwise. The explanatory variables, listed in Table 4.13, include water prices and allocations, socio-economic characteristics of the respondents and their farms.

4.3.5.2 Second Hurdle: Interval Censored Regressions

In the survey, conditional on being willing to trade some irrigation water, irrigators were further asked to indicate the amounts of water they are willing to trade. The payment card approach in this case provides value responses in the form of intervals rather than point values. Irrigators who have crossed the first hurdle and are willing to trade water choose from a menu of water quantity ranges, indicating the range in which their amount of willingness to trade falls. Therefore, each response provides information on the upper and lower bound of the amount they are willing to trade, but not the exact value. When a dependent variable is categorical, the OLS estimations can no longer produce the best linear unbiased estimator (BLUE); that is, the OLS estimates are biased and inefficient. Hence, interval censored regression estimations[7] are developed to model values of willingness to pay/accept in the water market.

There are two subgroups in the data, supply and demand. In each subgroup, there are up to 15 categories, one category for each amount interval listed on the payment cards in the survey. The dependent variables are CATEGORY and for comparison purposes, the explanatory variables are set the same as those in Section 4.3.4 for supply and demand equations, respectively (see Table 4.13).

4.4 Summary

In this study, the data were collected through mail surveys to six irrigation districts in southern Alberta. With the general response rate of 15%, 155 individuals responded and 90 respondents were selected for the water valuation analysis, which made it possible to construct a demographic profile for the survey

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[7] LIMDEP 9.0 provides a standard routine for estimating interval censored data models with the GROUPEDDATA command.

respondents and to test the sample representivity of the targeted population. However, the analysis of representivity indicates that the survey respondents are not well representative of irrigators in the province of Alberta, which may be a direct consequence of low response rate in the survey. It is evident in our study that changes in water prices affect the amount of water traded as well as the trading choice. Prior to any modeling specification, a simple statistical summary was conducted. This indicated that there was an expected relationship, though not strong, between water prices and supply/demand, and the demand for water was more elastic to prices than the supply in our sample. Based on the data characteristics of clustered zero responses and interval censored survey data, the OLS estimations and Double-Hurdle Cragg model were specified and conducted in this study. For the models using midpoints of the intervals, constant coefficients OLS regressions and random effects OLS regressions were conducted for the supply and demand equations, respectively; for the Cragg model, a MNL model was developed in the first hurdle to estimate the probabilities of participation in the water market and in the second hurdle, interval censored regressions were conducted for both supply and demand equations to estimate the amounts of water traded.

Chapter 5

Results and Discussion

5.1 Introduction

In this chapter, prior to presenting the empirical results, some econometric issues are first explored in the next section, namely multicollinearity, heteroscedasticity and heterogeneity. Section Three addresses the model results, the OLS estimations and the Cragg model, respectively. In the OLS regressions, constant coefficients regressions and random effects regressions are performed on both the supply and demand sides; in the Cragg model, a random effects multinomial logit model is used for the first hurdle and interval censored regressions for the second hurdle. Section Four presents estimates of water supply and demand curves and values of irrigation water in southern Alberta. The price elasticity of water demand is also explored in this section, as well as a comparison of water values found in the literature. Section Five concludes the chapter.

5.2 Econometric Issues

5.2.1 Multicollinearity

Some degree of multicollinearity among variables was expected in the models, particularly between variables such as *Age* and *Farming Experience*. The correlation coefficients among the variables were explored and are listed in Table 5.1. Only those correlations that exceeded an arbitrarily chosen value of 0.3 (in absolute value) are presented.

The results support the conclusion that *Allocation* is strongly correlated with *Price* and strong negative correlations also exist among irrigation systems, which was expected. However, the majority of variables show low correlations in this case. The absolute values of these correlation coefficients among variables are not surprisingly large, most of which are around 0.3 and 0.4. Multicollinearity is thus not a major concern in this study.

Table 5.1 Selected Sample Correlation Coefficients between Variables

Variable	*Variable*	*Correlation*
Allocation	Price	-0.72956
Allocation	Specialty	0.34125
Allocation	Forage	-0.33069
Farm Size	Low Pivot	0.47844
Farm Size	CAIS	0.43501
Farm Size	Income	0.37143
Farm Size	Off-farm Income	-0.36837
CAIS	Cereal	0.37555
CAIS	South	-0.31491
CAIS	Low Pivot	0.30970
CAIS	Gravity	-0.32313
CAIS	Age	-0.35269
Age	Household Size	-0.30178
Age	South	0.31730
Cereal	South	-0.34580
Gravity	South	0.43451
Gravity	Other Irrigation	-0.41167
Low Pivot	Other Irrigation	-0.60283

5.2.2 Heteroscedasticity and Heterogeneity

An assumption of homoscedasticity would indicate that the error variance is constant in the population, conditional on the explanatory variables (Wooldridge, 2006). The assumption of homoscedasticity is not appropriate when the variance changes within the population, in which case the error process is called heteroscedastic. In that case, the optimality of OLS for value estimates would not be affected; however, the t statistics derived from the parameters' estimated standard errors would not be reliable as well as their confidence interval estimates. Furthermore, if there is heteroscedasticity, the Gauss-Markov theorem, which proves the optimality of least squares among linear unbiased estimators of the regression equation, does not hold any more (Wooldridge, 2006). In that case, the OLS estimators are no longer BLUE (Best Linear Unbiased Estimator).

Besides, since the dataset in this study is similar to panel data, individual heterogeneity may exist and have deterministic effects on value estimations. With an intent to achieve a trade-off between the efficiency of estimates and the level of heterogeneity accommodated by models, random effects models were developed to capture cross-sectional (individual) heterogeneity which can be modeled as part of the error structure.

To test for heteroscedasticity, a Breusch-Pagan Lagrange Multiplier (LM) test is derived to identify the presence of heteroscedasticity and to find out which specification is preferred, the constant coefficients or random effects OLS regressions. The null hypothesis of the random individual effects model in this case is that the variance component for randomness across individuals is zero. If the null hypothesis is not rejected, the constant coefficients model is appropriate and the assumption of homoscedasticity is appropriate. In that case, the unobserved individual heterogeneity cannot be captured by random effects models. With a large test statistic χ^2, the null hypothesis could be rejected in favour of random effects models, which also provides evidence of the presence of heteroscedasticity and heterogeneity.

On the demand side, since the LM test statistic is 58.93 with one degree of freedom, we would reject the constant coefficients OLS regression in favour of the random effects regression; on the supply side, with the test statistic of 27.55, we would also reject the constant coefficients OLS regression. The result supports the presence of significant individual heterogeneity regarding the decision of how much water they are willing to trade, which is captured in error terms of random effects models. It also suggests that the variances vary across individuals, which is ample evidence of heteroscedasticity in both demand and supply data.

As a consequence, the random effects models, which capture individual heterogeneity to some degree by exploring error variance structures, are possibly preferred to the constant coefficients regressions in this study. In addition, the LM test results suggest the presence of heteroscedasticity in the dataset, indicating that standard errors in the constant coefficients regressions are inappropriate and require appropriate adjustments in calculations. Accordingly, heteroscedasticity-robust standard errors for the estimated coefficients are preformed.

5.3 Model Results

In this study, a total of 4 observations were generated per respondent, one observation per vote in the transaction scenarios. Since 90 surveys were eventually selected for valuation analysis, this generated a total of 360 observations. Specifically, 209 observations were zero bids, 49 observations of supplying water, and 102 observations of demanding water. Out of the 90 irrigators, 16 were sellers and 32 were buyers in at least one of the hypothetical transaction scenarios.

Data analysis was performed using the software package LIMDEP. The OLS regressions and the Cragg model were estimated, with different subsets of explanatory variables selected by the forward stepwise regression method discussed in Chapter 4.

As noted, different sets of explanatory variables were selected for the supply and demand equations, showing that the decisions of water supply and demand may have different determinants. For instance, raising livestock on farm and the participation in the CAIS program play significant roles in the supply equations but not in the demand. In contrast, food contract, off-farm income and the location of farms significantly contribute to the demand equations but not to the supply equations.

5.3.1 The OLS Regressions

Using the midpoint of each valuation interval on the payment card as the proxy of the dependent variable, the OLS regressions were estimated in this section. When estimating both supply and demand equations, in each case, "basic" models (Model 1 and Model 2) with only a constant and price and its derivative variables were estimated as well as "full" models (Model 3 and Model 4) with a subset of explanatory variables previously determined (see Chapter 4, Table 4.14). In terms of pooling data or not, a constant coefficients model and a random effects model were estimated to identify individual effects. The results of these OLS estimates are presented below (Table 5.2 and 5.3) for water supply and demand, respectively.

5.3.1.1 Supply Equations

In the supply equations, the variables *Dum1_p*, *Dum2_p* and *Price* are statistically significant at the 1% level of confidence in Model 1. However, except for *Dum1_p* in Model 3, the three variables are not significant in any other models. This may be a direct consequence of the supply being inelastic to price in this case. The inelasticity of water supply to price indicates that irrigators who possess excess water during droughts would consider water markets as an additional income opportunity and are motivated to sell their excess water.

The parameter estimate of *Dum2* is positive and significant at the 1% level in both Model 3 and 4, indicating that irrigators are more likely to sell some water in the drought scenario with 9 acre-inches water endowment (the median severity of drought) than in the other two scenarios. Along with intensified water scarcity, water prices in the transaction cards are increasing as well. The provided water prices in the scenario of 12 acre-inches endowment (the low severity scenario) are too low to provide irrigators enough incentive to sell water, even though they may have more excess water. In contrast, in the scenario of 6 acre-inch endowment (the high severity scenario), irrigators suffer more from water constraints and are less likely to have excess water.

Pspecialty is strongly negative and significant in both "full" models, which means that irrigators raising specialty crops are less likely to sell water. As expected, the results show that the higher the proportion of land used for specialty crops, the less irrigation water is sold.

The variable *Other Irrigation* is negative and significant at the 1% level. Other than low pivot and gravity irrigation systems, irrigators using other irrigation technologies, such as wheel move, sell less water and the higher the proportion of land irrigated by these technologies, the less irrigation water is sold.

Livestock08 is surprisingly positive and significant at the 5% level, indicating that irrigators raising livestock sell more water. This is inconsistent with what was expected. One possible explanation is that during severe droughts, people may be more inclined to sell water and rely more on revenue from the water market than from either livestock operations or growing crops.

As expected, *CAIS* is positive and significant at the 1% level. As a crop yield insurance to manage on-farm risks, irrigators who participate in the CAIS program share the costs of short-term income fluctuations with the provincial government. As a consequence, those irrigators have more incentive to sell water and obtain additional income.

Income is negative and significant at the 5% level in Model 3 but not in Model 4. With higher household income, irrigators have a greater capacity of risk tolerance and a larger flexibility in farming operation decisions. They are less vulnerable to income fluctuations, thus have less incentive to sell any water for additional income. Besides, farmers with higher household income are frequently involved in off-farm employment, which also provides a stable income source.

Farming Experience is positive and significant at the 1% level, which indicates that more experienced irrigators sell more water. Farmers with more experience are supposed to be more knowledgeable about irrigated farming and have stronger management abilities and experience with irrigation scheduling and farming operations. Therefore, as expected, they are more capable to mitigate water scarcity and can spare some limited quantities of water, though the magnitude of the impact is not that strong in this case.

Farm Size is not significantly different from zero in both full models, similarly for the other unselected potential variables in the models.

Table 5.2 Results of OLS Regressions (Supply Equations)

Variable	*Basic Models*		*Full Models*	
	Model 1 Constant Coefficients Regression	**Model 2** Random Effects Regression	**Model 3** Constant Coefficients Regression	**Model 4** Random Effects Regression
Dependent Variable = TRADE				
Intercept	5.26552***	4.74200***	-2.05880	-3.64180*
	(1.07571)	(.64468)	(1.42854)	(1.95678)
Price	-0.49104***	-0.02541	-0.11583	-0.03532
	(.17172)	(.06749)	(.12367)	(.08338)
Dum1_p	0.42252***	0.05511	0.26252**	0.09210
	(.11785)	(.07309)	(.12159)	(.08904)
Dum2_p	0.60181***	0.07151	0.08421	0.07550
	(.08358)	(.07264)	(.14473)	(.09204)
Dum2			8.62913***	8.33672***
			(1.41126)	(1.54384)
Farm Size			-3.49669	-1.36669
			(4.16006)	(4.04706)
Pspecialty			-21.7026**	-30.9675***
			(8.92829)	(11.52786)
Other Irrigation			-2.78306***	-3.46172***
			(.49428)	(.98434)
Livestock08			1.97045***	1.93805**
			(.63338)	(.83744)
CAIS			3.80973***	4.33148***
			(.51063)	(1.04445)
Income			-0.18627*	-0.14423
			(.098746)	(.12304)
Farming Experience			0.11612***	0.17660***
			(.035123)	(.04528)
No. of Obs.	49	16 individuals	45	15 individuals
Degrees of Freedom	45		33	
Adjusted R^2	0.1898439	0.362415	0.7591575	0.785651
Log Likelihood	-111.7237		-68.93820	

Notes:

i) ***, **, * indicates statistical significance at 1%, 5%, 10% level, respectively;

ii) Standard errors in parentheses. For constant coefficients models, robust standard errors in parentheses are provided.

5.3.1.2 Demand Equations

In the demand equations, the variables *Price, Dum1_p* and *Dum2_p* are statistically significant at either the 1% or 5% levels of confidence with expected signs in all models. This indicates that the expected negative relationship between water demand and price has been reflected in the models, which is that the demand for water decreases as price increases. Furthermore, the effects of initial water endowments on water trading activities have also been captured in the models through slope changes rather than parallel shifts of demand curves. Graphically, the demand curves are downward sloping; when water scarcity intensifies, i.e. the initial water endowment decreases from 12 acre-inches to 6 acre-inches, the demand curves become flatter and flatter (see Figure 5.1). In other words, when water becomes scarcer, irrigators need to pay more to purchase the same amount of water in the market, which is consistent with demand theory.

Unlike in the supply equations, *Farm Size* is significantly positive in the demand equations, indicating that irrigators with larger farms need to purchase more water during droughts. They are usually more involved in large-scale farming operations and have more incentive to maintain adequate water for crop needs.

Pspecialty is positive but surprisingly, not statistically significant in the demand equations. It seems that the production of specialty crops does not provide a significantly strong incentive for the growers to purchase more water.

As expected, among irrigation technologies, *Low Pivot* and *Other Irrigation* systems are both strongly negative and statistically significant at the 1% level. Since low pivot and other irrigation systems, other than gravity, have higher on-farm water use efficiencies in general, less water is lost on farms due to evaporation loss, surface run-off and other technical wastes. As a consequence, crops irrigated by more efficient systems require less applied water, thus less water needs to be purchased during droughts.

The variable *Contract08* is negative and significant at the 1% level in Model 3 but not in Model 4. As discussed, holding a food processing contract may provide a powerful incentive for crop producers to participate in water trading in order to manage short-term water shortage. In this case, irrigators holding food contracts in 2008 seem to purchase less water, which is not consistent with what we expected.

Household *Income* is found to be insignificant in both models while *Off-farm Income* is negative and significant at either the 1% or 10% levels. In contrast to household income, off-farm income plays a more significant role in irrigators' water trading decisions in this case. It provides a more stable source of income for the household especially during a drought year and households with off-farm income are less likely to engage in large-scale farming operations and therefore demand less irrigation water.

Farming Experience is significant and weakly negative in both models, indicating that more experienced irrigators purchase less water in the market. As discussed, superior irrigation scheduling knowledge and management ability of farming operations can be effective in improving on-farm water use efficiency. Irrigators with more farming experience are usually more knowledgeable and have stronger management abilities in irrigated farming. Thus, they are more capable of mitigating water scarcity through water use efficiency improvements.

In terms of location effect, *South* is positive and strongly significant at the 1% level. As expected, irrigators from the South Tributary group tend to purchase more water than those from the Central group. The South Tributary group has lower water reliability and less favourable conditions for crop productions and thus has traditionally experienced the most frequent and the most severe restrictions in water use. So it is expected that irrigators from the South Tributary group would acquire more water.

Table 5.3 Results of OLS Regressions (Demand Equations)

Variable	*Basic Models*		*Full Models*	
	Model 1 Constant Coefficients Regression	**Model 2** Random Effects Regression	**Model 3** Constant Coefficients Regression	**Model 4** Random Effects Regression
Dependent Variable = TRADE				
Intercept	5.35279*** (1.00749)	6.98178*** (.66301)	20.4133*** (1.84490)	20.3838*** (3.44575)
Price	-0.65520*** (0.20739)	-0.57022*** (.13942)	-0.71278*** (.13209)	-0.54071*** (.14745)
Dum1_p	0.63059*** (.14485)	0.34829** (.14248)	0.50860*** (.12401)	0.31115** (.15254)
Dum2_p	0.77165*** (.10371)	0.31485** (.14738)	0.46888*** (.12164)	0.28915* (.15376)
Farm Size			3.26682*** (.71529)	3.05357** (1.30689)
Pspecialty			1.18373 (1.47154)	0.40034 (2.53709)
Low Pivot			-12.3307*** (1.07697)	-12.9949*** (2.38904)
Other Irrigation			-10.6360*** (0.90392)	-11.1483*** (2.15274)
Contract08			-2.85255*** (0.92302)	-1.99140 (1.53739)
Income			-0.05436 (.068191)	0.01289 (.12918)
Farming Experience			-0.10630*** (.027927)	-0.10513** (.04412)
Off-farm Income			-1.44369*** (.49253)	-1.65178* (.92454)
South			3.19717*** (.62475)	2.97792*** (.94139)
No. of Obs.	102	32 individuals	95	30 individuals
Degrees of Freedom	98		82	
Adjusted R^2	0.0630781	0.0040	0.6761003	0.708938
Log Likelihood	-271.7624		-198.7021	

Notes:

i) ***, **, * indicates statistical significance at 1%, 5%, 10% level, respectively;

ii) Standard errors in parentheses. For constant coefficients models, robust standard errors in parentheses are provided.

5.3.2 The Cragg Model

5.3.2.1 First Hurdle: Market Participation Equation

Random effects multinomial logit (MNL) models were estimated to explore the relationship between individual-specific characteristics and water market participation. Four models were estimated with different subsets of explanatory variables, with an intent to explore the determinants of irrigators participating in water markets: a basic model with only water allocation and price (Model 1), one with farm characteristics added to the basic model (Model 2), one with irrigator demographics added (Model 3) and a "full" model with all potential determinants (Model 4).

In the MNL models, the category of zero bidders was chosen as the benchmark and coefficients of all explanatory variables on the supply and demand sides were estimated relative to the benchmark category. Therefore, it's important to keep in mind that the effects of all determinant variables on the probabilities of being water sellers or buyers were estimated relative to the benchmark (i.e. the category of zero bidders).

On the supply side, *Allocation* (i.e. initial water endowment) is significant at the 5% level in Model 1 but not in the other three models. In contrast, on the demand side, it is significant at the 1% level in all models with the expected sign. The initial water endowment is supposed to play a significant role in irrigators' decisions about market participation. As water endowment increases, irrigators may be more likely to sell water in the market and less likely to buy any, of which the latter is evidenced in this study. The negative sign on *Allocation* on the demand side indicates that irrigators are found to be less likely to purchase irrigation water when water endowment increases, which is not surprising.

Price is significant with expected signs on its coefficients for both supply and demand sides at varied levels of confidence, i.e. positive on the supply side and negative on the demand side. This is consistent with the "law of supply and demand"[8] as water allocation is set to be transferable as a private good during droughts. It is evident here that when the price of water increases, irrigators are more likely to enter the market as sellers and less likely to be buyers.

Farm Size is negative and significant at the 5% level in Model 2 on the supply side; on the demand side, it is strongly positive and significant at the 1% level in both Model 2 and Model 4. This indicates that irrigators with larger farms are less likely to enter the market as sellers but more likely to enter as buyers, though the effect of farm size on the probability of irrigators choosing to be sellers, compared to zero bidders, is not that strong.

South is not statistically significant either on the supply side or on the demand side, indicating that there is no significant location effect on irrigators' decisions about market participation in the sample.

As expected, *Livestock08* is significantly negative in Model 2 on the supply side and significantly positive on the demand side. Irrigators with livestock on farms in 2008 are found to be less likely to enter the market as water sellers and more likely to enter as buyers. As discussed above, on-farm livestock requires water and therefore intensifies the impact of water shortage during droughts. On the other hand, livestock operations may provide a better income opportunity, as a powerful incentive for irrigators to obtain adequate water. As a consequence, irrigators with livestock are more motivated to purchase water during droughts to maintain their livestock operations.

Specialty is significantly positive in Model 4 on the demand side but not on the supply side. As a dummy variable of whether irrigators raising specialty crops or not, the results suggest that raising specialty crops has a significant and positive effect on irrigators being water buyers but no significant effects on them being sellers. In other words, irrigators who grow specialty crops are more likely to purchase water in the market.

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[8] In economics, the "law of supply" is the tendency of suppliers to offer more of a good at a higher price; the "law of demand" states that consumers buy more of a good when its price decreases and less when its price increases.

In terms of irrigation systems, compared to gravity systems, *Low Pivot* is strongly positive and significant in Model 2 and 4 on the demand side but not on the supply side, while *Other Irrigation* is strongly negative and significant in Model 2 and 4 on the supply side and significantly positive in Model 2 on the demand side. This suggests that, compared to gravity irrigation, the adoption of low pivot irrigation systems significantly increase the probability of irrigators entering the market as buyers but has no significant effect on the supply side. In contrast, the adoption of other irrigation systems, other than low pivot and gravity systems, significantly lowers the probability of irrigators being water sellers and increases the probability of them being buyers. One possible explanation is that irrigators using irrigation systems with higher water efficiencies are more frequently involved in large-scale farming operations and have more incentive to participate in the market as buyers to ensure adequate water for crop requirements. This is also consistent with the findings by Nicol and Klein (2006) in SMRID's water trading practice in 2001 that water tends to be transferred from lower to higher efficiency irrigation systems.

CAIS is surprisingly positive and significant at the 1% level on the demand side but not on the supply side. It was expected that farmers participating in the CAIS program may have higher incentive to sell water and lower incentive to purchase water, which is not consistent. One possible explanation is that irrigators who participate in the CAIS program tend to be more engaged in large-scale farming and thus demand more irrigation water. The correlation between CAIS and farm size is positive with a correlation coefficient of 0.44, indicating that in general, irrigators with larger farms are more likely to participate in the CAIS program. As discussed above, they are less likely to enter the market as sellers but more likely to enter as buyers. Thus, it's not unreasonable to see that irrigators participating in the CAIS program are more likely to be water buyers, in which case the effect of participation in risk management programs on water trading decisions is overwhelmed by the effect of farm size.

Contract08 is strongly positive and significant at the 1% level on the demand side but not on the supply side. As expected, holding a food processing contract provides a powerful incentive for irrigators to participate as water buyers to ensure adequate water for their crops.

Age is weakly positive and significant at the 1% level on the demand side but not on the supply side, which indicates that older irrigators are more likely to participate in the market as buyers but no significant difference on the supply side. This is inconsistent with the expectation that older irrigators may be more likely to sell water and less likely to buy water in the market. This may be because the sampled irrigators in the South Tributary group are found to be older than those in the Central group and they tend to need more water during droughts because they traditionally suffer from more frequent and more severe water shortages. As a consequence, the desire of irrigators demanding water in the sample data overwhelms the negative effect of age on risk aversion.

Household Size is negative and significant in Model 3 on the supply side while positive and significant on the demand side at the 1% level. As discussed, household size has more than one possible effect on the household's risk aversion. For a larger household, it has higher subsistence consumption needs and thus the household would be more risk averse. On the other hand, it implies a greater availability of on-farm and/or off-farm labour and thus the household would be less risk averse. In this case, the positive effect of household size on risk aversion has dominated its negative effect. As a consequence, with a larger household, the irrigator is less likely to sell water but more likely to purchase water during droughts.

Income is significantly negative both on the supply and demand sides, indicating that irrigators with higher household income are less likely to enter the market either as sellers or buyers. In other words, household income has a negative effect on irrigators' participation decisions since they have a greater risk tolerance and are less vulnerable to income fluctuations.

Off-farm Income is negative and significant on the demand side. Irrigators with off-farm income are less likely to participate in the market as buyers. However no significant effects are found on the supply side.

Education is found to be positive and significant on both sides in accordance with the expectation that the higher the education level, the larger is the probability of market participation. In this case, for those with post-high school education, the probability of participating in the water market is larger, either as sellers or buyers. As discussed above, irrigators can benefit from formal education and irrigation training to develop strong management abilities on farming operations and to increase their access to various on-farm and off-farm businesses. Moreover, those with higher education are more likely to incorporate new things into their production practices, hence participating in the water market.

Farming Experience is significantly negative on the supply side, indicating that more experienced irrigators are less likely to be water sellers during droughts, which is not consistent with what was expected. On the demand side, the effect of farming experience is not clear as it has different signs in Model 3 and 4 with both statistically significant.

Membership is strongly positive and significant at the 1% level on the demand side. This reveals that memberships to agricultural and environmental associations do have strong and significant effects on encouraging irrigators to participate in the market as water buyers. Irrigators can benefit from such memberships for broader information sources and lower transaction costs. However, there is no significant effect on the supply side.

To sum up, most of the parameter estimates are statistically significant at either the 5% or 1% significance levels with expected signs. More specifically, market participation as water sellers is significantly promoted by water price but is mitigated by farm size, on-farm livestock, and the use of irrigation systems with high efficiencies, household size, household income and farming experience. In contrast, participation as water buyers is promoted by farm size, the raising of livestock and specialty crops, the use of irrigation systems with high efficiencies, CAIS participation, holding food contracts, age, household size, education and membership, but is mitigated by initial water allocation, water price, household income and off-farm income.

Table 5.4 Results of MNL Random Effects Models (Market Participation Equation)

Variable	***Model 1*** ***Basic Model***	***Model 2*** ***With Farm Characteristics***	***Model 3*** ***With Irrigator Demographics***	***Model 4*** ***Full Model***
Dependent Variable = CHOICE (=0 if zero bidder, 1 if seller, 2 if buyer)				
On the Supply Side (CHOICE=1)				
Intercept	-14.8933** (7.09216)	-32.6510** (15.0020)	-0.38687 (27.22401)	1.39748 (34.76336)
Allocation	-1.23167** (0.52134)	1.64477 (1.12805)	0.17007 (1.56920)	-0.17094 (1.97245)
Price	0.91952*** (.32039)	1.60830** (.62612)	2.99066*** (.72800)	1.54557* (.807648)
Farm Size		-17.5751** (8.62807)		0.07859 (18.60259)
South		-0.9587 (3.21433)		16.1049* (8.39798)
Livestock08		-9.09021** (4.35937)		0.35639 (5.35641)
Specialty		3.41171 (5.10068)		11.3250 (8.58426)
Low Pivot		-9.92183 (7.76820)		-10.7036 (13.54235)
Other Irrigation		-35.9267*** (10.46967)		-31.7961** (13.15679)
CAIS		-3.95829 (3.67863)		-11.7018 (7.99348)
Contract08		2.09004 (7.52653)		-15.0522 (14.78982)
Age			-0.26705 (.24758)	-0.46681 (.31102)
Household Size			-4.30312*** (1.56368)	-0.21449 (1.87312)
Income			-3.09724*** (.56334)	-1.84417* (1.09240)
Off-farm Income			-6.56472 (4.95747)	5.60207 (9.85120)
Education			7.75003 (5.85278)	25.4736** (11.17786)
Farming Experience			-1.55309*** (.21579)	-0.78505** (.36146)
Membership			7.04522 (4.88855)	2.45728 (5.47326)
On the Demand Side (CHOICE=2)				
Intercept	19.3877*** (4.41202)	23.1939*** (8.17471)	15.9623 (10.00538)	2.46847 (18.72504)
Allocation	-2.29192*** (.45053)	-8.63307*** (1.08937)	-7.62164*** (.81575)	-11.6298*** (1.89788)
Price	-0.99999*** (.21172)	-1.82946*** (.23551)	-1.51780*** (.21737)	-1.60888*** (.24909)

Farm Size		17.9528***		26.3580***
		(3.89408)		(7.01681)
South		-1.13333		-4.22879
		(2.32822)		(3.10219)
Livestock08		12.8448***		6.11191***
		(2.35519)		(2.35248)
Specialty		-0.03977		15.1439***
		(3.04490)		(4.75823)
Low Pivot		32.0841***		37.6632***
		(6.64412)		(9.99661)
Other Irrigation		12.1978***		-1.62315
		(4.45109)		(6.91660)
CAIS		10.1003***		8.89260***
		(2.80306)		(3.22075)
Contract08		28.0124***		17.1664***
		(4.53338)		(5.59843)
Age			0.48032***	0.50147***
			(.09848)	(.17287)
Household Size			6.96906***	7.92867***
			(.82502)	(1.55498)
Income			-1.15559***	-1.23609***
			(.23665)	(.38949)
Off-farm Income			-13.9573***	1.19995
			(2.02506)	(3.79556)
Education			12.1988***	8.41840**
			(2.69289)	(3.96256)
Farming Experience			-0.23717***	0.42109**
			(.06816)	(.16505)
Membership			21.7676***	11.2850***
			(2.57963)	(3.10361)
No. of Obs.	360	316	332	296
	(90 individuals)	(79 individuals)	(83 individuals)	(74 individuals)
Log Likelihood	-153.4952	-118.5822	-123.7136	-99.86674

Notes:
i) ***, **, * indicates statistical significance at 1%, 5%, 10% level, respectively;
ii) Standard errors in parentheses.

5.3.2.2 Second Hurdle: Supply and Demand Equations

Conditional on irrigators crossing the first hurdle and participating in the water market, interval censored regression models were estimated for the amounts of water they are willing to sell or buy based on subsamples of water supply and demand. Table 5.5 presents the results of the models estimated on the subsamples of irrigators indicating non-zero willingness to trade irrigation water, i.e. sellers and buyers. For each subsample, a basic model and a full model were estimated with the same subsets of explanatory variables as those in the OLS regressions for comparison purposes.

In both supply and demand equations, the results of interval censored regressions are quite similar to those in the OLS regressions in terms of the magnitudes and signs of covariate coefficients for explanatory variables and their statistical significant levels of confidence. In the demand equations, only the magnitudes of coefficient estimates for some variables are slightly different. More specifically, the estimates of the impacts of major variables (in absolute values), such as *Price, Dum1_p, Dum2_p, Farm Size, Low Pivot* and *Other Irrigation*, are a bit larger in the interval censored models than in the OLS models; while for other variables such as *Contract08, Off-farm Income* and *South,* they are slightly smaller. Graphically, the demand curves derived in the interval censored regressions are steeper than those in the OLS regressions.

To summarize, in the Cragg model, either in the participation equations or in the supply/demand equations, most of the covariate coefficient estimates have the same signs across both hurdles. However, the levels of coefficients' statistical significance, or even the signs of coefficients for some particular variables, are different, indicating that the decisions of market participation and levels of participation may be affected by different determinants. For instance, growing specialty crops significantly increases irrigators' participation in the water market as buyers but not in the demand equations (levels of participation). Household income mitigates participation as buyers but has no significant effects in the demand equations. The on-farm irrigation systems with high efficiencies, other than gravity systems, seem to have more complex effects, which are positively related to the participation decision as buyers but negatively affect the levels of participation in the demand equations, depending on which effect dominates during the decision process.

Table 5.5 Results of Interval Censored Regression Models

Variable	*Supply Equations*		*Demand Equations*	
	Basic Model	**Full Model**	**Basic Model**	**Full Model**
Dependent Variable = CATEGORY				
Intercept	5.25489*** (1.13345)	-2.07847 (1.38251)	5.51525*** (1.13255)	22.1984*** (2.33447)
Price	-0.48939** (.23812)	-0.11175 (.18021)	-0.80693** (.36174)	-0.82298*** (.24893)
Dum1_p	0.41833** (.19522)	0.25925* (.14458)	0.77099** (.31292)	0.60594** (.23908)
Dum2_p	0.60149*** (.17453)	0.08107 (.20313)	0.91369*** (.28927)	0.56494*** (.21928)
Dum2		8.65368*** (1.45192)		
Farm Size		-3.59126 (3.24362)		3.28685*** (.75104)
Pspecialty		-21.5823*** (7.69608)		1.15120 (1.89465)
Low Pivot				-13.9305*** (1.53797)
Other Irrigation		-2.78666*** (.48347)		-12.3322*** (1.47827)
Contract08				-2.78973*** (.96722)
Livestock08		1.97870*** (.46828)		
CAIS		3.81071*** (.53863)		
Income		-0.18751** (.07779)		-0.06905 (.089649)
Farming Experience		0.11647*** (.02972)		-0.10087*** (.026912)
Off-farm Income				-1.42932*** (.53647)
South				3.09090*** (.56579)
Sigma	2.37493*** (.24707)	1.08883*** (.12460)	3.58692*** (.26448)	2.00465*** (.15374)
No. of Obs.	49	45	102	95
Log Likelihood	-111.1716	-68.77978	-266.8712	-191.5273

Notes:
i) ***, **, * indicates statistical significance at 1%, 5%, 10% level, respectively;
ii) Standard errors in parentheses.

5.4 Value Estimates of Irrigation Water

5.4.1 Estimated Supply and Demand Curves

As discussed above, on the supply side, the sampled irrigators were inflexible to water price when selling their excess water in the market, which made it impossible to estimate proper supply curves and thus their WTA for irrigation water through statistical models. Table 5.6 shows that most of the slope estimates of water supply curves don't reflect the proper relationship between water supply and price. Fortunately, on the demand side, negative and sensitive relationships between quantities of water demanded and prices have been reflected in the models, as expected. Furthermore, the effects of initial water endowments on water demand have also been captured in the models through slope changes rather than parallel shifts of demand curves in this case. All the demand curves estimated by different models are downward sloping. When water scarcity intensifies, the demand curves become flatter and flatter (see Figure 5.1).

Table 5.6 shows the slopes of estimated supply and demand curves of irrigation water through different statistical estimations and under varied initial water endowments. Though estimated by different regressions, the slope estimates of the demand curves are quite similar under corresponding water endowments.

Table 5.6 Slopes of Estimated Supply and Demand Curves for Irrigation Water

	Initial Water Endowments		
	12 acre-inches	9 acre-inches	6 acre-inches
	Slopes of Supply Curves ($\partial Q/\partial P$)		
Constant Coefficients	-0.11583	-0.03162	0.14669
OLS Regression	(0.12436)	(0.09777)	(0.077519)
Random Effects OLS	-0.03532	0.04018	0.05678
Regression	(0.083465)	(0.038402)	(0.037634)
Interval Censored	-0.11175	-0.03068	0.14750
Regression	(0.25125)	(0.13316)	(0.10594)
	Slopes of Demand Curves($\partial Q/\partial P$)		
Constant Coefficients	-0.71278	-0.24390	-0.20418
OLS Regression	(0.13233)	(0.09311)	(0.05279)
Random Effects OLS	-0.54071	-0.25156	-0.22956
Regression	(0.14587)	(0.057222)	(0.03627)
Interval Censored	-0.82298	-0.25804	-0.21704
Regression	(0.24182)	(0.11645)	(0.062684)

Note: Standard deviations in parentheses.

Figure 5.1 presents the demand curves estimated by the OLS random effects estimation, holding all other explanatory variables equal to the sample means.

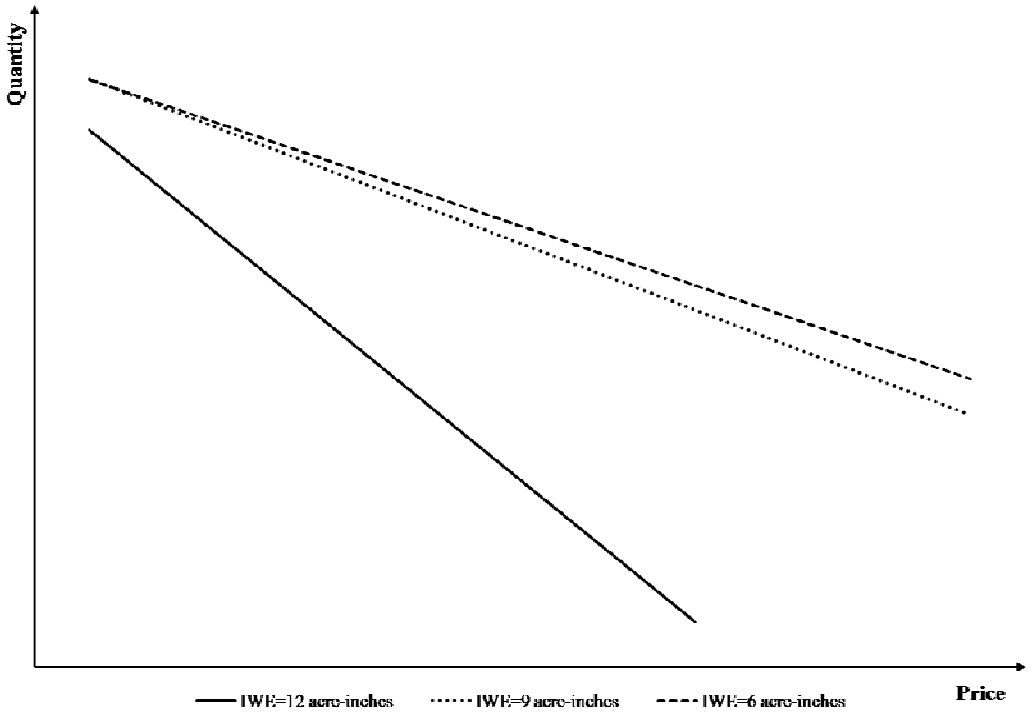

Figure 5.1 Estimated Demand Curves of Irrigation Water

5.4.2 Estimated WTP of Irrigation Water

From the estimated supply and demand curves, we can obtain the inverse supply and demand curves in which price is treated as a function of quantity supplied/demanded. Irrigators' WTP could also be estimated as the marginal values of each additional quantity (e.g. 1 acre-inch in this case) of irrigation water demanded, which equal to the absolute values of the slopes of the inverse demand curves ($\partial P/\partial Q$).

Table 5.7 lists the irrigators' WTP estimates based on different estimations and under varied initial water endowments. It shows that WTP estimates through the OLS estimations and interval censored regressions are very close. More specifically, irrigators' WTP with the initial water endowment of 12 acre-inches is \$1.22-1.85/acre-inch (\$14.64-22.20/acre-foot), and the WTP with the endowment of 9 acre-inches is $3.88-4.10/acre-inch ($46.56-49.20/acre-foot) while the WTP with 6 acre-inches is $4.36-4.90/acre-inch ($52.32-58.80/acre-foot). It is evident that irrigators' WTP of irrigation water increases when water scarcity intensifies.

Table 5.7 Estimated Values of Irrigation Water (WTP)

	Initial Water Endowments *(Acre-inch)*								
	12	9	6	12	9	6	12	9	6
	$/acre-inch			$/acre-foot			$/cubic meter		
Constant Coefficients OLS Regression	1.40 (0.3088)	4.10 (2.2967)	4.90 (1.9631)	16.80	49.20	58.80	0.014	0.040	0.048
Random Effects OLS Regression	1.85 (1.4543)	3.98 (1.2324)	4.36 (0.7788)	22.20	47.76	52.32	0.018	0.039	0.042
Interval Censored Regression	1.22 (1.4576)	3.88 (2.0168)	4.61 (2.7062)	14.64	46.56	55.32	0.012	0.038	0.045

Note: Standard deviations in parentheses.

The estimates in irrigators' WTA are poor and unreliable which are somewhat expected due to the small sub-sample size in this case, with only 49 observations (16 individuals) selected for valuation modeling in the subgroup of sellers.

5.4.3 Price Elasticity of Irrigation Water Demand

The price elasticity of demand is a measure of the sensitivity of quantity demanded to changes in its price. It is measured by taking the value of the percentage change in demand divided by the percentage change in price ($E_P = (\frac{\partial Q}{Q}) \Big/ (\frac{\partial P}{P}) = \frac{\partial Q}{\partial P} \times \frac{P}{Q}$). The price elasticity of water demand is traditionally less than one, i.e. it is inelastic, reflecting a low sensitivity to price changes. One of the possible reasons is the lack of real substitutes for water in the market.

Table 5.8 lists the price elasticity of irrigation water demand under varied provided prices based on the random effects OLS regression, holding all other explanatory variables equal to their sample means. The results reveal that, the demand for irrigation water is generally inelastic to price, showing a low sensitivity to price changes during droughts. Furthermore, the demand for irrigation water becomes more inelastic to price when water scarcity intensifies.

The magnitude of the price elasticity of demand decreases at corresponding prices when the initial water endowment falls from 12 acre-inches to 6 acre-inches. With a water endowment of 12 acre-inches, the demand for water becomes elastic to price at the water price of $7/acre-inches and the turning point is $16 and $17/acre-inches for the endowments of 9 and 6 acre-inches, respectively.

Table 5.8 Price Elasticity of Irrigation Water Demand (in Absolute Values $|E_p|$)

	***Price** ($/acre-inch)*											
IWE*	4	5	6	7	8	9	10	11	14	15	16	17
12	0.40	0.56	0.75	**1.34**								
9	0.15	0.20	0.25	0.30	0.36	0.42	0.49	0.57	0.86	0.98	**1.12**	
6						0.37	0.43	0.50	0.73	0.83	0.93	**1.05**

Note: *Initial Water Endowment (acre-inch).

5.4.4 Comparison of Water Values in Varied Beneficial Uses

As mentioned in the literature review of Chapter 3, a wide variation has been found in estimated water values across varied water uses. While not the lowest, values of water in the agricultural sector tend to be much lower than in domestic and industrial uses. Within the agricultural sector, the value of water is universally higher when used on high-value crops such as specialty crops than when used on grain and cereal crops. In addition, the value of water for household and industrial purposes is usually much higher than the value for irrigation, while the value of water for environmental and ecological purposes falls in the middle.

Table 5.9 compares the values of irrigation water estimated in this study to the values of water estimated in the most recent literature for varied beneficial uses in Canada. It is evident that the value of water in the agricultural sector ($0.012-$0.048/m^3 in this study) is much lower than in other beneficial uses, either in industrial ($0.26-$1.29/m^3 in Dachraoui and Harchaoui (2004)) or municipal sectors ($1.13-$1.27/m^3 in Renzetti (2009)). Within the agricultural sector, the values of irrigation water estimated in this study, generally consistent with those estimated in the literature, have a relatively narrower range of possible values and a lower upper bound.

There are several possible reasons for the observed discrepancies between this study and the literature.

First, the value of water is a function of location. Though Alberta's South Saskatchewan River Basin is targeted as the general study region in the literature listed, the specific targeted population is not identical for each study. For instance, Nicol and Klein (2006) focus on the practice of water trading undertaken within SMRID in 2001, while our study targets five other districts within Alberta due to survey data availability. The variation in irrigation water values within Alberta is partly induced by the presence of heterogeneity in farming conditions, crop patterns and farmer management abilities among irrigation districts.

Second, different valuation techniques adopted in the studies may also contribute to the variation of water value estimates. For instance, this study develops a CB approach to directly ask irrigators about their contingent behaviour changes in response to a water market framework and hypothetical water scarcity by survey, while Samarawickrema and Kulshreshtha (2008) use a residual imputation approach to explore the benefits from irrigation during a drought year.

Third, other contributing factors may include differences in the dataset, input factors and assumptions assumed for model simplification, such as data collection methods, the procedures for developing econometric models and the assumption of crop patterns, etc. For instance, the assumed water availability to the targeted population in each study is slightly different, which is expected to be a significant component in framing the value estimates of water.

Table 5.9 Values of Water in Varied Beneficial Uses in Canada

	Agriculture (Irrigation)						***Industrial***	***Municipal***
Value ($\$/m^3$)	0.012-0.048 during droughts	Short Run: 0.003-0.127 Long Run: 0-0.05	0.004-1.139	Short Run: 0.026-0.035 Long Run: 0.011-0.016	0.016-0.114 Average: 0.064	0.026-0.061	0.26-1.29 Average: 0.73 (Shadow Price)	1.13-1.27
Region	Alberta SSRB	Alberta SSRB	Alberta SSRB	Alberta SSRB	Alberta SSRB (SMRID)	Alberta SSRB	National	National
Source	This study	Gardner Pinfold et al (2006)	Bruneau (2007)	Samarawickrema and Kulshreshtha (2008b)	Nicol and Klein (2006)	Mahan et al (2002)	Dachraoui and Harchaoui (2004)	Renzetti (2009)
Valuation Technique	Contingent behaviour	N/A	Residual imputation approach	Derived demand functions	Market-based transaction approach	Non-linear programming model	Short-run cost function	Water market prices
Unit	2009$	2005$	1996$	2007$	2001$	1995$	*	2004$

Note: * The research was done in 2004 based on the data of the period 1981-1996.

5.5 Summary

In this chapter, the correlation coefficient matrix of variables shows no obvious multicollinearity concerns in the dataset. However, the presence of heteroscedasticity and heterogeneity indicates that random effects OLS regressions may be preferred to constant coefficients OLS regressions in this study. The heteroscedasticity-robust standard errors are more appropriate to be presented in the model results. The coefficient estimates and water value estimates explored through the different estimations are very close and robust. The Cragg model indicates that in the water market, the decisions of market participation and levels of participation are affected by different determinants for both sellers and buyers. Moreover, the decisions to become water sellers or buyers, as well as the decisions of how much water to trade (either to sell or to buy), are determined by different sets of determinants. The estimated WTP for irrigators during droughts is comparable to values from the previous literature. These values are \$1.22-4.90/acre-inch (\$0.012-0.048/cubic meter) in general. More specifically, the WTP with an initial water endowment of 12 acre-inches is \$1.22-1.85/acre-inch (\$0.012-0.018/cubic meter), and the WTPs with 9 acre-inches and 6 acre-inches are \$3.88-4.10/acre-inch (\$0.038-0.040/cubic meter) and \$4.36-4.90/acre-inch (\$0.042-0.048/cubic meter), respectively. It is evident that the WTP for irrigation water increases when water scarcity intensifies. Moreover, the estimated price elasticity of irrigation water demand supports a conclusion that, in general, the demand for irrigation water is inelastic to price, showing a low sensitivity to price changes during droughts. Furthermore, the demand for irrigation water becomes more inelastic to price when water stress intensifies. Unfortunately, due to the small subsample size for sellers, the supply curve for water and thus WTA estimates for irrigators are poor and considered to be not reliable.

Chapter 6

Conclusions

6.1 Summary

This study represents a successful first attempt at applying a stated preference (SP) method, in particular a contingent behaviour (CB) approach, to identify irrigators' market behaviour within a water trading framework and to estimate their WTP for irrigation water during droughts in southern Alberta. The objectives of this study were achieved by the application of a contingent behaviour survey using a design similar to the payment card format. The survey provided a collection of valuable quantitative and qualitative data. Using a mail-out questionnaire, sample irrigators from selected irrigation districts were asked to reveal their choice to participate in the water market and their quantity of trading irrigation water based on their participation decision. Utilizing the theoretical framework of WTP/WTA modeling enabled estimation of water supply and demand changes as a result of price increases and water scarcity intensifications and thus the corresponding value estimates for irrigation water.

The process of collecting the CB data enabled an assessment of the characteristics of the potential participants in water markets. Similar to evidence from previous water trading experiences, results of the survey indicate that there is a tendency for water markets to induce a transfer of water from less productive to more productive users and from less efficient to more efficient irrigation systems, thereby enhancing water productivity and water efficiency. More specifically, in terms of crops, buyers in the survey raised more specialty crops and oilseed while sellers raised more forage, indicating that water would be transferred from lower to higher valued crops. In addition, a greater percentage of buyers raised livestock on farm than did sellers. In terms of irrigation technologies, buyers operated more efficient irrigation systems than did sellers, indicating that water moves from less efficient to more efficient irrigation equipment.

It is evident that irrigators' decisions on market participation and levels of participation are determined by two separate stochastic processes and are affected by different sets of determinants. In other words, some factors may have significant impacts on irrigators making the first decision of whether to enter the market, but the effects may be less important for their second decision on the amount of water to trade, and vice versa. Furthermore, in the second decision, the supply and demand equations also have different determinants.

There is a tendency for irrigators to change their water supply/demand as water price increases and water scarcity intensifies. The survey shows that changes in prices affected the amount of water that irrigators were willing to trade as well as their participation choices. The demand for water is significantly dependent on both water prices and water availability in an expected way, though inelastic to prices, as anticipated. Furthermore, the demand for water is more inelastic to prices when water stress intensifies. However, the supply of water does not show significant responses to price increases and water availability changes, which may be because potential sellers consider the market as an income opportunity and are motivated to sell their excess water without sensitivity to prices.

The irrigator's WTP/WTA were estimated as the marginal values of each additional quantity of irrigation water demanded/supplied. The estimates of WTP are robust and comparable to other values found in the literature. They are in the range of $1.22-4.90/acre-inch ($0.012-0.048/cubic meter). In contrast, the estimates of WTA are poor and not particularly reliable as a consequence of a small subsample size. In addition, irrigators from the Southern Tributary group who experience relatively more water scarcity were more active in participating in the water market and were willing to purchase more water than those from the Central group during a drought year, reflecting regional differences in their perception of water scarcity threats.

The results support the view that the presence of water markets can play a crucial role in water reallocation during a drought year and the productivity and efficiency of water use would be promoted through temporary water markets, the extent to which depends on how active are water markets. The presence of water markets provides sellers with a good opportunity of obtaining additional income by disposing of excess water while providing buyers a flexible way to manage short-term water shortage via the purchase of water in the market. The survey detected some minor opposition to water trading based on respondents' attitudes, but this does not appear to constitute a significant barrier to water market development.

6.2 Limitations and Directions for Further Research

The main limitation of this study was data availability due to the low response rate of mail surveys. The small sample size of the dataset, especially on the supply side, may have prevented the models from detecting the effects of some determinants on water supply and demand decisions. It also limited the choice of model specifications. In addition, the sampled respondents may not be well representative of irrigators in southern Alberta, as a direct consequence of non-response bias in the survey. Thus generalizing the findings of this study to the whole southern Alberta region would be questionable. Given a more representative and better dataset, more variables could be introduced into the models and some assumptions, such as the one discussed below, could be relaxed. In which case, it may be possible to improve the validity of the models and their ability to explain actual water trading behaviour.

Heterogeneity in both individual behaviour and regions remains an issue. The data were collected from five irrigation districts and heterogeneity across individuals and regions was detected. However, the random effects models developed here, treating individual heterogeneity as part of the error term, may lead to biased and inconsistent estimates of the variables in the models. Unfortunately, we do not have enough observations to support a fully individual-specific specification to control for the heterogeneity among irrigators and among regions, which is also a potential way to improve the validity of model estimates.

Crop prices play a vital role in driving agricultural activities and irrigation water demands. This is not thoroughly explored in this study. Further attention should be paid on the effects of crop prices on water markets to find the quantitative relationship between crop price and water supply/demand.

Further information and research are also needed to determine the effects of transaction costs in water markets. The framework of this study is hypothetical and no transaction cost is considered during the water trading and in the valuation modeling. However, transaction costs could play a role in water transactions and thus affect water supply and demand.

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Appendix A: Survey Questionnaire: the LNID Sample

Trading Through the Next Drought
Survey 2008

UNIVERSITY OF ALBERTA

ALBERTA INGENUITY CENTRE FOR WATER RESEARCH

LNID

COMMUNITIES PEOPLE AGRICULTURE SINCE 1921

Part 1: General information about your farm

Please complete these questions by filling in the blanks or marking a check [√] next to your answer.

1. How many **irrigable acres** do you currently **farm** within the district?
   ____________ acres

2. How many irrigable acres did you **rent** from within the district this year?
   ____________ acres

3. Did you hold any irrigable land within the district in **2001**?
   [ ] Yes or **[ ]** No

4. In **2008**, did you raise any livestock that were intended for sale?
   [ ] Yes or **[ ]** No

5. In **2008**, did you raise any crops that were intended for sale?
   [ ] Yes or **[ ]** No

6. Is there anyone on your farm who has gotten any formal irrigation training (e.g. Alberta Irrigation Management Program given by the Irrigation Branch of AAFRD)? **[ ]** Yes or **[ ]** No

7. Are you more concerned about rising energy prices than rising wat**er r**ates?
   [ ] Yes or **[ ]** No

8. Are you more concerned about rising fertilizer prices than rising water rates?
   [ ] Yes or **[ ]** No

9. Please list the number of irrigation systems you own and the crops they are used to irrigate:

Irrigation Method	**Acres Irrigated** (acres)	**Crops Irrigated**
Low-pressure pivot	____________	____________________
Wheel move	____________	____________________
Gravity	____________	____________________
Others (Medium and high-pressure pivots, hand move, micro-drip, etc.)	____________	____________________

Part 2: 2008 crops intended for sale

In this section, we ask that you check [√] the box if you seeded these crops for sale in **2008** and fill in the blank with the number of irrigable acres that was dedicated to each crop you raised.

If you seeded any crops intended for sale that are not listed, please use the blank spaces at the bottom of the page to write in the other crops and acreage you seeded in **2008**. For your reference, we have included approximate conversions between hectares, acres and quarter-sections below.

If you did not seed any crops intended for sale, please skip to the next page.

10 hectares ≈ 25 acres (24.71 acres)
1 Quarter-section ≈ 65 hectares (64.75 hectares)
1 Quarter-section = 160 acres

Cereals:

[ ] Durum wheat ____________ acres
[ ] Feed Barley ____________ acres
[ ] Malt Barley ____________ acres
[ ] Oats ____________ acres
[ ] Rye ____________ acres
[ ] Spring wheat ____________ acres
[ ] Triticale ____________ acres
[ ] Winter wheat ____________ acres

Oilseeds:

[ ] Canola ____________ acres
[ ] Flaxseed ____________ acres
[ ] Safflower ____________ acres
[ ] Sunflower ____________ acres

Specialty crops:

[ ] Chick peas ____________ acres
[ ] Corn ____________ acres
[ ] Dry beans ____________ acres
[ ] Dry peas ____________ acres
[ ] Fababeans ____________ acres
[ ] Lentils ____________ acres
[ ] Mustard ____________ acres
[ ] Potatoes ____________ acres
[ ] Sugar beets ____________ acres

Forages:

[ ] Alfalfa ____________ acres
[ ] Brome hay ____________ acres
[ ] Clover ____________ acres
[ ] Timothy ____________ acres
[ ] Wheat grass ____________ acres

If you raised any crops that were not listed, please use the spaces provided below to list all your crops.

[ ] __________ ____________ acres

[ ] __________ ____________ acres

[ ] __________ ____________ acres

[ ] __________ ____________ acres

[ ] __________ ____________ acres

Part 3: Information about droughts

Droughts would be much more likely to occur in the future

In 2001, most of southern Alberta experienced a severe drought which required rationing irrigation allocations. For the first time on record, irrigators' allocations were reduced to approximately 8 inches/acre, nearly 45% of the usual expected quantity. While some irrigators were able to cope using no more than 8 acre-inches, others were desperate to obtain more water for their crops.

Many believe we are witnessing a **global climate change** that will alter global climate and weather patterns in the near future. Among the predicted impacts for Southern Alberta is an increase in the intensity, duration and frequency of extreme weather events. As a result, severe droughts like the one witnessed in 2001 are more likely to occur.

One reasonable approach to minimize losses caused by drought is to allow irrigators to trade water amongst themselves in water markets. Trading is one type of instruments that promotes water conservation and efficiency by providing the incentive of private profits to individual irrigators. Those who can reduce their demand for water by investing in more efficient irrigation delivery systems can use the water savings to their own benefit.

Suppose there was a water trading market in your district, and you could trade your irrigation water with any member within your district as you want, we are seeking your willingness to pay (or to sell) for the extra water due to a hypothetical drought.

PLEASE NOTE: Research has shown that how people act on a survey is often not a reliable indication of how people would actually do. In surveys, some people ignore the monetary and other sacrifices they would really have to make in the real life. We call this **hypothetical bias**.

Even though the scenarios and water trading markets you will be presented are hypothetical, we ask that you **respond as if you were faced with the same decisions in a real-world context**, **complete with real economic consequences in response to your choices.** The sincerity of your responses is important to us, and contributes valuable information to the benefit of all irrigators within the district.

In the drought scenarios, you will notice that we provide the hypothetical water ration and the going water rate. We ask that you consider the **number of irrigable acres <u>you</u> are farming** as well as all **<u>your</u> relevant crop needs** when indicating the **number of inches per irrigable acre** that you would be willing to trade with another member within your district that **would only last for one season**.

Part 3.1: Instructions

Please read the following information carefully before completing the questions below.

This section is intended to assess your willingness to trade irrigation water with irrigators within the district in response to a hypothetical drought that requires water rationing. Below, we describe a hypothetical drought scenario and water trading conditions; then we ask that you consider trading options relying on your farming experience and farming operation.

Suppose there was a significant drought in the region, to address water scarcity three trading options are available:

- **Buy additional inches for every irrigable acre you farm from another irrigator within the district,**

  (the water purchased adds to your water ration, which can be distributed on your crops as you see fit)
- **Sell some (or all) of your irrigation water to another irrigator within the district,**
  (this may involve converting some or all of your land to dry-land farming)
- **Choose not to trade.**
  (your water use is limited by your water ration).

If you choose to be involved in a trade, you will be asked to select the quantity of acre-inches you want to trade. If you choose not to trade, please be sure to complete the question that follows the last scenario.

To avoid confusion, we have included an example to familiarize you with this type of question before presenting the hypothetical drought scenarios. Please take a moment to review the example provided below.

In this example, suppose the following assumptions apply:

1. You are farming 100 acres (all irrigable).
2. Your crops need 12 inches of irrigation water per acre on average to produce a reasonable yield.
3. All irrigation water allocations in your district are rationed to **9 acre-inches** (about 50% of the current 17.5 acre-inches allocation) due to a severe drought.
4. The going rate for water to be traded is $5 per acre-inch.

   (Suppose you can easily find another member within your district to trade water with at this going rate, regardless of whether you are buying or selling.)

   ****This value will vary in the scenarios****

Part 3.1: Instructions continued…

The following explanations will guide you through the example and outline how to evaluate the information and complete the trading options provided in the drought scenarios.

- If you choose to buy more irrigation water, first check [√] the box **I want to BUY some acre-inches** and then choose the appropriate quantity under the '**Willing to Buy**' column (as shown in the example on the next page). Due to the water ration, you have an average shortage of 3 inches on all your 100 irrigable acres, so you would circle the box **2.1to 3** under the 'Willing to Buy' column and you would need to buy 300 acre-inches totally (3 inches per acre * 100 acres = 300 acre-inches) to ensure you have enough irrigation water for your crops.
    - At a cost of $5 per acre-inch, this would cost you $1,500 in total (300 acre-inches * $5 = $1,500) to obtain extra irrigation water.
- If you choose to sell your irrigation water, first check [√] the box **I want to SELL some acre-inches** and then choose the appropriate quantity under the '**Willing to Sell**' column. Since you have a ration of 9 inches/acre, and are farming 100 irrigable acres, you have a total of 900 acre-inches available to sell (100 acres * 9 inches per acre = 900 acre-inches).
    - Say you decided to sell all 9 inches per acre, you would circle the box **8.1to 9** at the bottom of "Willing to Sell". At the price of $5 per acre-inch, you would obtain $4,500 (900 acre-inches * $5 = $4,500).
    - If you only want to sell one-third (three inches per acre) of you water ration, you would circle the box **2.1to 3** under the "Willing to Sell" column. This would leave you with 6 inches of irrigation water per irrigable acre as well as the $1,500 income generated by the trade (100 acres * 3 inches per acre * $5 = $1,500).
- If you choose not to trade, check [√] the box **I am not interested in trading any acre-inches** and move on to the next page. You will have 9 inches of irrigation water per acre on all your 100 acres for the entire growing season, and no money would change hands.
    - Please take a moment to answer the question immediately following the last scenario regarding the reason(s) you chose not to trade.

Every transaction card is presented on a single page with an accompanying scenario. Please be sure to read the details of each scenario on the top of the page carefully to ensure you are fully aware of the severity of the hypothetical drought.

Part 3.2: Example Scenario

- During a severe drought, your irrigation water allocation for the entire season is rationed to **9 inches** per acre (about 50% of the current 17.5 acre-inches allocation).
- To buy one acre-inch of irrigation water for your crops costs **$5**.
- The revenue you receive from selling one acre-inch of irrigation is also equal to **$5**.

Please check [√] one of the three boxes indicating your response; then, in the appropriate column below, circle the box that contains the number of acre-inches you are interested in trading.

I want to SELL some acre-inches	**[ ]**	(choose and circle **one** box under the "Willing to Sell" column below)
I want to BUY some acre-inches	**[√]**	(choose and circle **one** box under the "Willing to Buy" column below)
I am not interested in trading any acre-inches	**[ ]**	(go to scenario 2 on the *next* page)

Willing to Sell

- Less than 1
- 1 to 2
- 2.1 to 3
- 3.1 to 4
- 4.1 to 5
- 5.1 to 6
- 6.1 to 7
- 7.1 to 8
- 8.1 to 9

Willing to Buy

- Less than 1
- 1 to 2
- [✓ 2.1 to 3]
- 3.1 to 4
- 4.1 to 5
- 5.1 to 6
- 6.1 to 7
- 7.1 to 8
- 8.1 to 9
- 9.1 to 10
- 10.1 to 11
- 11.1 to 12
- 12.1 to 13
- 13.1 to 14
- More than 14

That is all that is required to complete a transaction card. You will be presented with four scenarios, each with slightly different levels of hypothetical rates. **Each scenario should be considered independently of the others.** Please consider the **number of irrigable acres <u>you</u> are farming** as well as all **<u>your</u> relevant crop needs** when indicating the **number of inches per irrigable acre** that you would be willing to trade that **would only last for one season**.

Part 4.1: Scenario 1

PLEASE TREAT EACH SCENARIO INDEPENDANTLY FROM THE OTHERS.

Scenario:

- During a severe drought, your irrigation water allocation for the entire season is rationed to **9 inches** per acre (about 50% of the current 17.5 acre-inches allocation).
- To buy one acre-inch of irrigation water for your crops costs **$3**.
- The revenue you receive from selling one acre-inch of irrigation is also equal to **$3**.

Please remember that your response applies to all of your irrigable acres.

Please check [√] one of the three boxes indicating your response; then, in the appropriate column below, circle the box that contains the number of acre-inches you are interested in trading.

I want to SELL some acre-inches	**[ ]**	(choose and circle **one** box under the "Willing to Sell" column below)
I want to BUY some acre-inches	**[ ]**	(choose and circle **one** box under the "Willing to Buy" column below)
I am not interested in trading any acre-inches	**[ ]**	(go to scenario 2 on the *next* page)

Willing to Sell		**Willing to Buy**	
Less than 1	1 to 2	Less than 1	1 to 2
2.1 to 3	3.1 to 4	2.1 to 3	3.1 to 4
4.1 to 5	5.1 to 6	4.1 to 5	5.1 to 6
6.1 to 7	7.1 to 8	6.1 to 7	7.1 to 8
8.1 to 9		8.1 to 9	9.1 to 10
		10.1 to 11	11.1 to 12
		12.1 to 13	13.1 to 14
		More than 14	

Part 4.2: Scenario 2

PLEASE TREAT EACH SCENARIO INDEPENDANTLY FROM THE OTHERS.

Scenario:

- During a severe drought, your irrigation water allocation for the entire season is rationed to **9 inches** per acre (about 50% of the current 17.5 acre-inches allocation).
- To buy one acre-inch of irrigation water for your crops costs **$5**.
- The revenue you receive from selling one acre-inch of irrigation is also equal to **$5**.

Please remember that your response applies to all of your irrigable acres.

Please check [√] one of the three boxes indicating your response; then, in the appropriate column below, circle the box that contains the number of acre-inches you are interested in trading.

I want to SELL some acre-inches **[ ]** (choose and circle **one** box under the "Willing to Sell" column below)

I want to BUY some acre-inches **[ ]** (choose and circle **one** box under the "Willing to Buy" column below)

I am not interested in trading any acre-inches **[ ]** (go to scenario 2 on the *next* page)

Willing to Sell

Less than 1
1 to 2
2.1 to 3
3.1 to 4
4.1 to 5
5.1 to 6
6.1 to 7
7.1 to 8
8.1 to 9

Willing to Buy

Less than 1
1 to 2
2.1 to 3
3.1 to 4
4.1 to 5
5.1 to 6
6.1 to 7
7.1 to 8
8.1 to 9
9.1 to 10
10.1 to 11
11.1 to 12
12.1 to 13
13.1 to 14
More than 14

Part 4.3: Scenario 3

PLEASE TREAT EACH SCENARIO INDEPENDANTLY FROM THE OTHERS.

Scenario:

- During a severe drought, your irrigation water allocation for the entire season is rationed to **9 inches** per acre (about 50% of the current 17.5 acre-inches allocation).
- To buy one acre-inch of irrigation water for your crops costs **$7**.
- The revenue you receive from selling one acre-inch of irrigation is also equal to **$7**.

Please remember that your response applies to all of your irrigable acres.

Please check [√] one of the three boxes indicating your response; then, in the appropriate column below, circle the box that contains the number of acre-inches you are interested in trading.

I want to SELL some acre-inches	**[ ]**	(choose and circle **one** box under the "Willing to Sell" column below)
I want to BUY some acre-inches	**[ ]**	(choose and circle **one** box under the "Willing to Buy" column below)
I am not interested in trading any acre-inches	**[ ]**	(go to scenario 2 on the *next* page)

Willing to Sell

Less than 1	1 to 2
2.1 to 3	3.1 to 4
4.1 to 5	5.1 to 6
6.1 to 7	7.1 to 8
8.1 to 9	

Willing to Buy

Less than 1	1 to 2
2.1 to 3	3.1 to 4
4.1 to 5	5.1 to 6
6.1 to 7	7.1 to 8
8.1 to 9	9.1 to 10
10.1 to 11	11.1 to 12
12.1 to 13	13.1 to 14
More than 14	

Part 4.4: Scenario 4

PLEASE TREAT EACH SCENARIO INDEPENDANTLY FROM THE OTHERS.

Scenario:

- During a severe drought, your irrigation water allocation for the entire season is rationed to **9 inches** per acre (about 50% of the current 17.5 acre-inches allocation).
- To buy one acre-inch of irrigation water for your crops costs **$9**.
- The revenue you receive from selling one acre-inch of irrigation is also equal to **$9**.

Please remember that your response applies to all of your irrigable acres.

Please check [√] one of the three boxes indicating your response; then, in the appropriate column below, circle the box that contains the number of acre-inches you are interested in trading.

I want to SELL some acre-inches **[ ]** (choose and circle **one** box under the "Willing to Sell" column below)

I want to BUY some acre-inches **[ ]** (choose and circle **one** box under the "Willing to Buy" column below)

I am not interested in trading any acre-inches **[ ]** (go to scenario 2 on the *next* page)

Willing to Sell

- Less than 1
- 1 to 2
- 2.1 to 3
- 3.1 to 4
- 4.1 to 5
- 5.1 to 6
- 6.1 to 7
- 7.1 to 8
- 8.1 to 9

Willing to Buy

- Less than 1
- 1 to 2
- 2.1 to 3
- 3.1 to 4
- 4.1 to 5
- 5.1 to 6
- 6.1 to 7
- 7.1 to 8
- 8.1 to 9
- 9.1 to 10
- 10.1 to 11
- 11.1 to 12
- 12.1 to 13
- 13.1 to 14
- More than 14

Part 4.5: A follow-up question

Please answer this question **only if you chose not to trade** in any of the above scenarios.

Which statement **best** expresses your reason for choosing not to trade?

[ ] I. I can get by with my ration of water.

[ ] II. I cannot afford to pay more than I already do to have access to the extra water.

[ ] III. It is unfair or immoral to expect irrigators to pay more money for access to the extra water during droughts.

[ ] IV. I would not be able to easily find another member within my district to trade water with.

[ ] V. I would rather leave the surplus in the canals and rivers for conservation reasons than sell it.

[ ] VI. I don't believe that this type of trading regime will exist.

[ ] VII. None of the above,
*please specify*____

Just a few more questions to go…

Part 5: General information about you

This information will only be used for academic researches. We would like to remind you that your responses will never be linked to your identity. Please try to answer all the questions.

Please indicate your responses with a check **[√]** next to your answer or by filling in the blank where appropriate.

1. Age: _________

2. Gender: **[ ]** Male **[ ]** Female

3. How many people live in your household (including yourself)? ________

4. What is the **highest** level of education you have completed?

   [ ] Junior High **[ ]** High school **[ ]** University

   [ ] College or Technical school **[ ]** Graduate school

5. How long have you been involved in irrigated farming?

   ____________ years

6. Please check **[√]** the box next to the range which best describes your **2007 annual gross household income**.

[ ] Less than $30,000	**[ ]** $60,000 to $69,999	**[ ]** $100,000 to $109,999
[ ] $30,000 to $39,999	**[ ]** $70,000 to $79,999	**[ ]** $110,000 to $119,999
[ ] $40,000 to $49,999	**[ ]** $80,000 to $89,999	**[ ]** $120,000 to $129,999
[ ] $50,000 to $59,999	**[ ]** $90,000 to $99,999	**[ ]** More than $130,000

7. Do you or anyone in your household perform any off-farm work (eg. paid off-farm work or operating off-farm business)?

   [ ] Yes or **[ ]** No

   7a. If 'yes', what percentage of your **2007 annual gross household income** is generated off the farm?

   [ ] Less than 5.0% **[ ]** 5.1-10.0% **[ ]** 10.1-20.0% **[ ]** 20.1-30.0% **[ ]** 30.1-40.0%

   [ ] 40.1-50.0% **[ ]** 50.1-60.0% **[ ]** 60.1-70.0% **[ ]** 70.1-80.0% **[ ]**Over 80.0%

8. In 2007, did you participate in the Canadian Agriculture Income Stabilization (CAIS) program?

[ ] Yes or **[ ]** No

8a. If 'yes', what percentage of the value of your crops was covered under the CAIS program?

[ ] 70% **[ ]** 80% **[ ]** 90% **[ ]** 100%

9. Have you been involved in any water trading transactions since 2000? (Excluding transfers between 2 parcels you own) **[ ]** Yes or **[ ]** No

10. Did you have a contract to provide a local food processor for 2008?

[ ] Yes or **[ ]** No

11. Do you have a contract to provide a local food processor for 2009?

[ ] Yes or **[ ]** No

12. Do you use the information available on the following websites in your farming decisions? (please check all that apply)

[ ] "*Ropin' the Web*" hosted by Alberta Agriculture and Food

[ ] "*Water Supply Outlook for Alberta*" hosted by Alberta Environment

[ ] Other websites

[ ] None

13. Are you affiliated to any of the following? (please check all that apply)

[ ] An environmental organization or watershed group

[ ] A cooperative (other than your district)

[ ] An agriculture club

[ ] A charitable/volunteer organization

[ ] Other (please identify) ___________________________________

14. Your role in the farming operation is: (please check all that apply)

[ ] owner **[ ]** operator **[ ]** manager **[ ]** other (please specify) __________

Appendix B: Cover Letter

Dear District Member,

My name is Yihong Wang, a graduate student working on my Master's thesis at the University of Alberta. My supervisor (Dr. Chokri Dridi) and I are conducting a study to assess the effectiveness of the current water trading approach to conserving water during severe droughts in the Albertan portion of the South Saskatchewan River Basin.

We have been in contact with your irrigation district to produce a meaningful study. Based on the number of irrigators and the variety of crops produced your irrigation district is an important part of this study. We ask for your help by completing the enclosed survey. At any moment, you can opt-out from this study by not returning the survey.

If you choose to participate, your answers will contribute to a report that we will share with your irrigation district once the study is complete. Additionally, an individual assessment of your potential gains in a hypothetical water trading experiment can be sent to you. The report will focus on estimating the demand for irrigation water during a severe **hypothetical** drought. Results from this study could serve as a benchmark for irrigators in future water trades should a drought similar to 2001 re-occur. Completing this survey will also provide you the opportunity to review some aspects of your farming operation.

Be assured that your responses are strictly confidential. Only the researchers listed below will have access to your individual answers. Your answers will be deleted from any record after five (05) years. Your name will never appear with your answers. Only a summary of the results will be made public. This research is being funded by the Alberta Ingenuity Centre for Water Research and is not being conducted on behalf of any government agency or private interests.

If you are interested in participating in this study, please try to answer all of the questions. If there is any question you cannot answer, leave it blank and move on to the next one. Once completed, please return the survey to us in the enclosed postage pre-paid envelope. Please be sure to complete the contact information on the **Individualized Results** in the separate sheet if you are interested in receiving an assessment of your potential gains in this hypothetical water trading study. Filling in this survey will take no more than 30 minutes of your time.

Thank you, we appreciate your help with this project.

Yihong Wang

Appendix C: Individualized Results Sheet

If you would like to receive an individualized result to the hypothetical water trading experiment, please write your address in the space provided on the reverse of this page. We will provide you with results detailing the quantity of water you either bought or sold from a fellow irrigator within your district as well as the total cost or compensation required for the trade. This page will be sent back to you without us keeping a record of your address.

If this had been a real drought, based on your responses, you would have (bought / sold) ________ acre-inches of irrigation and (paid / received) $_______ in total for the exchange.

Thank you for participating in this study!

Best Regards,
Yihong Wang and Dr. Chokri Dridi.

Appendix D: Reminder Letter

Dear District Member,

My name is Yihong Wang, a graduate student working on my Master's thesis at the University of Alberta. About 2 weeks ago we mailed you a questionnaire for a study of water trading during severe droughts similar to those experienced in 2001. The study was custom-designed for you and other irrigators in your district.

Please consider this note as a friendly reminder for you to complete and return the questionnaire in the prepaid self-addressed envelope. Completing the questionnaire allows you to consider practical water trading opportunities and be prepared should a severe drought occur.

If you need another copy of the questionnaire or have any other concerns, please do not hesitate to contact me by email (yihong@ualberta.ca) or by phone at (780) 906-8648. If you have already mailed the survey back to us, please accept our sincere thanks and disregard this note.

Thank you for your timely action. We truly appreciate your help with this study.

Yours sincerely,

Yihong Wang

Email: yihong@ualberta.ca

Department of Rural Economy
515 General Services Buildings
University of Alberta
Edmonton, Alberta T6G 2H1

Appendix E: Advantages and Disadvantages of Mail Surveys

	Advantages	***Disadvantages***
Costs	➢ Low cost per unit surveyed ➢ Personnel requirements easily met ➢ Manageable given time frame constraints	➢ May indicate a potential participant that the survey is not as important as one using expensive interview approaches
Sample Participation	➢ High probability of survey package reaching the respondent where other methods fail ➢ High probability of selected respondents being located ➢ High probability of reaching all potential respondents	➢ Potential perception as "junk mail" ➢ High probability of unit non-response and item non-response ➢ Limited ability to clarify reasons for non-response ➢ Limited opportunity to motivate the potential participant ➢ Probability of the respondent who filled the survey may not be the selected one ➢ Potential respondent may be excluded because of literacy problem
Data Quantity	➢ Low personal cost to additive respondents	➢ Fewer questions possible in a mail survey due to the necessity of keeping the survey short
Data Quality	➢ Potential of avoiding interviewer bias ➢ Capability of using visual aids either to explain questions and concepts or to attract potential participants ➢ Manageable time frame for the participant to complete the survey and reconsider his responses ➢ Highest probability to obtain honest and social undesirable responses	➢ No opportunity to probe or clarify unclear responses ➢ Potential of question misunderstanding ➢ High probability of the participant skipping important details of the scenarios or questions

Sources: Dillman (1978); Mitchell and Carson (1989); MacDonald (1999).

Appendix F: Classifications of Crops and Irrigation Technologies

Appendix F-1 Classification of Major Crops

Cereals	*Forages*	*Oilseeds*	*Specialty Crops*	
Barley CPS Wheat Durum Wheat Hard Spring Wheat Malt Barley Oats Rye Soft Wheat Triticale Winter Wheat	Alfalfa - Two cuts Alfalfa - Three cuts Alfalfa Hay Alfalfa Silage Barley Silage Brome Hay Corn Silage Grass Hay Green Feed Milk Vetch Millet Oats Silage Pasture Rye Grass Sorghum/Sudan Grass Tame Pasture Timothy Hay Tritcale Silage	Canola Flax	Alfalfa Seed Black Currant Canary Seed Caraway Seed Carrots Catnip Chick Peas Corn Dill Dry Beans Dry Peas Faba Beans Fresh Peas Grass Seed Hemp Lawn Turf	Lentils Mint Monarda Mustard Nursery Onions Potatoes Pumpkins Safflower Seed Potatoes Small Fruit Soy Beans Sweet Corn Sugar Beets Sunflower

Appendix F-2 Irrigation System Classification

Pivot Sprinkler	*Wheel-Move*	*Gravity*	*Other*
Pivot High Pressure Pivot High Pressure - Corner arm Pivot Medium Pressure Pivot Medium Pressure - Corner Arm Pivot Low Pressure Pivot Low Pressure - Corner Arm Linear - High Pressure Linear - Low Pressure	Wheel Move - Two Laterals Wheel Move - Four Laterals	Gravity - Developed - No Control Gravity - Developed - Controlled Gravity - Undeveloped - Flood Gravity - Undeveloped - Subsurface	Volume Gun - Stationary Volume Gun - Traveler Solid Set (underground sprinkler) Hand Move (sprinkler above ground) Micro - Spray - Sprinkler Micro - Drip - Trickle Other Application Use

Appendix G: Characteristic Breakdown of Respondents by Roles

Appendix G-1 General Characteristics of the Respondents for Valuation Analysis

	Zero Bidders			*Buyers*			*Sellers*		
Sample Size	65			32			16		
Characteristics	**N**	**%**	**Sample Mean**	**N**	**%**	**Sample Mean**	**N**	**%**	**Sample Mean**
Age									
Under 35 Years	3	4.7%	56.1	0	0.0%	53.0	1	6.3%	56.9
35-54 Years	24	37.5%		18	56.3%		5	31.3%	
55 Years and Over	37	57.8%		14	43.7%		10	62.5%	
Gender									
Male	61	98.4%		32	100%		15	93.8%	
Female	1	1.6%		0	0.0%		1	6.2%	
Household Size									
Under 4 Persons	43	69.4%	3.0	16	50.0%	4.2	10	62.5%	2.9
4 Persons and Over	19	30.6%		16	50.0%		6	37.5%	
Education									
High School and Under	22	34.4%		5	15.6%		5	31.3%	
Technical Diploma and Over	42	65.6%		27	84.4%		11	68.7%	
Irrigation Training									
Yes	8	12.5%		11	34.4%		0	0.0%	
No	56	87.5%		21	65.6%		16	100%	
Membership									
Yes	37	56.9%		20	62.5%		7	43.7%	
No	28	43.1%		12	37.5%		9	56.3%	
Farming Experience									
≤ 10 Years	7	11.1%	28.2	4	12.9%	27.1	2	13.3%	25.4
≥ 11 Years	56	88.9%		27	87.1%		13	86.7%	
2007 Annual Gross Household Income									
Under \$60,000	13	21.3%		9	29.0%		3	20.0%	
\$60,000-99,999	18	29.5%		6	19.4%		6	40.0%	
\$100,000 and Over	30	49.2%		16	51.6%		6	40.0%	
Off-farm Work									
Yes	40	62.5%		18	56.3%		13	86.7%	
No	24	37.5%		14	43.7%		2	13.3%	
Farming Operation Role									
Owner	59	92.2%		28	87.5%		15	93.8%	
Operator	37	57.8%		13	40.6%		8	50.0%	
Manager	29	45.3%		13	40.6%		5	31.3%	
Trade Experience									
Yes	2	3.0%		4	12.5%		2	12.5%	
No	63	97.0%		28	87.5%		14	87.5%	

Appendix G-2 Farm Characteristics of the Respondents for Valuation Analysis

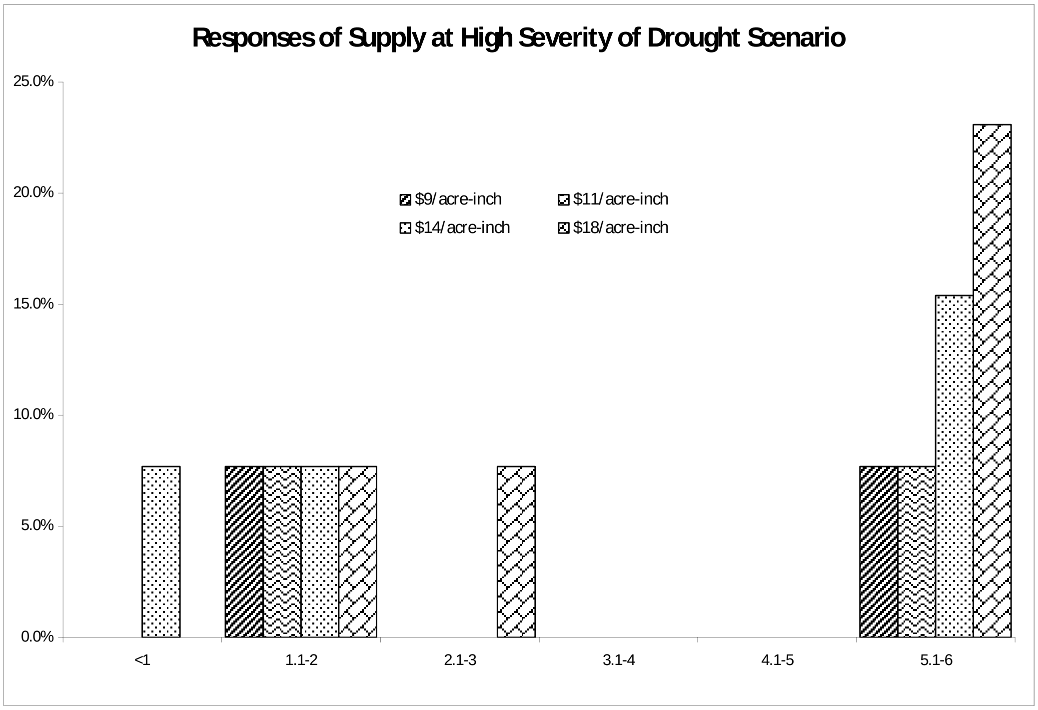
	Zero Bidders			***Buyers***			***Sellers***		
Sample Size	65			32			16		
Characteristics	**N**	**%**	**Sample Mean**	**N**	**%**	**Sample Mean**	**N**	**%**	**Sample Mean**
Farm Size (Acres)									
Under 10	2	3.1%		0	0.0%		0	0.0%	
10-69	16	25.0%		5	15.6%		3	18.8%	
70-129	7	10.9%		4	12.5%		5	31.3%	
130-239	14	21.9%		6	18.8%		3	18.8%	
240-399	9	14.1%	263.8	5	15.6%	395.4	3	18.8%	180.2
400-559	6	9.4%	Acres	5	15.6%	Acres	2	12.5%	Acres
560-759	4	6.3%		3	9.4%		0	0.0%	
760-1,119	4	6.3%		1	3.1%		0	0.0%	
1,120-1,599	1	1.6%		3	9.4%		0	0.0%	
1,600 and Over	0	0.0%		0	0.0%		0	0.0%	
Rent Acres									
Under 10	1	7.7%		1	8.3%		0	0.0%	
10-99	3	23.1%		3	25.0%		0	0.0%	
100-299	5	38.5%	291.2	4	33.3%	296.4	1	100%	13.1
300-499	2	15.4%	Acres	2	16.7%	Acres	0	0.0%	Acres
500-699	0	0.0%		0	0.0%		0	0.0%	
700-999	1	7.7%		1	8.3%		0	0.0%	
1000 and Over	1	7.7%		1	8.3%		0	0.0%	
Irrigation District									
AID	8	12.3%		2	6.3%		2	12.5%	
LID	6	9.2%		2	6.3%		3	18.8%	
LNID	45	69.2%		22	68.8%		7	43.8%	
MID	5	7.7%		5	15.6%		2	12.5%	
MVID	1	1.5%		1	3.1%		2	12.5%	
Holding land in 2001									
Yes	60	93.8%		30	93.8%		14	87.5%	
No	4	6.2%		2	6.2%		2	12.5%	
Livestock in 2008									
Yes	36	56.3%		21	65.6%		8	50.0%	
No	28	43.7%		11	34.4%		8	50.0%	
Crops for Sale 2008									
Yes	50	76.9%		25	78.1%		12	75.0%	
No	15	23.1%		7	21.9%		4	25.0%	
Crop Mix									
Cereal	33	52.4%		17	53.1%		8	50.0%	
Oilseed	16	25.4%		7	21.9%		2	12.5%	
Specialty	9	14.3%		7	21.9%		2	12.5%	
Forage	32	50.8%		18	56.3%		10	62.5%	
Irrigation Systems									
Low-pressure Pivot	25	38.5%		21	65.6%		5	33.3%	
Wheel Move	42	64.6%		25	78.1%		9	60.0%	
Gravity	9	13.8%		2	6.3%		3	20.0%	
Others	19	29.2%		6	18.8%		2	13.3%	

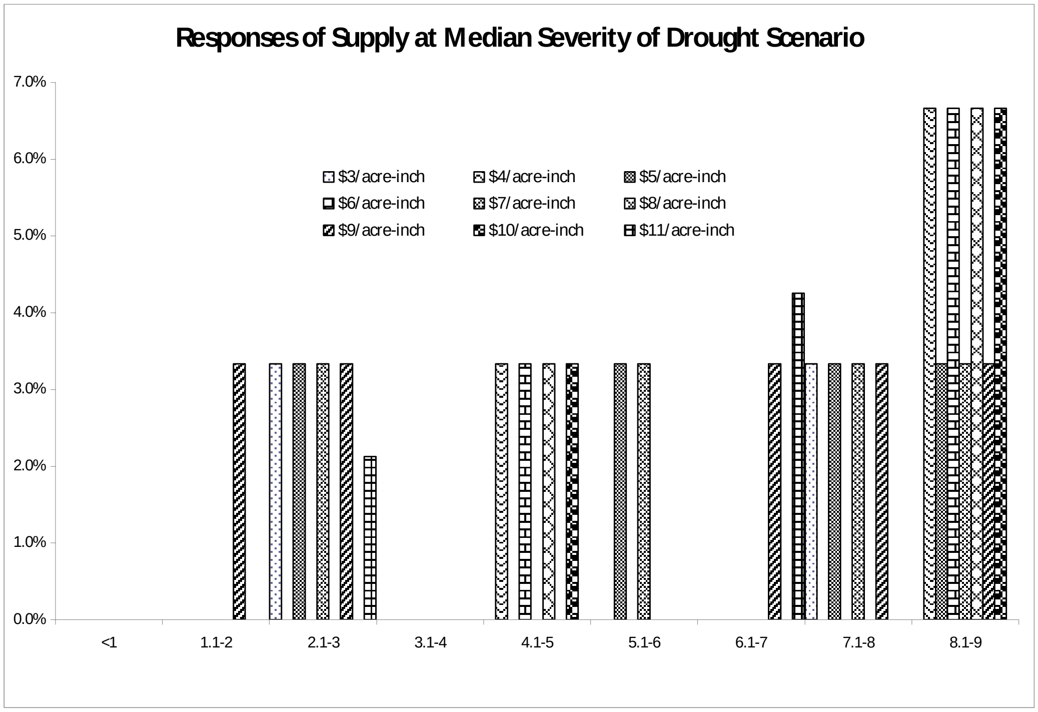
CAIS Participation						
Yes	31	50.0%	22	73.3%	6	40.0%
No	31	50.0%	8	26.7%	9	60.0%
Food Contract in 2008						
Yes	8	13.1%	6	19.4%	1	6.7%
No	53	86.9%	25	80.6%	14	93.3%
Food Contract in 2009						
Yes	7	11.9%	6	19.4%	2	13.3%
No	52	88.1%	25	80.6%	13	86.7%

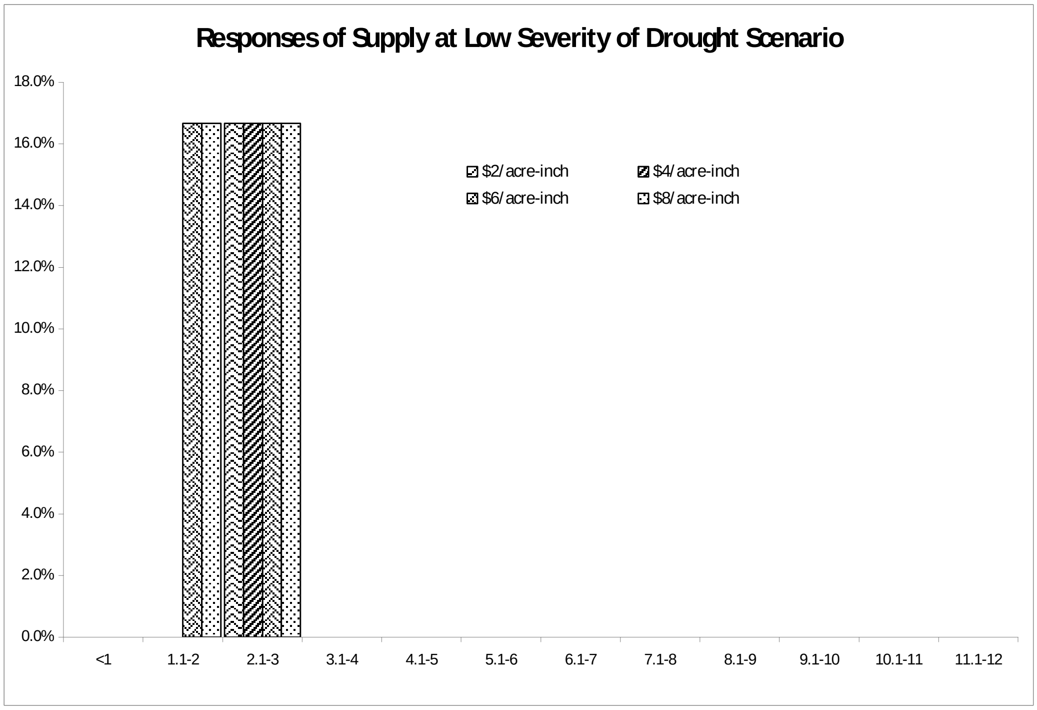
Appendix H: Response Distributions in the Survey

The distributions of responses (in terms of percentage of responses) on both supply and demand sides for irrigation water regarding levels of water scarcity and water prices were summarized here.

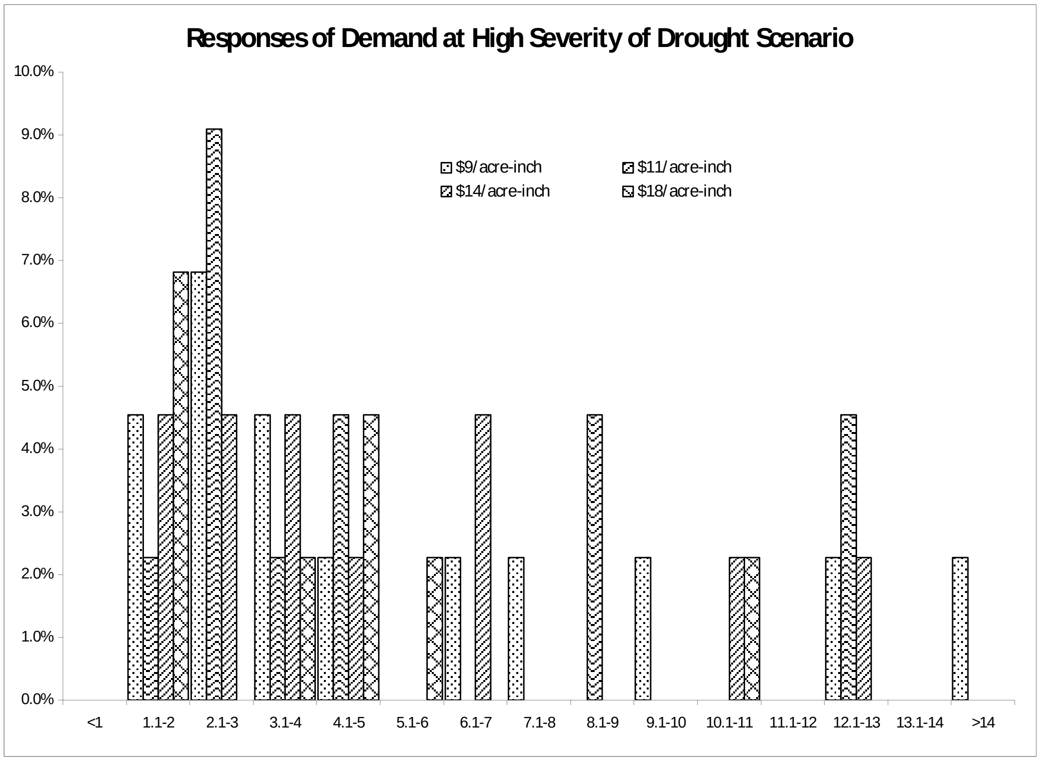
Appendix H-1 Response Distributions on the Supply Side

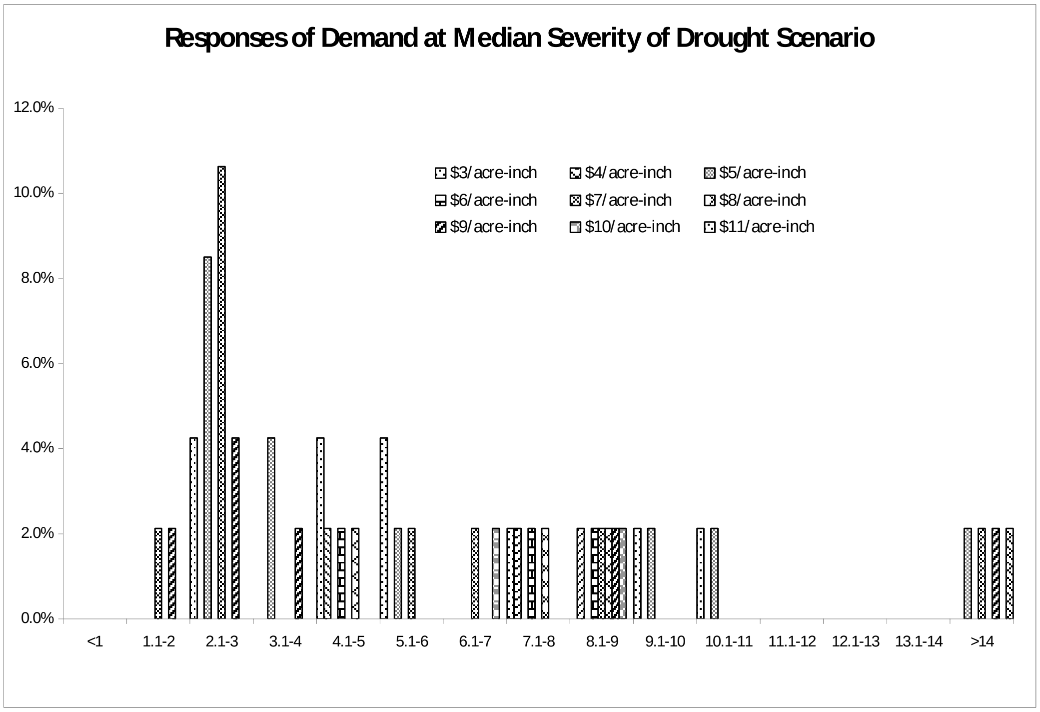


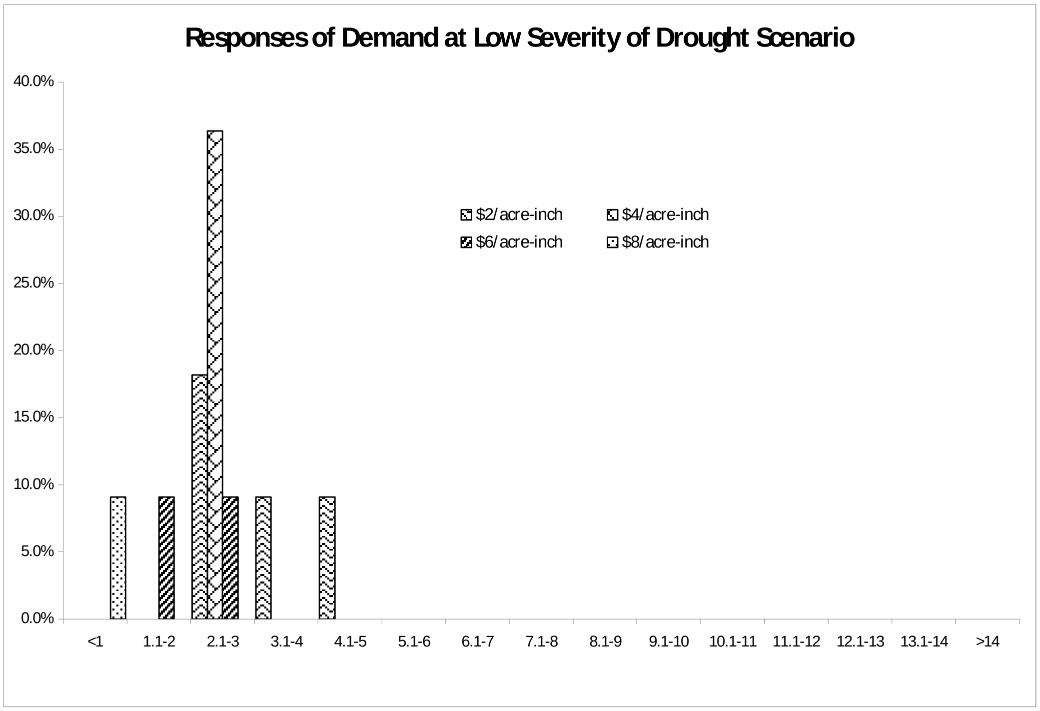

Responses of Supply at Median Severity of Drought Scenario
7.0%
6.0%
5.0%
4.0%
3.0%
2.0%
1.0%
0.0%
<1
1.1-2
2.1-3
3.1-4
4.1-5
5.1-6
6.1-7
7.1-8
8.1-9
$3/acre-inch
$4/acre-inch
$5/acre-inch
$6/acre-inch
$7/acre-inch
$8/acre-inch
$9/acre-inch
$10/acre-inch
$11/acre-inch


Responses of Supply at Low Severity of Drought Scenario
18.0%
16.0%
14.0%
12.0%
10.0%
8.0%
6.0%
4.0%
2.0%
0.0%
<1
1.1-2
2.1-3
3.1-4
4.1-5
5.1-6
6.1-7
7.1-8
8.1-9
9.1-10
10.1-11
11.1-12
$2/acre-inch
$4/acre-inch
$6/acre-inch
$8/acre-inch

Appendix H-2 Response Distributions on the Demand Side






Responses of Demand at Low Severity of Drought Scenario
40.0%
35.0%
30.0%
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
$2/acre-inch
$4/acre-inch
$6/acre-inch
$8/acre-inch
<1
1.1-2
2.1-3
3.1-4
4.1-5
5.1-6
6.1-7
7.1-8
8.1-9
9.1-10
10.1-11
11.1-12
12.1-13
13.1-14
>14