SOUTH SASKATCHEWAN RIVER BASIN

IRRIGATION in the 21st Century

Volume 5: Economic Opportunities and Impacts

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IRRIGATION IN THE 21ST CENTURY

INDEX TO VOLUMES

South Saskatchewan River Basin Irrigation in the 21st Century

Volume5: Economic Opportunities and Impacts

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Alberta Irrigation Projects Association
909, 400 – 4th Avenue South
Lethbridge, Alberta T1J 4E1
(403) 328-3068

and the

Irrigation Branch, Alberta Agriculture, Food and Rural Development
Agriculture Centre
100, 5401 – 1st Avenue South
Lethbridge, Alberta T1J 4V6
(403) 381-5140

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Volume 5 Economic Opportunities and Impacts

I. Assessing the Farm Financial Risks and Impacts of Irrigation Water Supply Deficits

Prepared by:

Richard Heikkila[1], Peter Woloshyn[1], Len Bauer[2], Wally Chinn[3], Dale Kaliel[1] and Renn Breitkreuz[1]

[1] Economics Unit, Alberta Agriculture, Food and Rural Development, Edmonton, Alberta
[2] Professor *Emeritus*, University of Alberta, Edmonton Alberta
[3] Irrigation Branch, Alberta Agriculture, Food and Rural Development, Lethbridge, Alberta

EXECUTIVE SUMMARY

As irrigated agriculture in Alberta moves into the 21st century, there is continued interest in expanding the irrigated land base, particularly within the 13 irrigation districts in southern Alberta. As these districts expand their irrigated areas, they are also approaching the limits of available water supplies. Through the latest in irrigation water demand modelling (Irrigation District Model - IDM), water diversion requirements have been projected for many different irrigation development scenarios. When merging those demands with the modelled water supply (Water Resources Management Model – WRMM), the magnitude, frequency and duration of water supply deficits related to the demands can be determined. However, even with potential supply deficits quantified, the potential impact of those deficits on the irrigation producer is still somewhat unclear. As a result, the Farm Financial Impact and Risk Model (FFIRM) was developed to take the expansion impact analysis a step further, quantifying that impact in economic terms. Not only is it critical to know how significant incurred deficits may be, and how often they may occur, or how long they may persist based on the historical record, the question still needs to be answered as to what the effect of irrigation water shortages may mean to the financial returns for an impacted water user.

Therefore, the primary objectives of this component of the overall Irrigation Water Management Study were:

a) to develop a computer model that could analyze the effects of irrigation water deficits on various crop production systems; and
b) quantify the impacts on farm incomes of such deficits as they may occur with time.

Within the scope of the Irrigation Water Management Study, entitled *South Saskatchewan River Basin – Irrigation in the 21st Century*, several different irrigation water demand scenarios were modelled. From those, seven scenarios were analyzed through the FFIRM to better quantify the risks and impacts of water supply deficits that may be encountered as the industry continues to expand. Many different farm enterprises were analyzed, including considerations for various debt levels among farm types. Farm enterprises were characterized by the type of crop mix, size of operation, the type of on-farm irrigation systems used, as well as the agro-climatic region in which a given farm enterprise operated.

The analyses included assessments of crop yield reductions projected to be incurred under varying deficit conditions and how those yield reductions translate into diminished returns to the irrigation producer. Several different financial performance measures were tested within any given scenario. These included:

> Net farm income;
> Probability of negative net farm income;
> Farm debt to asset ratio; and
> Risk of insolvency.

From the analyses performed, water supply deficits clearly had varying degrees of impact on the financial status of a given enterprise, depending upon the agro-climatic region in which the farm was operated and the type of crop mix that characterized a given farming operation. Where higher-valued specialty crops were produced in a rotation with other crop-types, there was a greater opportunity for an irrigator to optimize returns during times when water was in short supply, than in circumstances where only lower value commodities were produced. As a result, diversified farm enterprises were generally found to be able to withstand irrigation deficit conditions better than enterprises that relied primarily on crop mixes of conventional grains and oilseeds.

The financial analysis picture also differed somewhat between basins. For the irrigation operations within the Oldman Basin, there was a slightly higher potential for negative financial impacts than was the case for the Bow Basin. This was primarily due to the fact that the water supply deficits encountered in the Bow Basin, although having a somewhat greater frequency than in the Oldman Basin, were not nearly as significant in magnitude as deficit conditions experienced by farm enterprises in the Oldman Basin. Nonetheless, as the frequency of back-to-back years of water supply deficit increased, the risk of increasing potential for experiencing negative net farm incomes also increases.

Clearly, moving to irrigation management practices where crop moisture consumption is allowed to reach 90% of optimum has a significant effect on the financial ability of an enterprise to withstand projected levels of water supply deficit. The increased revenues that are achieved through increased yields, resulting from higher irrigation application amounts, help in a large way to offset any downturn in revenue that may be the result of reduced yields from water supply deficits incurred in low supply years. Also, it was assumed that in moving to scenarios where crop moisture consumption draws closer to near-optimum conditions, other inherent water use management and efficiency gains would simultaneously be occurring, both at the farm and the irrigation district level. For the positive financial results to be achieved, improving water management conditions must also be occurring while near-optimum moisture consumption conditions are applied.

Based on the application of the financial impact and risk analysis tool (FFIRM) and the assessments of the scenarios as developed within the *Irrigation in the 21st Century* Irrigation Water Management Study, it is concluded that opportunities for irrigation expansion are available to irrigation districts and associated water users in both the Oldman and Bow River Basins. However, these opportunities may be somewhat greater in the Bow Basin than in the Oldman Basin and will be subject to shifts in irrigation water management that encourage greater water use efficiencies and increased primary production output.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Background

Irrigation is an important part of the economy of southern Alberta. The irrigation sector has experienced significant growth during the past three decades. Continued expansion would be economically beneficial to the farming community as well as to the irrigation districts. Irrigation farming generally has higher, more stable returns compared to non-irrigation farming. As well, expansion of the irrigated land base would provide further economic support for irrigation districts through increased revenues derived within current water licence allocations. In addition, the overall economy of southern Alberta would benefit from more intensive agricultural production through increased spin-off economic activity, from increased supplies and services to farm enterprises, to the possible expansion of the value-adding processing sector.

Although irrigation farming has grown steadily in recent years, the potential for further expansion will be constrained by limited water supplies. With the existing irrigated area and water management practices, most irrigation districts currently can face water deficits, to some degree, in hot, dry, high demand years. In order to facilitate more production, water will need to be used more efficiently. Improvements in water management can occur in several ways.

- Shifts in on-farm systems to systems with higher application efficiencies.
- On-farm system management efficiency improvements.
- Increased on-farm crop water utilization.
- Improved district conveyance efficiencies and return flow management.

Purpose

This report (Volume 5) is part of a broad study entitled "Irrigation into the 21st Century." The purpose of the study was to assess irrigation district water requirements and water management opportunities in Alberta's South Saskatchewan River Basin. More specifically, the purpose was to provide a comprehensive, scientifically sound analysis of current and future water management within the irrigation districts.

Three separate computer models were applied in the study analysis.

- IDM – Irrigation District Model
- WRMM – Water Resource Management Model
- FFIRM – Farm Financial Impact and Risk Model

The first two models, which deal with water demand and supply modelling at the irrigation district and river basin level, are described in detail in Volume 4. Part I of this Volume describes the FFIRM. The IDM and the FFIRM were specifically developed as required components in the overall irrigation water management study.

The purpose of this study was to assess the financial impact and risk of different water management strategies. The IDM and WRMM models were used to assess the water demand

and supply, and to estimate and assess the potential for water supply deficits resulting from these different water management strategies across different irrigation districts or blocks. The FFIRM uses the water demand and supply information provided by these other models to estimate and assess the potential financial impact and risk of the water management strategies at the farm level.

METHODS

Farm Financial Impact and Risk Model (FFIRM)

An economic model (FFIRM) was developed to assess the financial impact and risks associated with different water management strategies. The source of risk assessed in this study is that of water supply shortages. The FFIRM has two main financial analysis components: a) an irrigation water allocation optimization component that determines the optimal allocation of water between fields to maximize farm revenue in any given year, and b) a farm financial simulation component that tracks farm finances with time. These two components are described in later sections of this Volume. This Methods section also includes some discussion of issues related to risk of water shortages and provides background information about the model, including descriptions of the representative farms (size, crop mix, irrigation equipment, capital assets), yield estimation formulas, crop prices and production cost profiles. The Results and Discussion section provides a summary of the outcomes from the farm financial analysis.

A main objective of the FFIRM is to provide an indication of the financial impact of alternative water management strategies on individual farm operations. To conduct the farm level analysis, a dynamic farm model was developed on an Excel workbook. The model is “dynamic” since it tracks the financial analysis for the farm model over time. That is, the farm finances (assets and liabilities) were tracked with time as various conditions changed, particularly crop prices and the growing conditions represented through heat and moisture parameters.

Historical records were used for each of these three main input variables. The time series data relating to crop moisture requirements, irrigation demand and water supply conditions covered 68 years (1928 to 1995). These data series were used to establish time series estimates of water demand and supply for various zones within irrigation districts (referred to as irrigation “blocks”). This process is described in more detail in Volume 4.

The crop price time series were collected for the period 1975 to 1998. These crop series were repeated several times in order to establish a 68-year time series to match the weather and water supply data time series. The crop prices are discussed in more detail in a later section of this report.

Risk of Water Shortages

The amount of water available to farms determines crop yields and ultimately production revenues. Water deficiencies result in lower crop yields and reduced financial returns. The risk of incurring water deficiencies can be described in a number of ways. Most of them describe the risks associated with the farm not being supplied with sufficient water through the works of an irrigation district, from a diversion source. They include:

- the ***magnitude*** of water shortages - how large are the deficits?
- the ***frequency*** of water shortages - how often or in how many years do deficits occur?
- the ***duration*** of water shortages - in how many consecutive years would a deficit occur?
- the ***timing*** when water shortages occur - at what point or during what period of the growing season do water supply shortages exist?

This study only assesses the first three sources of risk. It does not account for the timing of water shortages. The crop yield formulas (described in a later section of this report) relate only to the total annual crop consumptive use of water. Since the crop yield formulas do not account for possible impacts of water deficiencies occurring at different periods within the growing season, they do not allow for a risk analysis of the seasonal timing of the water deficits.

An additional risk of crop water deficiency is due to farm management decisions, primarily:

- the ***irrigation management level*** at which irrigators apply water relative to meeting optimum crop water demands that support optimum crop yields.

It has been determined that, currently, irrigators apply somewhat less water to their crops than what would be required to achieve optimum yields. Depending on the type of crop, irrigation producers are currently applying irrigation water to meet between 75 and 95 percent of optimum crop water use. By applying more water than usual, when it is available, water users could generate higher yields, resulting in higher returns.

Representative Farms

In order to assess the financial impact at the farm level, 19 representative farm enterprises were developed describing five different farm types for six different agro-climatic regions. The agro-climatic regions were derived for regions with commonality in length of growing season, annual heat units, precipitation potential, potential evapotranspiration and typical crop production characteristics. Figure A illustrates the geographical distribution of these agro-climatic zones or regions and their respective alignment with specific irrigation districts or portions thereof.

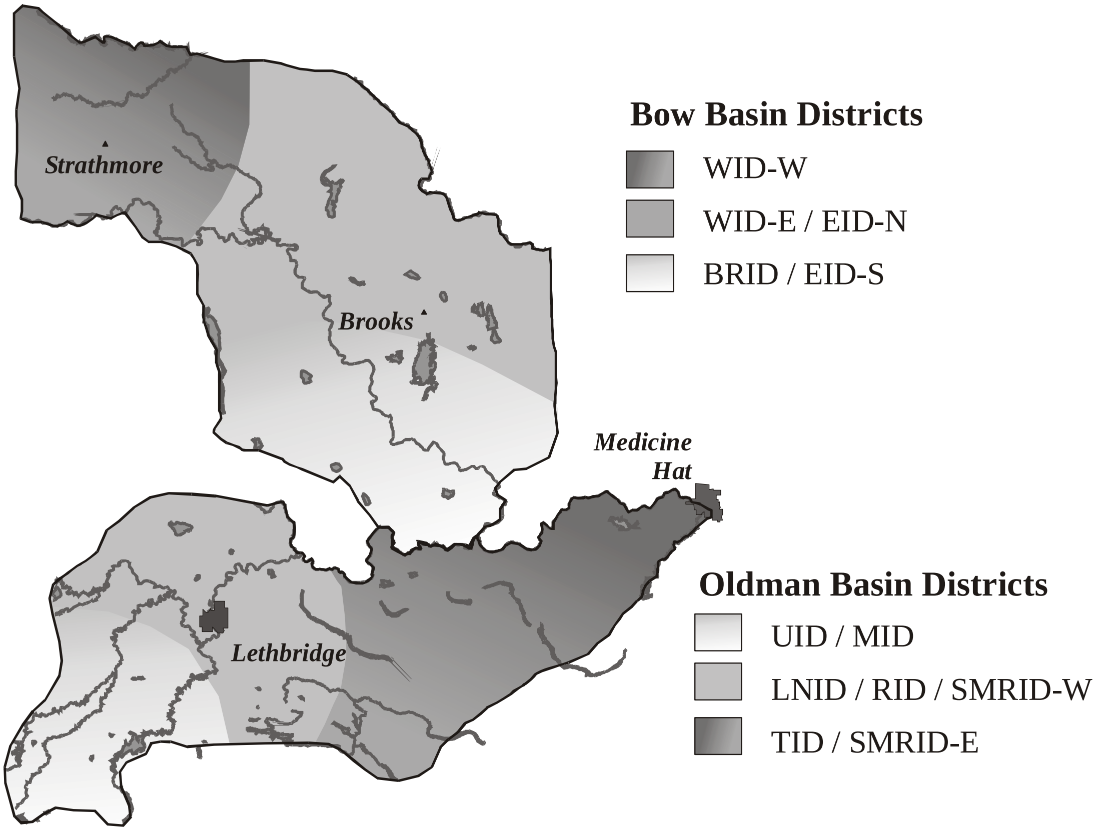


Figure A. Climate and crop regions applied in the FFIRM analyses.

Representative Farm Types. The five representative farm or enterprise types modelled and analyzed are listed below.

a) Grains and Oilseed Mix -	Farms that have only grain and oilseeds within the crop mix.
b) Sugar Beet Mix -	Farms that have sugar beets in the crop mix, in addition to grains, oilseeds and/or forages.
c) Potato Mix -	Farms that have potatoes in the crop mix, in addition to grains, oilseeds and/or forages.
d) Grain and Forage Mix -	Farms that emphasize grains and oilseeds in the crop mix, but include some forages.
e) Forage Mix –	Farms that emphasize forages, but may have some grain in the crop mix.

For each of the six irrigation or agro-climatic regions, two to four representative farm enterprises were identified. These are described in Table 1, along with the specific crop mix and irrigation area components. For example, the first irrigation block in the table represents the United Irrigation District (UID) and the Magrath Irrigation District (MID). This irrigation block has two representative farms, labeled U1 and U2. The crop mix of U1 includes grains, oilseeds and forages, while U2 places more emphasis on forages.

5

Table 1. Description of representative farms.

Irrigation Block *	Farm Type		Crops (% of farm area)										
			Alfalfa	Barley Silage	Tame Grass	HRS Wheat	Durum	SWS Wheat	Barley	Canola	Sugar Beets	Dry Beans	Potatoes
UID/MID area 225-ha farm	U1	Grain and Forage Mix	25			30			25	20			
	U2	Forage Mix	40		30				30				
Lethbridge area LNID RID SMRID-W 300-ha farm	L1	Grains & Oilseeds Mix					20	20	40	20			
	L2	Sugar Beet Mix	30					20	30		20		
	L3	Grain and Forage Mix	25	25				25	25				
	L4	Forage Mix	30	20	30		20						
Burdett area TID SMRID-E 360-ha farm	B1	Grains & Oilseeds Mix					20	20	40	20			
	B2	Sugar Beet Mix	30						30		20	20	
	B3	Potato Mix						25	25	25			25
	B4	Forage Mix	35	30	15		20						
Enchant area BRID EID-S 325-ha farm	E1	Grains & Oilseeds Mix					20	20	40	20			
	E2	Sugar Beet Mix	30					20	30		20		
	E3	Potato Mix						25	25	25			25
	E4	Forage Mix	35	30	15		20						
Strathmore area WID-W 220-ha farm	S1	Grain and Forage Mix	25			30			25	20			
	S2	Forage Mix	40		30				30				
Rosemary area WID-E EID-S 325-ha farm	R1	Grains & Oilseeds Mix					20	20	40	20			
	R2	Grain and Forage Mix	25	25				25	25				
	R3	Forage Mix	30	20	30		20						

* The Irrigation Blocks represent nine of the 13 Irrigation Districts in southern Alberta, either in part or in whole. The Irrigation Districts represented are: United, Magrath, Lethbridge Northern, Raymond, St. Mary River (East and West), Taber, Bow River, Eastern, and Western.

Irrigation Equipment. Field inventory data for 1999 indicate that on-farm irrigation application methods vary within the six regions. The mix of irrigation equipment identified and established in this study for each irrigation region is described in Table 2.

Table 2. Irrigation equipment mix.

Irrigation Region	Methods Mix (% of area)				
	Surface Flood Undeveloped	Surface Flood Developed	Sprinklers Wheel Move	Sprinklers Pivot: High Pressure	Sprinklers Pivot: Low Pressure
UID/MID	22	9	36	14	19
Lethbridge	4	9	38	23	26
Burdett	2	7	28	11	52
Enchant	3	12	33	35	17
Strathmore	14	4	24	49	9
Rosemary	8	29	25	12	26

Irrigation Equipment Capital Costs and Application Efficiencies. The specific mix of irrigation equipment determines the total irrigation asset value of the farm as well as the variable cost per unit of irrigation area for labour, repairs and maintenance, and energy. Capital costs as well as application efficiency rates for each irrigation method are provided in Table 3.

Table 3. On-farm irrigation system capital costs and application efficiencies.

System Type	Capital Cost for New Equipment ($/ha)	Application Efficiency (Net)	
		Std.*	Good*
Gravity – Flood	310	20%	30%
Gravity – Developed	990	54%	62%
Gravity – Controlled	1,665	70%	80%
Sprinkler - Hand-move, Solid Set or Wheels	1,360	65%	70%
Sprinkler - Pivot / Linear - Hi Pressure w/ or w/o Corner Systems	1,665	71%	74%
Sprinkler - Pivot / Linear - Lo Pressure w/ or w/o Corner Systems	1,600	75%	80%
Sprinkler - Volume Gun, Traveller	1,550	63%	66%
Micro	2,720	82%	87%

***** Reflects different levels of on-farm system management by an irrigation system operator.

Representative Farm Assets. For each of the 19 representative farms, a generalized complement of farm assets was devised for each, including land, machinery, equipment and buildings. The present market values (2001) of those farm assets are listed in Table 4.

Table 4. Representative farm asset values.

Irrigation Block	Farm Type	Machinery and Equipment * $	Irrigation Equipment $	Buildings $	Land $
UID/MID area	U1 grain, forage	231,500	127,524	111,925	825,000
	U2 forages	200,000	127,524	149,000	825,000
Lethbridge area	L1 grain, oilseed	273,100	193,809	144,000	825,000
LNID	L2 sugar beet	337,080	193,809	118,500	825,000
RID	L3 grain, forage	267,880	193,809	118,125	825,000
SMRID-W	L4 forages	222,076	193,809	143,750	825,000
Burdett area	B1 grain, oilseed	313,600	236,313	154,660	1,760,000
TID	B2 sugar beet	398,630	236,313	114,900	1,760,000
SMRID-E	B3 potato	464,224	236,313	299,200	1,760,000
	B4 forages	209,802	236,313	145,700	1,760,000
Enchant area	E1 grain, oilseed	313,600	208,800	148,100	880,000
BRID	E2 sugar beet	377,980	208,800	120,900	880,000
EID-S	E3 potato	464,224	208,800	279,500	880,000
	E4 forages	209,802	208,800	144,500	880,000
Strathmore area	S1 grain, forage	231,500	134,804	111,390	1,200,000
WID-W	S2 forages	200,000	134,804	148,700	1,200,000
Rosemary area	R1 grain, oilseed	215,000	134,024	130,060	1,300,000
WID-E	R2 grain, forage	221,500	134,024	110,050	1,300,000
EID-N	R3 forages	198,500	134,024	141,200	1,300,000

* Not including irrigation equipment.

The total estimated asset values for each of the representative farms are dependent on the farm's type, size, location and mix of irrigation equipment. For example, potato farms have the highest machinery asset values due to the machinery complement required. As another example, the total land value is highest for the representative farms in the Burdett block due to the higher land values per unit area, as well as the larger size of the Burdett block representative farms.

Farm Debt Categories. The amount of debt that a farm carries has a tremendous impact on the financial viability of the farm. For this analysis, three different starting debt levels were assessed for each representative farm. The base debt level at the start of the model simulation is a debt / asset ratio of 15 percent. The medium and high starting debt levels are 30 and 50 percent.

Crop Yields

Overview. Crop yields are estimated within the FFIRM through the use of yield formulas. Yields have a direct correlation to the total water consumed by the crop, which is directly related to the amount of moisture available to it through the growing season. The total water availability is itself a function of two variables: precipitation and net irrigation water application amounts. Finally, net water application amounts are a function of crop water demand, irrigation water supply, irrigation equipment application efficiencies and an irrigation water management factor (the level of meeting crop moisture requirements relative to optimum). This process is described in more detail in the following sections.

Irrigation Water Supply, Demand and Deficits. The FFIRM receives water demand and supply information from the two water management models. Irrigation demands are generated through the Irrigation District Model (IDM), while the irrigation water supply values are established in the Water Resources Management Model (WRMM). Both models are described in detail within Volume 4 of the overall water management study report. The difference between the water demand and water supply values is the predicted deficit in irrigation water supply.

This supply deficit is realized almost exclusively at the farm gate level, since it is assumed that all other consumptive and return flow losses, within the storage and conveyance systems, will continue to exist in their same order of magnitude. These reservoirs and delivery networks will still encounter the same order of magnitude of evaporation and seepage losses, even at times when water is short and is rationed throughout the whole of the distribution system. Therefore, any deficit that occurs is equated to the gross water deficit in each irrigated area (i.e. at the farm gate). The actual net irrigation deficit to each irrigated crop is then a function of the application efficiency of the respective irrigation method (system or equipment) applying water to each irrigated field.

It is assumed that when a deficit in water supply to an irrigation block occurs, that deficit is distributed equally to all irrigators within that block on a depth per unit area basis. However, the FFIRM allows for a re-distribution of that deficit between the various crops within the representative farms, based on economic optimization. This field water allocation process is addressed in a later section of this report.

In the IDM and WRMM models, the deficit in water supply to an irrigation block is expressed as:

$$\text{IDM Demand (dam}^3\text{/week)} - \text{WRMM Supply (dam}^3\text{/week)} = \text{Deficit dam}^3\text{/week)}$$

The crop yield formulas applied in the FFIRM are a function of water consumption expressed in millimetres of evapotranspiration by the crop. Therefore, all demand and supply volumes of water derived through the IDM and WRMM are converted to annual values expressed in millimetres of water over an entire block area.

$$\text{Demand (mm/year)} - \text{Supply (mm/year)} = \text{Deficit (mm/year)}$$

The deficit is assumed to be applied equally across the irrigation blocks; therefore,

Deficit (D) = mm/block area = mm/hectare

It is important to note that the demand estimations at the irrigation block level take into account the mix of different irrigation methods for that specific block. Therefore, the application efficiencies as well as the downtime losses of the various irrigation systems or methods have been taken into account in determining the overall irrigation demand at the block level.

The application efficiencies as well as downtime losses of various irrigation systems or methods can be quite variable. Application efficiencies can range from about 25% up to as high as 90%, while downtime losses can vary between 2% and 9% of the overall delivery demand to the irrigated field. Farms that have less efficient irrigation systems demand more water to achieve similar yields of farms with more efficient systems.

The application efficiency factor also affects the crop water deficit calculations. The application efficiency ratings for irrigation systems are listed back in Table 3. The real deficit to the crop, therefore, is:

$$D_c = (D - Loss_{downtime}) \times e_a$$

where:

D_c	=	Moisture deficit realized at the crop root zone (mm)
D	=	Gross deficit realized at the delivery point to the irrigated field (mm)
$Loss_{downtime}$	=	Water demanded at the delivery point lost due to system downtime caused through system set changes or mechanical breakdowns (mm)
e_a	=	Application efficiency of the irrigation system or method used (%)

Irrigation Requirement. Irrigation requirement is a function of total crop use during the growing season, the amount of precipitation received and the change in soil moisture. It is defined as:

$$IR = (CU - R - \Delta SM)/e_a$$

where:

CU	=	Crop consumptive use of water (mm)
R	=	Precipitation in the form of rainfall (mm)
ΔSM	=	Change in soil moisture level between beginning and end of year (mm)
e_a	=	Application efficiency of the irrigation system (%)

A number of steps were taken to estimate the historical crop water use for the study period (1928 to 1995) under the different water management scenarios.

Base Evapotranspiration Potential. The first step was to determine the overall potential evapotranspiration (PE) for each irrigation block. This was derived from weather data from the

Gridded Prairie Climate Database (GRIPCD), with each block assigned a specific gridded climate data reference point (GCDP).

Alfalfa is the reference crop for the base PE. The individual crop evapotranspiration potentials for other crops are derived from this base PE by applying crop-specific evapotranspiration coefficients. The PE, expressed in millimetres, represents the seasonal total. The daily value of potential evapotranspiration is labelled as Etp.

Crop Evapotranspiration Potential. Since crops have different physiology and growing periods, they also have different daily evapotranspiration values (Etc) that are unique to each crop. The ETc is the seasonal total for each specific crop and is expressed in millimetres. It is the summation of the daily values (Etc) at a specific GCDP over the respective growing season of the specific crop.

Crop Evapotranspiration. Crop-specific evapotranspiration values are a function of the crop's potential evapotranspiration and its crop water use coefficient. The daily value is defined as:

$$Etc = Etp \times k_c$$

where:

where:	Etc	=	Daily crop water use value for a given crop and geographical location (mm)
	Etp	=	GCDP daily potential evapotranspiration value (mm)
	k_c	=	Crop water use coefficient, for a given crop at a given stage of growth, as defined for a specific day in the growing season.
and where:			
	ETc	=	The seasonal summation of all respective Etc values for a given crop.

Actual Crop Evapotranspiration. The crop-specific ETc values define the crop water use assuming water, available through rainfall and irrigation, is not limiting to full crop requirements. Actual crop water use may be reduced due to either specific irrigation management practices or irrigation water deficits.

If irrigation applications are limited due to irrigation management practices, then crops will not be able to reach their water use potentials, resulting in less than optimal yields. To account for different management practices, the IDM allows the user to model irrigation demands below the optimum consumption values through the application of an ET Scaling Factor (SF_{et}). The factor must be between 0 and 1, but for most crops and irrigation districts it presently ranges between 0.75 and 0.95.

The actual crop evapotranspiration value, taking into account reduced irrigation water applications due to management practices or water deficits, is defined as:

$$ETa = (ETc \times SF_{et}) - d$$

where:	ETa	=	Actual crop evapotranspiration / consumptive use (mm)
	ETc	=	Potential crop water use when water is not limiting (mm)
	SF_{et}	=	Scaling factor to discount crop water use due to operator irrigation management practices
	d	=	Net deficit in water supply to the crop

Crop Yield Equations. Yield response predictive equations were selected from previous development work carried out. Empirical yield response equations were developed from collected data for ten of the principle crop types grown in the irrigated areas of southern Alberta (Palmer et al.1982). The crop yield equation, for each specific crop-type, projects yields on the basis of the actual moisture consumption for a given year, relative to: a) the potential water use for that year, and b) the maximum yield possible through the potential crop water use for that year. Crop yield equations derived for southern Alberta are listed below. The respective crop coefficients for the yield equation are listed in Table 5.

$$Y_a = K_{ay}\ x \left[A_0 + \left(A_1\ x\ \frac{ETa}{ETp} \right) + \left(A_2\ x \left(\frac{ETa}{ETp} \right)^2 \right) \right] x\ Y_m$$

$$Y_p = K_{py}\ x \left[A_0 + \left(A_1\ x\ \frac{ETc}{ETp} \right) + \left(A_2\ x \left(\frac{ETc}{ETp} \right)^2 \right) \right] x\ Y_m$$

$$Y_m = K_{my}\ x \left[B_0 + \left(B_1\ x\ \frac{ETp}{1000} \right) + \left(B_2\ x \left(\frac{ETp}{1000} \right)^2 \right) \right]$$

where:	Y_a	=	Actual crop yield for each crop type under prevailing water supply conditions
	Y_p	=	Potential yield attainable for each crop type if water is not limiting
	Y_m	=	Maximum yield attainable for each crop type where no inputs are limiting and where all yields are expressed in kg/ha.

Table 5. Yield equation coefficients for common southern Alberta irrigated crops.								
Crop Type	K_{AY} & K_{PY}	A_0	A_1	A_2	K_{MY}	B_0	B_1	B_2
Alfalfa	1.44	-0.297	1.272	-0.313	3.95	-2,970	12,720	-3,130
Barley	1.18	-0.299	1.696	-0.644	2.05	-2,990	16,960	-6,440
Barley Silage	1.18	-0.201	2.763	-0.244	1.30	-2,010	27,630	-2,440
Canola	1.22	0.021	1.121	-0.360	7.50	21	1,121	-360
Dry Beans	1.22	-0.650	2.498	-1.038	1.20	-6,500	24,980	-10,380
Tame Grass	1.20	-0.334	1.781	-0.701	2.00	-334	17,810	-7,010
HRS Wheat	1.20	-0.291	1.628	-0.557	11.50	-291	1,628	-557
SWS Wheat	1.20	-0.291	1.628	-0.557	11.10	-437	2,442	-836
Potatoes	1.19	-0.618	2.467	-1.014	7.50	-6,180	24,670	-10,140
Sugar Beets	1.19	-0.501	2.528	-1.144	9.85	-5,010	25,280	-11,440

The crop yield equations are quadratic in form, with two independent variables relating to evapotranspiration (ETa and ETp). Since the yields are based solely on water consumption, this assumes that all other input parameters such as fertilizer are not limiting.

The evapotranspiration values for each crop represent the total for the growing season, rather than monthly or weekly ETa values. Most crop yield formulas available in the literature relate yield response to total seasonal evapotranspiration. Very few yield functions have been estimated based on monthly or weekly water consumption. Monthly or weekly consumption yield formulas would be preferable to formulas based on annual consumption because crop yield, as well as quality, can be significantly affected by the timing of any incurred water deficit during the growing season. For example, some grain crops are more sensitive to moisture deficits during the early shot-blade stage of plant development, while other crops are more dependent on moisture for fruit development near the end of the season.

In summary, yields are a function of actual water consumption and the potential moisture consumptive use in any given year, and of the overall maximum yield possible assuming ideal moisture and temperature conditions. It can generally be concluded that in very warm seasons, both yield potential and moisture consumption will be quite high, whereas in cooler years both factors will be reduced.

Crop Prices

Eleven crops were selected to be included in the crop rotations of the 19 representative farms. One of the 10 crop-yield equations was modified to include an eleventh crop type. Yield equations were modified to recognize yield potentials of both soft white spring (SWS) wheat and hard red spring (HRS) wheat. The crop prices used for the 11 crops in the analysis are provided in Tables 6 and 7.

Table 6. Nominal crop prices.									
Year	Alfalfa	Barley Silage	Tame Grass	HRS Wheat	SWS Wheat	Barley	Canola	Sugar Beets	Dry Beans
	$/tonne	$/tonne	$/tonne	$/tonne	$/tonne	$/tonne	$/tonne	$/tonne	$/tonne
1975	55.88	21.21	39.63	146.11	137.78	106.10	223.82	33.07	423.35
1976	60.16	17.27	42.66	115.10	108.58	86.35	266.99	26.83	247.14
1977	62.46	15.20	44.29	117.74	110.92	75.99	278.54	34.26	289.43
1978	65.59	13.38	43.36	159.79	143.13	66.93	278.34	37.98	334.80
1979	74.20	20.81	56.41	197.75	176.35	104.08	270.82	74.05	628.19
1980	103.00	26.22	68.94	216.29	206.24	131.12	275.44	66.99	756.61
1981	105.65	21.43	64.28	192.93	184.18	107.21	282.40	43.19	394.05
1982	88.04	18.86	69.15	185.66	171.78	94.31	279.00	45.52	346.70
1983	99.68	23.15	68.31	186.87	161.54	115.82	406.02	38.76	554.41
1984	110.67	28.57	79.85	179.23	152.23	142.92	347.37	31.49	742.51
1985	136.42	22.51	85.97	149.45	119.24	112.60	265.35	25.00	600.88
1986	126.47	14.27	59.65	120.23	94.40	71.37	202.69	21.83	619.16
1987	87.73	14.09	56.65	128.18	103.15	70.50	264.66	30.52	385.24
1988	94.34	24.20	61.65	194.07	175.03	121.03	295.28	37.33	872.03
1989	102.22	21.52	58.35	158.92	145.61	107.65	262.84	45.19	781.94
1990	104.41	18.87	60.38	117.10	96.89	94.34	245.81	40.86	393.61
1991	87.74	16.98	49.46	117.42	109.13	84.93	228.94	32.10	343.39
1992	85.39	19.15	58.97	145.45	133.65	95.77	279.88	38.19	448.68
1993	109.29	17.80	59.61	171.16	109.86	89.00	339.55	38.83	783.48
1994	109.99	23.44	62.76	186.43	155.52	117.22	357.83	43.02	444.71
1995	109.75	32.23	75.44	234.83	208.33	161.22	372.24	43.7	514.98
1996	136.69	27.30	88.70	185.57	157.85	136.52	397.13	42.13	599.78
1997	124.82	26.58	81.18	170.31	129.96	132.92	380.00	48.30	604.63
1998	134.43	23.18	72.71	165.80	113.46	115.90	338.07	33.82	535.90

The farm financial analysis was conducted through an extended time period, assuming that inflation was not a factor. In other words, the analysis was conducted with time using “constant” dollars. Another common expression for this is that the analysis was conducted in “real” dollars. Therefore, the nominal crop price data needed to be adjusted to reflect constant dollars. However, it was not possible to simply adjust for inflation because technological gains in crop production have contributed to shifts in crop prices. Moreover, the amount that technological advancements have affected crop prices varies considerably by crop. For instance, “real” wheat prices have fallen steadily with time, whereas “real” alfalfa prices have actually increased. A process was needed to derive time series data for “real” crop prices that took into account these different rates of technological influences, but still reflected the inherent price variability of the individual crops.

Table 7. Crop prices in constant dollars.										
Year	Alfalfa	Barley Silage	Tame Grass	HRS Wheat	SWS Wheat	Barley	Canola	Sugar Beets	Dry Beans	Potato
	$/tonne	$/tonne	$/tonne	$/tonne	$/tonne	$/tonne	$/tonne	$/tonne	$/tonne	$/tonne
1975	84.73	26.33	43.15	177.03	122.30	131.68	276.41	32.14	475.33	110.00
1976	88.57	21.15	46.15	138.90	96.84	105.77	325.81	26.14	274.01	110.00
1977	89.36	18.37	47.61	124.66	99.41	91.89	335.93	33.47	316.96	110.00
1978	91.27	15.98	46.31	144.10	128.91	79.91	331.80	37.19	362.33	110.00
1979	100.48	24.53	59.86	199.72	159.61	122.70	319.15	72.70	671.59	110.00
1980	135.88	30.53	72.70	231.85	187.59	152.67	320.92	65.94	799.34	110.00
1981	135.83	24.65	67.34	189.42	168.35	123.30	325.36	42.62	411.45	110.00
1982	110.39	21.42	72.00	174.15	157.80	107.15	317.89	45.04	357.93	110.00
1983	121.97	26.00	70.69	187.91	149.14	130.03	457.55	38.45	565.86	120.00
1984	132.24	31.70	82.12	184.64	141.25	158.56	387.23	31.32	749.34	120.00
1985	159.25	24.68	87.86	161.55	111.20	123.46	292.63	24.93	599.56	120.00
1986	144.31	15.46	60.60	129.84	88.49	77.35	221.16	21.83	611.01	120.00
1987	97.91	15.11	57.20	146.15	97.18	75.54	285.75	30.59	375.99	120.00
1988	103.03	25.63	61.87	175.40	165.75	128.22	315.51	37.52	842.07	120.00
1989	109.27	22.55	58.22	134.26	138.61	112.78	277.96	45.54	747.14	120.00
1990	109.32	19.54	59.87	95.45	92.71	97.75	257.31	41.28	372.03	120.00
1991	90.00	17.40	48.75	103.40	104.97	87.04	237.25	32.52	321.15	120.00
1992	85.86	19.41	57.79	122.23	129.23	97.08	287.15	38.79	415.42	120.00
1993	107.74	17.85	58.09	187.71	106.79	89.27	344.94	39.54	718.06	130.00
1994	106.37	23.26	60.80	216.07	151.97	116.32	359.96	43.93	403.30	130.00
1995	104.15	31.65	72.65	215.85	204.66	158.32	370.84	44.74	462.56	130.00
1996	127.35	26.53	84.93	180.66	155.90	132.68	391.84	43.25	533.26	130.00
1997	114.19	25.57	77.29	201.25	129.05	127.86	371.39	49.72	532.38	130.00
1998	120.80	22.06	68.83	127.33	113.28	110.36	327.31	34.91	467.18	130.00

The process used for developing a constant dollar crop price included the following steps:

1. Collect nominal crop price data.
2. Calculate the 10-year average crop prices (1990 – 1999).
3. Estimate independent trend lines for each crop.
4. Calculate the variation of crop prices around the respective trend line.
5. Apply the price variations established in step 4) to the average prices established in step 2.
6. Convert the crop price data to the units “dollars per kilogram.”

The potato price series was based on expert opinion because an historical Alberta price series was not available.

Production Costs

Overview. For this study, most field level production costs were assumed to be constant with time. A primary objective of the study was to assess the impact, with time, on farm revenues and financial sustainability of different water management strategies, assuming the current farm structure and operating characteristics. Therefore, current production costs were assumed to apply to all of the years in the study. The only exceptions were some of the variable costs relating to irrigation, which are a function of amount of water applied to each field.

Direct Cash Costs: Non-Irrigation. The field level operations, inputs and input prices are based primarily on conditions in 2000, but 1999 costs were considered as well, particularly with regard to energy and fertilizer prices. The non-irrigation variable costs, by crop, are provided in Table 8.

Direct Cash Costs: Irrigation. Irrigation variable costs are expressed as a linear function of the amount of water applied to the field. The equation coefficients for labour costs, repairs and maintenance (R & M) costs and energy costs are listed in Table 9 and are shown as cost per millimeter of water applied per hectare.

Labour costs (per unit of water applied) are highest for the gravity flood system, and lowest for the pivot sprinkler systems. Repair and maintenance costs are highest for the micro system, and lowest for the gravity system types. Finally, energy costs are highest for the volume gun sprinkler, and lowest for the gravity system types.

Capital Costs. In the earlier Table 4, the beginning asset base for each representative farm at the start of the simulation was presented. With time, capital assets depreciate and need to be replaced. This process of capital asset replacement at the whole farm level is accounted for within the farm financial model, which is described in detail in an up-coming section of this report.

The Water Allocation Optimization Component of FFIRM

The FFIRM has two main analysis components. The first is the water allocation optimizer. In this component, farm revenue is maximized with respect to irrigation levels on a field-by-field basis. For each year of the analysis, the model uses an optimization routine to allocate the total irrigation water available to the farm amongst the different fields, defined by the different crops within the farm, so as to maximize total farm revenue.

The water allocation optimization process is based on the incremental yields for each crop as determined by the yield formulas. Since crop prices are constant in any given year, the marginal revenue for each field, with respect to incremental changes in irrigation water, is directly proportional to the “marginal yield” curve. The model uses the Solver add-in feature available within the Excel workbook to perform the optimization process.

The optimization process in the FFIRM is illustrated through the two hypothetical examples in Tables 10 and 11.

Table 8. Direct cash costs by crop (excluding irrigation costs).

Variable Costs	Alfalfa	Barley Silage	Tame Grass	HRS Wheat	SWS Wheat	Barley	Canola	Sugar Beets	Dry Beans	Potato
48Seed	24.71	24.71	24.71	34.59	32.12	24.71	37.07	128.05	116.14	24.71
Fertilizer	51.89	98.84	24.29	98.84	108.73	98.84	126.02	128.49	93.90	24.29
Chemicals	9.88	18.53	--	49.42	49.42	49.42	74.13	234.75	185.33	--
Hail/Crop Insurance	--	--	--	7.41	7.41	6.18	11.12	12.36	27.18	--
Trucking and Marketing	24.71	--	9.66	12.36	12.36	12.36	12.36	61.78	12.36	--
Fuel and Lubricants	56.83	37.07	13.02	27.18	27.18	24.71	27.18	86.49	61.78	9.66
Machinery Repairs/Maintenance	76.60	29.65	0.84	29.65	29.65	29.65	29.65	148.26	91.43	13.02
Building Repairs/Maintenance	4.94	2.47	34.59	2.47	2.47	2.47	2.47	7.41	2.47	0.84
Utilities and Miscellaneous	34.59	34.59	--	34.59	34.59	34.59	34.59	49.42	34.59	34.59
Custom Work	39.54	12.36	--	12.36	12.36	12.36	12.36	98.84	24.71	--
Paid Labour	54.36	29.65	19.77	29.65	29.65	29.65	29.65	123.55	86.49	19.77
Property Tax/Insurance/Water Rates	37.07	37.07	37.07	37.07	37.07	37.07	37.07	37.07	37.07	37.07

16

Table 9. On-farm irrigation system costs and application efficiencies.			
System Type	Labour Cost ($/mm/ha)	R & M Cost ($/mm/ha)	Energy Cost ($/mm/ha)
Gravity – Flood	0.101	0.0065	0.000
Gravity - Developed	0.079	0.020	0.000
Gravity - Controlled	0.045	0.049	0.037
Sprinkler - Hand-move, Solid Set or Wheel-Roll	0.067	0.057	0.195
Sprinkler - Pivot / Linear - High Pressure w/ or w/o Corner Systems	0.022	0.109	0.220
Sprinkler - Pivot / Linear - Low Pressure w/ or w/o Corner Systems	0.022	0.111	0.160
Sprinkler - Volume Gun, Traveller	0.045	0.084	0.350
Micro	0.027	0.185	0.067

Table 10. Water allocation optimizer: hypothetical example with no water constraint.				
Crop – Sugar Beet Mix	Alfalfa	Barley	Sugar Beets	SWS Wheat
Field Size (hectare)	90	90	60	60
Total	300			
Total Irrigation Water Available (Farm Level) (mm)	533			
Net Irrigation Available*	362			
Water Demand (mm)	690	360	467	419
Water Supply (mm)				
Precipitation	191	128	154	129
Irrigation	**499**	**232**	**313**	**290**
Total	690	360	467	419
Total Irrigation Water Used (mm)	**484 (340)**			
Water Deficit	0	0	0	0
Yield (per hectare)	14.4 tonnes	5.7 tonnes	49.8 tonnes	2.4 tonnes.
Revenue (per hectare)	$1,616	$366	$2,073	$652
Revenue (per field)	$145,440	$32,940	$124,380	$39,120
Total	**$341,880**			

* After adjusting by the average system efficiency rating of 0.675.

In this hypothetical case study, the representative farm has 300 hectares producing alfalfa, barley, sugar beets and wheat as shown in Table 10. The next four lines are the input water supply and demand data provided by the two models (IDM and WRMM). In the particular year of the example, a total irrigation water supply of 533 mm is available at the farm level. After adjusting by the average system efficiency rating of 0.675, the irrigation water available to the crops averages 362 mm. Water demand (by field) is the ETc value described earlier in this report (Irrigation Requirement). The water supply totals (by field) are the sum of the precipitation values from the associated climate station database and the actual irrigation supply as determined through the IDM and WRMM.

In the above case, irrigation is not a constraint. There is sufficient irrigation water available to meet the demand for each crop. The gross amount of water applied, on average, was 484 mm, which is below the total supply of 533 mm. The average amount of irrigation water reaching the crops was 340 mm. However, considerably more irrigation water was allocated to the alfalfa crop (499 mm) than the others. Barley received the least amount (232 mm).

The last few rows in Table 10 list the respective crop yields and revenues. Total farm revenue, which is the sum of the individual field revenues, is the variable that is maximized by the optimization program.

In the second hypothetical case study, irrigation water is a constraint at 333 mm. This is equivalent to a net application of 226 mm that is available, on average, to the crops. Based on the marginal yield/revenue curves, the optimization program allocates water incrementally to the most profitable fields. In the above case, the alfalfa and sugar beet fields received the optimal amount of water to meet the respective total demands. The barley and wheat fields, however, did not receive the total amount of water demanded. Since barley was the least valuable crop, it received no irrigation water. The next lowest valued crop, wheat, received only 20 mm of irrigation, all the water left from the allocated amount. The weighted average amount of irrigation water applied is equal to the total available to the farm, 226 mm. This distribution of irrigation water between the four crops results in a maximized revenue of $281,850.

The Farm Financial Analysis Component of FFIRM

Overview. The farm financial analysis component of the FFIRM is used to track and assess the financial performance of representative farms with time. The model is run through a 68 year time period. For each year in the analysis, input data relating to water demand, water supply and crop prices are applied to the water allocation optimization routine (described in the previous section.) to determine the maximum annual income given the total annual water availability to the representative farm. These results are combined with operating and capital expenditure estimates within the farm financial component of FFIRM to calculate a wide range of financial results for each crop year. The model tracks the financial performance of the representative farms with time by applying the closing balances of each annual financial statement to the opening balances of the following year’s financial statement. Issues related to financial analysis and the details of the farm financial analysis component of the FFIRM are reviewed in the following sections.

Table 11. Water allocation optimizer: hypothetical example with a water constraint.				
Crop – Sugar Beet Mix	Alfalfa	Barley	Sugar Beets	SWS Wheat
Field Size (hectare)	90	90	60	60
Total	300			
Total Irrigation Water Available (Farm Level) (mm)	333			
Net Irrigation Available*	226			
Water Demand (mm)	690	360	467	419
Water Supply (mm)				
Precipitation	191	128	154	129
Irrigation	**499**	**-**	**313**	**20**
Total	690	128	467	149
Total Irrigation Water Used (mm)	**333 (226)**			
Water Deficit	0	232	0	270
Yield (per hectare)	14.4 tonnes	0.25 tonnes	66.7 tonnes	1.74 tonnes
Revenue (per hectare)	$1,616	$17	$2,073	$175
Revenue (per field)	$145,440	$1,530	$124,380	$10,500
Total	**$281,850**			

* After adjusting by the average system efficiency rating of 0.675.

Financial Analysis. Like any other business, success in farming is invariably measured by the financial performance of the operator in managing the farm's assets. The business of farming, from a financial analysis point of view, focuses on deploying farm assets, labour and other inputs across "production opportunities" to yield the best return on assets. This is subject to the owner/operator's comfort with risk plus other constraints or demands that may cause him to deviate from the "optimal" long-term management plan.

The process of determining "financial performance" begins with a basic set of farm accounts. These accounts embody the principles of economics and accounting, leading to an objective, standardized statement of result. Farm accounts can be used to derive statements of profitability, growth and risk. From a historical point of view, they yield measures of performance. Looking forward, they reveal both potential and risk.

The financial assessment of the model's representative farms focuses on the three basic elements of liquidity, solvency and profitability. Built into this assessment are general assumptions about the operators' risk and labour use preferences. The following discussions describe the use of "T-accounts" in assessing the financial performance of the representative farms and, in turn, the financial impact of the alternative irrigation water management scenarios.

What are T-Accounts? T-accounts make up the basic framework of an accounting system. The "t's" represent the ledger, or account elements. In the most general sense, the accounts represent a running tally of assets controlled by the farm, and a statement of claim on these assets in the form of liabilities or owner's equity. A generalized T-account for an irrigation farm is shown in Table 12.

Transactions, grouped into categories, track the manner in which funds, values or obligations flow among the accounts. Transactions entered into the accounts follow the fundamental rule of double-entry accounting that each action (entry) has an equal and opposite reaction (offsetting entry). Each entry must, by definition, be in balance.

Table 12. Generalized T-Account.

Year 1	Assets		Liabilities		Equity	
	Cash on Hand	Fixed Assets	Term Debt	Arrears	Owner's Equity	Other Equity
Opening Balance						
Income						
Direct Cash Costs - Non-Irrigation						
Direct Cash Costs - Irrigation						
Interest Payments						
Current Year Depreciation						
Line of Credit						
Arrears Payments						
Principal Payments						
New Capital Purchase						
Extra Principal Payment						
Closing Balance						

Why are T-Accounts Used? The T-accounts within the model are used to assess financial performance of a variety of operational scenarios for a range of southern Alberta irrigated farm types. Specific elements within the t-account framework result in financial measures relating to the key management concerns: profitability, growth and risk. The farm financial accounts are based on various concerns, in particular production (e.g., water availability, soil type), economic (e.g., product prices, input costs, asset / infrastructure requirements) and financial (e.g., opening farm financial structure, debt load). The basic questions posed are:

- Will the farm generate sufficient revenues to
  - Cover operating expenses?
  - Service existing and new debt?
  - Take advantage of opportunities and / or new ventures?

- Can the farm generate sustained profit, sufficient to
  - Achieve a reasonable long term rate of return of assets used (compared to other "investment" alternatives)?
  - Meet the owners "withdrawal" or income requirements?
  - Fuel financial growth?

- Does the variability in net income
  - Pose a threat to long term financial viability?
  - Unduly reduce long term average profitability?

Combinations of these questions address the key issues of liquidity, solvency and profitability. These in turn can be combined to give an interpretation of financial risk. The overall goal of using the T-accounts in the model is to readily determine the farm's financial progression over time given a defined set of constraints and productive capabilities.

Accounts Used. T-accounts in the model are set up according to the basic accounting relationship,

Assets = Liabilities + Owner's Equity

Under each of these broad areas are specific accounts, as follows:

a) *Assets.*
   - Bank / Cash-on-Hand
     - all cash transactions clear in this account.
     - the sum of all transactions yields the ending net cash position.

   - Fixed Assets
     - cash and non-cash transactions relating to acquisition, disposition and change in fixed asset values.
     - the sum of all transactions yields the fiscal year end net value of farm assets, before outstanding accumulated depreciation is accounted for.

   - Accumulated Depreciation
     - non-cash transactions regarding estimated depreciation of machinery, equipment, buildings and improvements.
     - the sum of all transactions is the net amount of outstanding depreciation. When a farm is meeting its priority cash obligations and assets are being replenished, the account typically nets to zero change at the end of the fiscal year. If this is not the case, un-retired accumulated depreciation can be carried forward to the next fiscal year.
     - the sum of the fixed asset account and the accumulated depreciation account yields the closing valuation of long term farm assets.

b) *Liabilities.*

- Original Term Debt – Non Current Portions
  - contains the non-current portions of term debt (due past the current fiscal year) defined in the opening farm debt structure.
  - non-cash transfers of non-current to current portions are logged into this account plus cash buydowns of term debt principal.
  - the sum of all transactions yields the ending balance of debt outstanding associated start-up constraints.

- Original Term Debt – Current Portions Due
  - the account opens with current portions of (original) term debt principal portion carried forward from the previous fiscal year.
  - non-cash transfers of non-current to current portions are logged into this account. Cash transfers of current amounts paid are tallied here as well. If the farm is meeting its priority cash obligations, the account nets to the closing balance of current portions of term debt principal due in the next fiscal year.

- New Term Debt – Non-Current Portions
  - similar to the corresponding "old" debt account, except contains debt obligations taken on from the beginning of the model farm run.
  - new debt is logged in as the financed portion of asset acquisition.
  - the sum of this account during the fiscal year is the balance of term debt outstanding, prior to adjustments for current portions due for the following year plus allowance for term debt buy-down.

- New Term Debt – Current Portions Due
  - similar to the corresponding "old" debt account, except contains current portions of debt obligations taken on from the beginning of the model farm run.
  - non-cash and cash elements plus the account sums are similar to the old debt account as well.

- Arrears
  - contains the running balance of arrears incurred by the farm in years where there is difficulty in meeting cash priority obligations. Arrears are akin to emergency financing from the bank to cover off the inability to meet debt servicing and capital acquisition requirements.
  - transactions appear as an offsetting cash transfer.

- Line of Credit
  - contains the running balance of operating line of credit funds used.
  - transactions appear as an offsetting cash transfer.

c) *Owner's Equity*

- Profit / Loss
  - this account harbours both cash and non-cash transactions that combine to form the Farm Income Statement.

- combined with the "Other Equity" account, sums to reflect the contribution of retained earnings to farm financial growth.

- Other Equity
  - the "Other Equity" account holds the equity of the farm business with time.
  - positive and negative retained earnings are transferred, in a non-cash manner in and out of this account. The sum of the other equity account during a fiscal year represents the change in the farm's equity position.

The Accounting Process of the Model: Priority for Cash. The "call for cash" generated by the farm has a priority weighting with regard to "who gets paid first." It is generally represented by the order of the account item within the T-table (spreadsheet).

The following listing highlights the general priority for cash payments.

- Direct cash expenses.
- Base salary / withdrawals.
- Other cash expenses including interest, income taxes, bonus withdrawals.
- Reduction of line of credit.
- Reduction of arrears outstanding.
- Term debt principal payments.
- Capital replacement (including down payments).
- Term debt buy-down.

Water Management Scenarios

The irrigation demand and water supply analysis was conducted for 10 different water management scenarios. These scenarios were formulated considering 1999 conditions, projected future conditions and various future management options. For each scenario, a set of assumptions were developed for the following variables.

- Irrigation expansion scenario.
- Crop mix.
- Mix of on-farm irrigation methods/equipment.
- On-farm system operating and application efficiencies.
- On-farm management capability (e.g., increased irrigation application rates).
- Distribution system efficiency.
- Improved district water supply operations and reduced return flows.

The 10 scenarios are summarized in Table 13.

Although 10 water management scenarios were developed (Table 13), FFIRM analysis was carried out on seven different and most significant scenarios – S1, S3, S4, S7, S8, S9 and S10.

A summary of the analysis variables is provided below. A more detailed description is available in Volume 1: Summary Report.

Irrigation Area - In scenario S3, the 1991 Regulation limit of irrigation expansion was used for all districts except the EID. The EID irrigation limit has been increased since 1991 from 111,293 hectares to 115,740 hectares. The total irrigation area for scenario S3, for all districts, excluding

Ross Creek, is 535,400 hectares. Scenarios S4, S8 and S9 consider a 10% expansion above the regulation limits to 588,940 hectares. Scenarios S7 and S10 consider a 20% expansion above the limits to 642,480 hectares.

Table 13. Summary description of the modelled water management scenarios.

Scenario Number	Irrigation Area*	Crop Mix	On-Farm System Mix	On-Farm System Effic.	Crop Water Management	District Return Flow Mgmt.
S1	1999	1999	1999	68%	80% of Optimum	1999
S2	1991 limit	1999	1999	68%	80% of Optimum	1999
S3	1991 limit	1999	1999	71%	90% of Optimum	Improved
S4	1991 limit plus 10%	1999	1999	70%	80% of Optimum	1999
S5	1991 limit plus 10%	Future	1999	70%	80% of Optimum	1999
S6	1991 limit plus 10%	1999	Future	70%	80% of Optimum	1999
S7	1991 limit plus 20%	1999	1999	70%	80% of Optimum	1999
S8	1991 limit plus 10%	1999	1999	71%	90% of Optimum	Improved
S9	1991 limit plus 10%	Future	Future	78%	90% of Optimum	Improved
S10	1991 limit plus 20%	Future	Future	78%	90% of Optimum	Improved

* 1991 limit refers to the expansion limits identified in the 1991 SSRB Water Allocation Regulation

Crop Mix – The crop mix used for scenarios S1, S3, S4 and S8 is based on a crop mix distribution as grown in 1999. The future crop mix for scenarios S9 and S10 considered the trend toward an increased area of forage to support the livestock industry, an increased area of specialty crops to support value-added processing, and a reduced area of cereal grains.

On Farm System Mix – The on-farm system mix includes irrigation systems (e.g., surface irrigation, sprinkler irrigation) as well as types of on-farm equipment, all of which have a bearing on application efficiency. The 1999 system mix was used in scenarios S1, S3, S4, S7 and S8. The future system mix considered a shift from gravity surface irrigation to sprinkler irrigation, and a shift toward low-pressure centre pivot systems.

On-Farm System Management – On-farm application efficiency is dependent on both the method practiced, or type of system used, and on how well irrigation farmers manage water applications. The average on-farm application efficiency in 1999 of 68% was set for scenario S1. In scenarios S4 and S7, system management levels are assumed to have improved to 70%. For scenarios S3 and S8, system management was projected to further improve to an average application efficiency of 71% for all districts. Finally, for scenarios S9 and S10, the system management application efficiency for all districts was projected to improve to nearly 78%.

Crop Water Management – In recent years, irrigated crops received, on average, about 84% of the total moisture required for optimal yields. (Total crop moisture includes soil moisture, growing season precipitation and irrigation applications.) An average application of 80% of optimum was used to represent 1999 crop water management in scenarios S1, S4 and S7. This level of irrigation management was projected to increase to as high as 90% of optimum for scenarios S3, S8, S9 and S10.

District Return Flow Management – Return flow is comprised of operational spills, on-farm system downtime losses, drainage from irrigated fields, and base flow. Downtime losses and runoff from irrigated fields are primarily a function of on-farm irrigation methods and on-farm management. Other factors affecting district return flow management include the extent to which district works have been rehabilitated, the extent of automation of structures, the location and number of balancing and supply reservoirs, district irrigation area density, monitoring, communication between operating staff and water users, and staff training. Future return flows were projected based on the forecast mix of methods, systems and reduced base flows that reflect an improved level of district return flow management.

Analysis Method and Results

Financial Impact and Risk. While the model provides for a wide range of economic performance indicators, the study focused attention on four factors.

- Net farm income.
- Probability of negative net farm income.
- Farm asset / debt ratio.
- Farm solvency.

a) Net Farm Income (NFI). An indicator of the average profitability of the representative farms under different water management scenarios, NFI is total revenue minus farm cash costs (excluding capital replacement costs) and minus depreciation.

b) Probability of Negative Net Farm Income. This represents the variation of NFI over the course of the simulation period. A higher risk of negative NFI increases the likelihood of farm financial difficulties, primarily through increased borrowing needs, and the possible risk of reduced credit ratings and higher loan rates. Although a new water supply scenario may provide an increase in the average NFI during the 68-year period, it is possible that the variability in income also increases.

c) Farm Debt / Asset Ratio. An important indicator of farm financial conditions is the farm debt / asset ratio. Assets include cash, machinery and equipment, and land. Debt categories include outstanding loans, lines of credit and arrears. Net worth is equal to total assets minus debt.

d) Risk of Insolvency. The model estimates the likelihood that representative farms would experience financial difficulties to the extent of facing bankruptcy, or financial insolvency. For the purposes of this analysis, the debt / asset ratio and the current ratio were used in tandem to create an "insolvency condition." The model farm, for each given scenario, was considered to be insolvent when the debt / asset ratio exceeded 0.6 (i.e., more than $0.60 of total debt per dollar of total assets) and the current ratio fell below 1.0 (i.e., less than $1 in current assets per dollar of current liabilities) at the same time.

The relationship of net farm income, net worth and debt is illustrated in Figures 1 and 2. Figure 1 illustrates a farm in a difficult financial position (e.g., a grains and oilseed farm type that has a high starting debt level.) It shows how net worth can decline over time. The annual net farm income (using the left-side axis labels) is more frequently negative than positive. Consequently, the net worth of the farm generally declines over time while the debt level generally climbs. As the debt level rises, interest costs also rise, which puts further downward pressure on the annual net farm income levels.

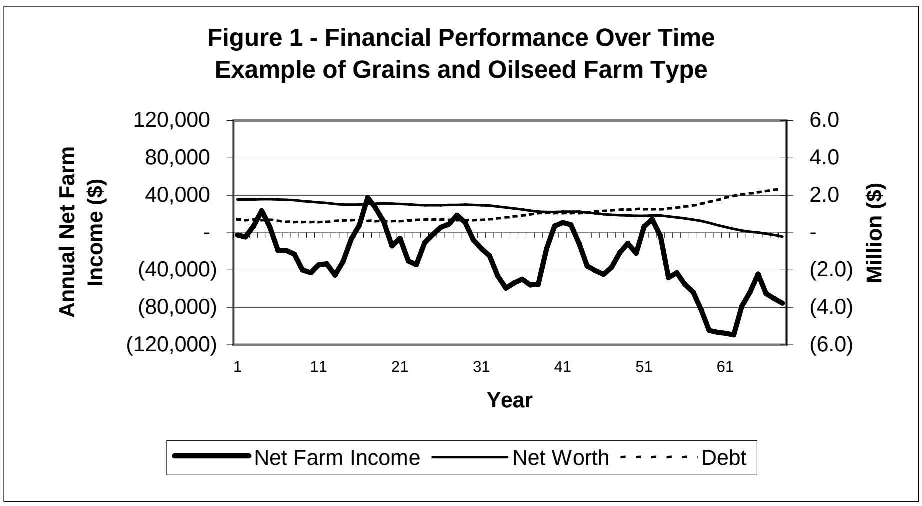
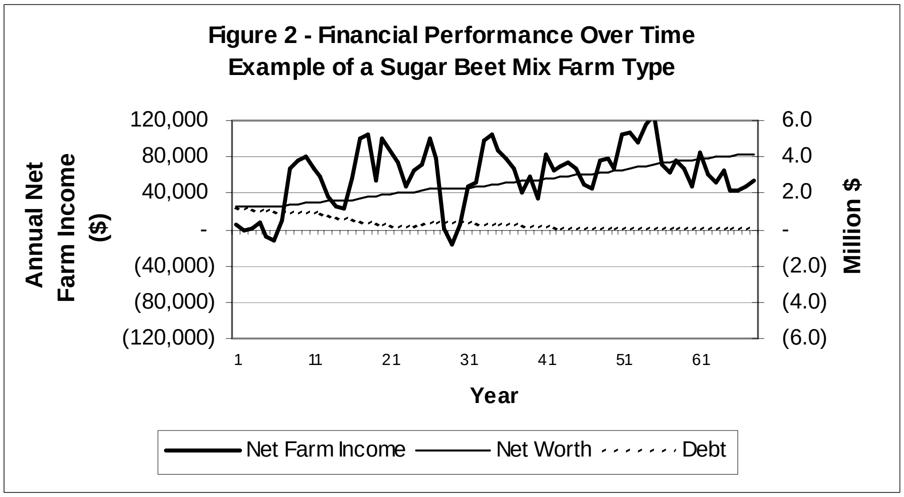


Figure 2 shows similar accounts for a farm with a positive financial outlook (e.g., a farm that includes specialty crops within the mix). The average net farm income is usually positive, despite the relatively high variability in net farm income. As a result, the farm depth level generally is eliminated with time, and the farm net worth continues to rise.



Financial Impact Analysis of Alternative Water Management Strategies. FFIRM simulation runs were conducted for six climate / crop regions. Within each climate region, separate runs were conducted for different farm types, as determined by crop mix. There were two to four different farm types, depending on the region. As well, each farm type was evaluated at three different starting debt levels (base, medium, high). These representative farms were described previously and summarized in Table 1.

Based on the above three factors, a total of 57 different farm simulations were assessed for each water management scenario. The Bow Basin accounted for 27 farm simulations, while the remaining 30 were for the Oldman Basin.

In the following sections a) through g), charts illustrate financial analysis results for each water management scenario. The first two charts show the average NFI over the 68-year assessment period, for the 27 farm simulations for the Bow Basin and the 30 farm simulations for Oldman Basin, respectively. The NFI results have been sorted from lowest to highest. This permits an easy assessment of the overall financial outcome for each basin and scenario.

For scenarios S3 through S10, the charts show two sets of average NFI results: those for the base case scenario S1 and those for the alternative scenario. This allows for a direct comparison of the two scenarios. For example, if the shape of the line for scenario S3 is generally higher than that of scenario S1, then that indicates the financial returns are expected to be generally higher for scenario S3 than for the base scenario. However, since the results for each scenario are sorted from lowest to highest, specific farms may not line up in the same order for each scenario. For example, representative farm #3 under scenario S1 may turn up as farm #4 under scenario S3.

The next two charts assess the risk of negative NFI for each basin / water management scenario. The representative farms are sorted from highest risk to lowest risk (e.g., from worst to best). A probability of 100% indicates that the representative farm could expect a negative NFI every year. A probability of 20% indicates the farm could expect a negative NFI in one year out of five, on average.

As with the NFI results, separate charts are provided for the Bow Basin and Oldman Basin, and the scenario S1 results are repeated on the alternative scenario charts for direct comparison. Again, the order of the representative farms on the charts may vary for each scenario, so a direct comparison between the numbered representative farms is not possible. Instead, the overall shape (height) of the lines / bars should be compared across water management scenarios. A lower line suggests an overall lower level of risk for that scenario.

RESULTS AND DISCUSSION

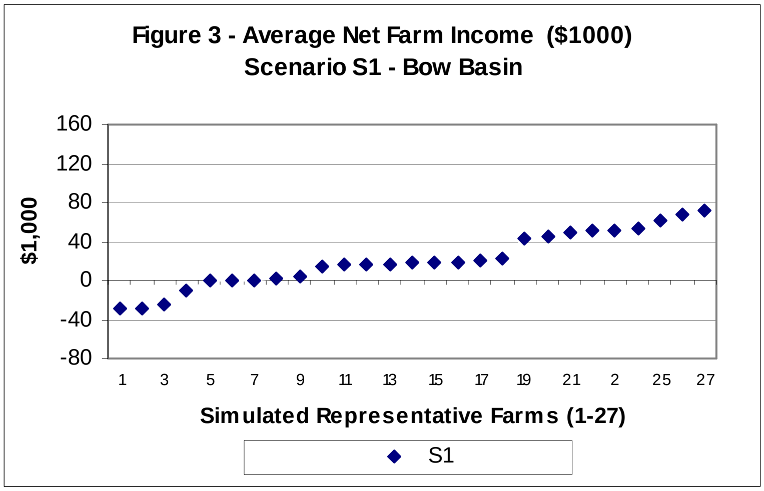
In analysing the various scenarios, the focus is not so much on the absolute values but rather on a comparison of each scenario relative to the base case or current condition scenario (S1). As there are so many variables that can be unique for each farm situation, a comparative assessment of a defined farm that is constant in its characteristics and that same farm as individual conditions change is the emphasis on the results analysis.

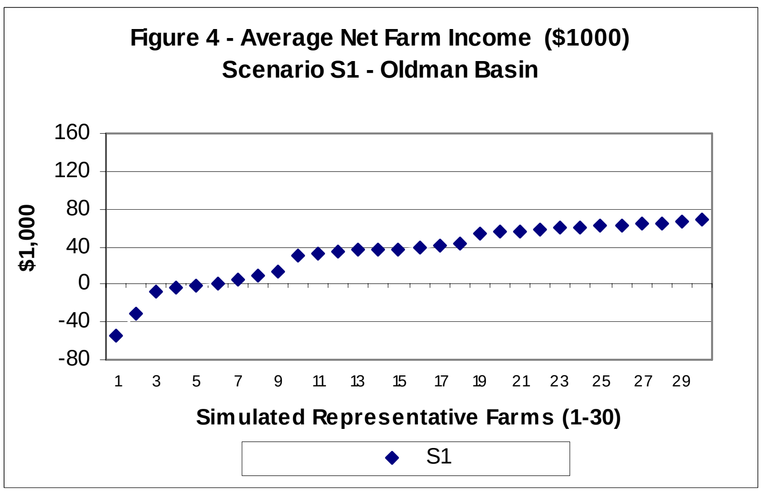
Scenario 1

As described in Table 13, the base case water management scenario S1 represents 1999 conditions regarding water demand and supply deficits. The main financial analysis results for scenario S1 are shown in Figures 3 through 6.

Net Farm Income (NFI). The average NFI for the simulated representative farms in the Bow Basin for the base case scenario ranged between -$29,000 and +$71,000. Six of the 27 farms in the basin had a negative average NFI. In general, the lower NFI was associated with farm types that emphasize grains and oilseeds, while the highest NFI was associated with farm types that include specialty crops within the mix.

In the Oldman Basin, NFI ranged from -$54,000 to +$68,000. Five of the 30 representative farms had a negative average NFI. In general, NFI for the simulated farms in the Oldman Basin was a little higher than that of the Bow Basin, due to the higher number of specialty crops included in the crop mixes of Oldman Basin farms.





Probability of Negative Net Farm Income. Figure 5 shows that 10 of the representative farms (37%) in the Bow Basin demonstrated significant risks of negative NFI, a probability of greater than 20%, or one year in five. For the Oldman Basin, eight of the farms (27%) had a probability of negative NFI of greater than 20%. About 30% of the representative farms in each basin had little or no risk. Since the Grains and Oilseed Farm Type have the lowest average NFI, these farms would be most prevalent in the higher risk categories.

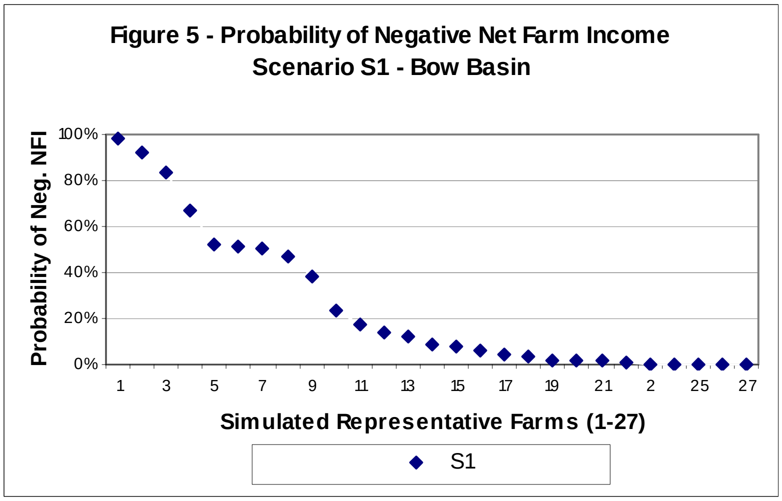


Figure 5 - Probability of Negative Net Farm Income
Scenario S1 - Bow Basin

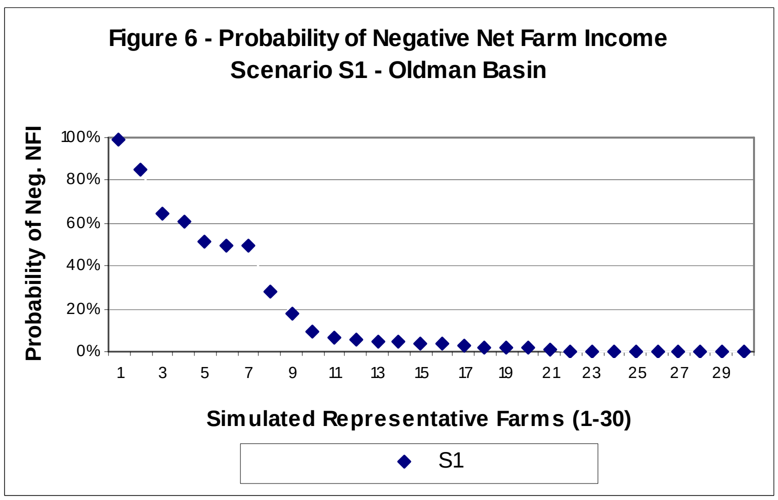
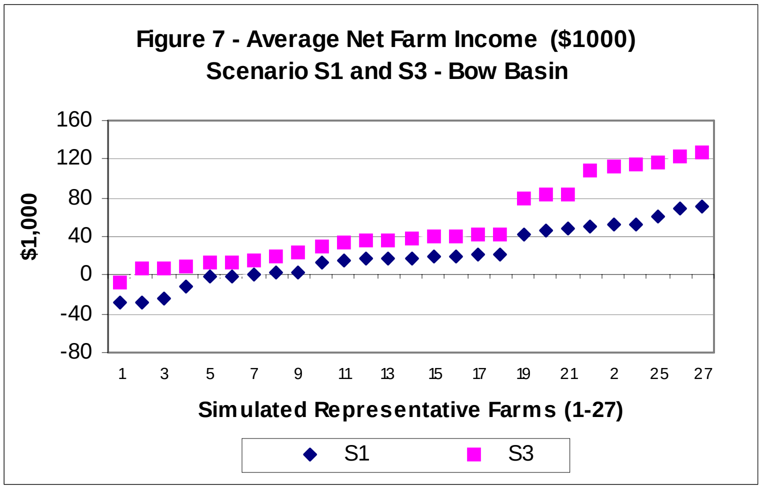


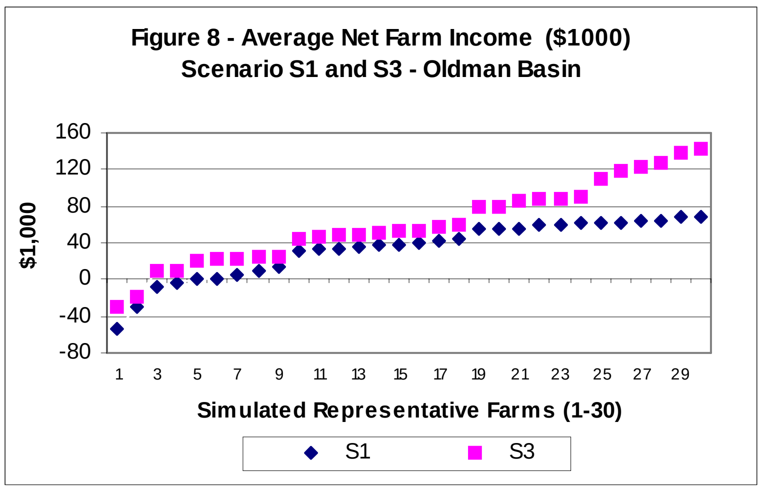
Figure 6 - Probability of Negative Net Farm Income
Scenario S1 - Oldman Basin

Scenarios S3

Net Farm Income. In scenario S3, the average NFI for the 68-year period would increase from that of scenario S1 for all representative farms in the Bow Basin, despite a somewhat greater frequency of water deficits. The higher on-farm water application rates for scenario S3 result in higher yields in non-deficit years, and therefore in higher NFI. The improved financial outlook in the non-deficit years more than offsets the increased frequency of water deficits and associated decline in NFI. Only one of the 27 representative farms in the Bow Basin had a negative average NFI, compared with six in scenario S1. Moreover, 12 farms (44%) had an increase of $30,000 or greater.

As with the Bow Basin, all of the farms in the Oldman Basin show an increase in NFI compared to scenario S1. The farms growing higher value crops show a significant increase. Two of the 30 representative farms in the Oldman Basin had a negative average NFI, compared to five in scenario S1.





Probability of Negative Net Farm Income. In the Bow Basin, the probability of negative NFI declined for about half of the farms, despite the increase in water deficits. Deficits would be small, and water applications in most deficit years would be greater than in scenario S1, with the crop water application at 80% of optimum. One third of the farms experienced a significant reduction in risk of negative NFI, which is reflected in a reduced risk of farm insolvency (as described in a later section of this report).

In the Oldman Basin, the probability of negative NFI declined for nine of the 30 farms, but slightly increased for some. In the Oldman Basin, the magnitude of the deficits was larger, resulting in lower crop water applications than in scenario S1 for some farms.

Figure 9 - Probability of Negative Net Farm Income Scenario S1 and S3 - Bow Basin

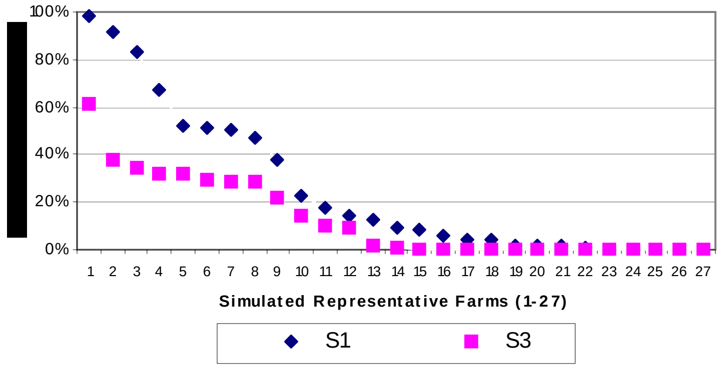
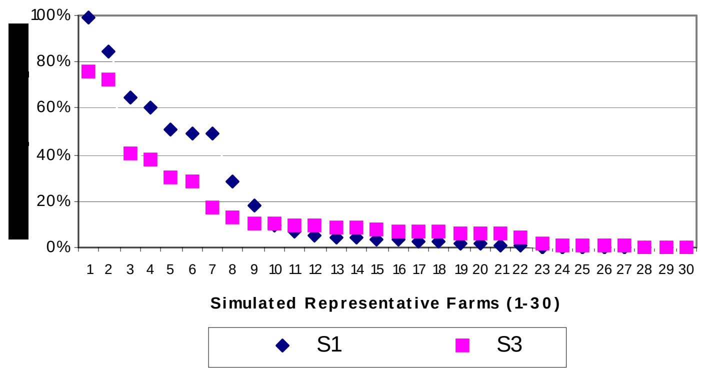


Figure 10 - Probability of Negative Net Farm Income Scenario S1 and S3 - Oldman Basin



Scenario S4

Net Farm Income. In the Bow Basin, NFI under scenario S4 was almost identical to scenario S1. Only a few farms demonstrated any appreciable decline in NFI. This means that the financial gains resulting from improved on-farm irrigation system management offset any potential financial losses resulting from increased water deficits attributable to the expansion of irrigation area by 10%.

The results for the Oldman Basin were slightly less favourable since most of the farms had marginally lower NFI than under scenario S1.

Figure 11 - Average Net Farm Income ($1000)
Scenario S1 and S4 - Bow Basin

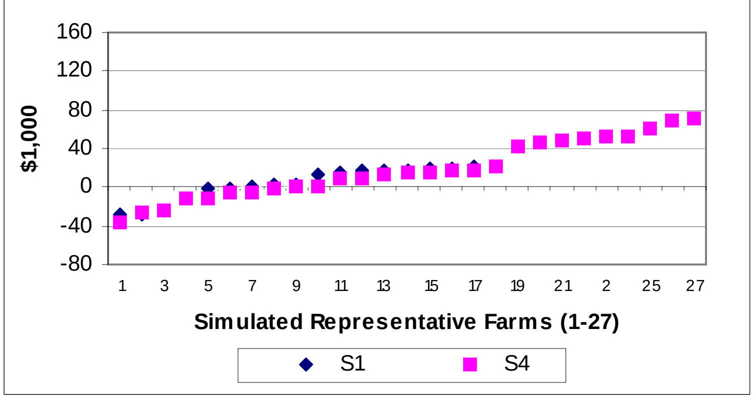
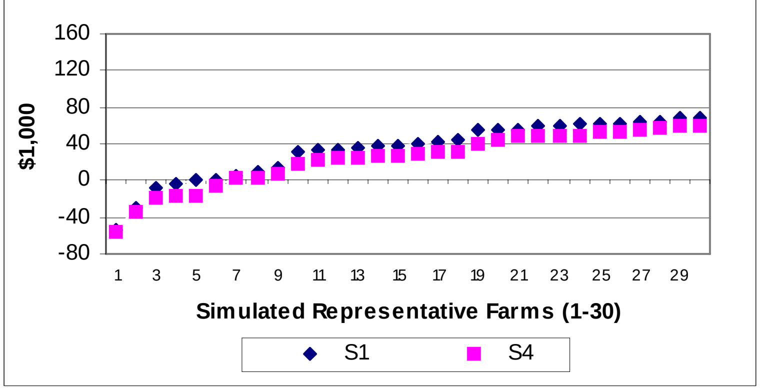
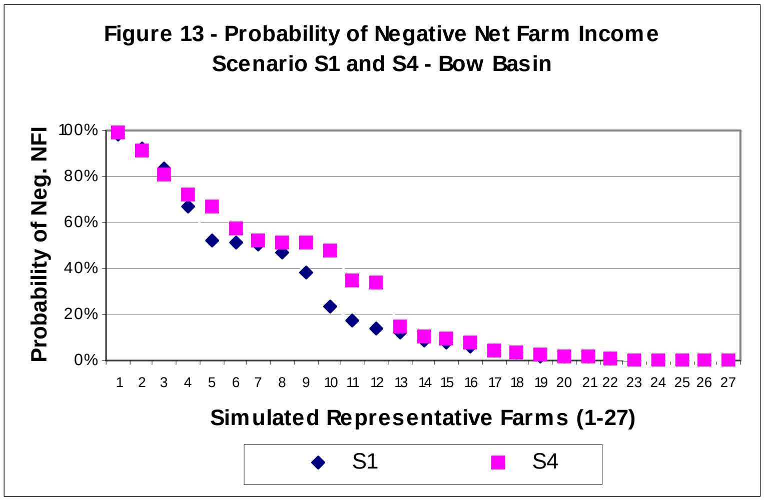


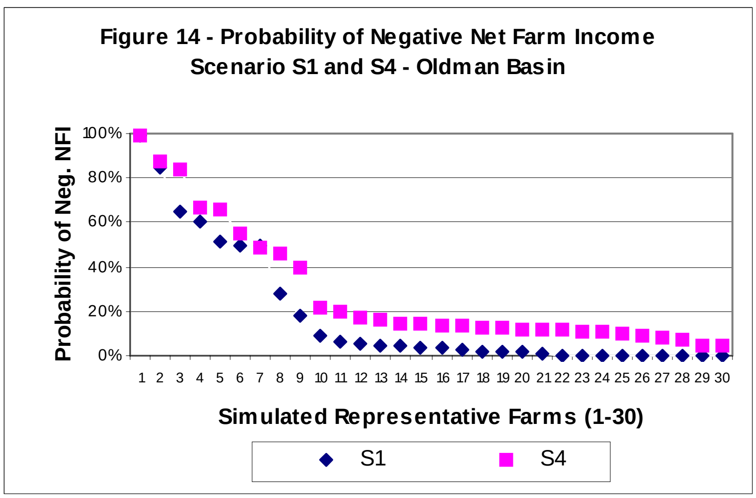
Figure 12 - Average Net Farm Income ($1000)
Scenario S1 and S4 - Oldman Basin



Probability of Negative Net Farm Income. The probability of negative average NFI in the Bow Basin was significantly higher for five of the 27 farms in the Bow Basin compared to scenario S1 (i.e., an increase of 10 percentage points or more). The remaining farms showed little change in financial risk.

In the Oldman Basin, two thirds of the farms showed a substantial increase in the probability of negative NFI. However, the increase in probability always less than 20 percentage points. Furthermore, for many of these farms, the risk of negative NFI under scenario S4 was still relatively small, 20% or less.





Scenario S7

Net Farm Income. Despite the larger expansion of irrigated area modelled in scenario S7 compared to scenario S4 (20% versus 10%), the average NFI results were almost identical for the Bow Basin farms for the two scenarios. Only a few farms had a lower NFI than under the base case scenario, and the declines were small.

The income losses were somewhat larger for the Oldman Basin farms compared to both scenario S1 and S4. Four farms would experience a decline in average NFI of greater than $20,000.

Figure 15 - Average Net Farm Income ($1000)
Scenario S1 and S7 - Bow Basin

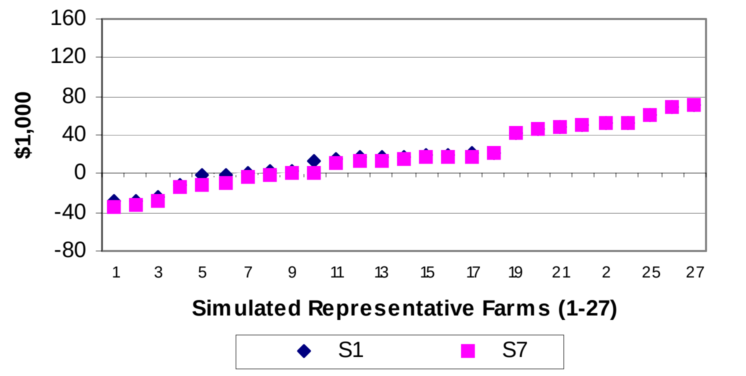
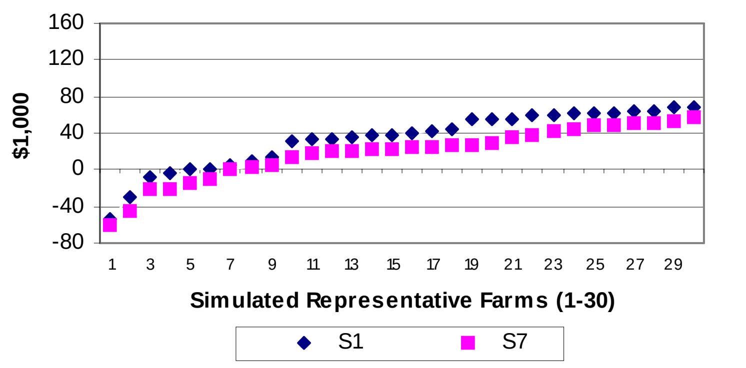
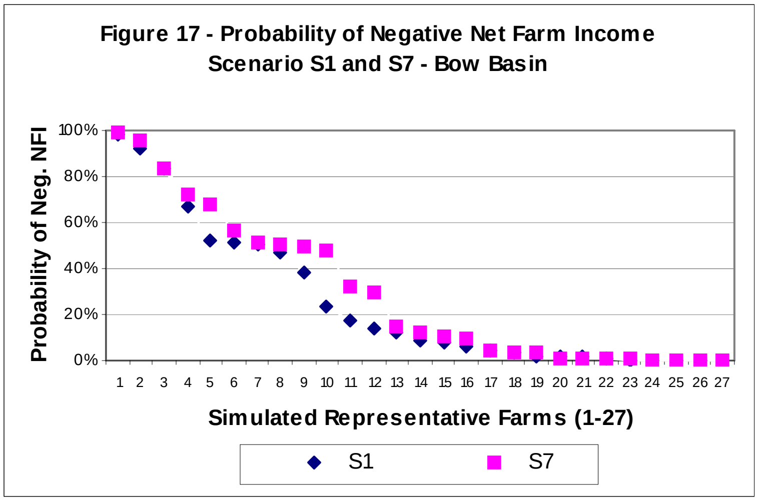
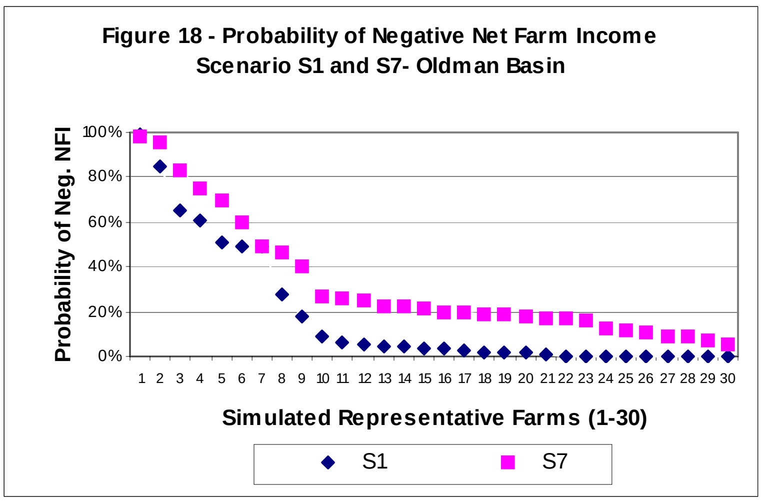


Figure 16 - Average Net Farm Income ($1000)
Scenario S1 and S7- Oldman Basin



Probability of Negative Net Farm Income. The level of financial risk was higher under scenario S7 compared to the base case, especially for the Oldman Basin farms. In the Bow Basin, about five farms would experience an increase in the probability of negative NFI of 10 percentage points or more. In the Oldman Basin, about 80% of the farms would experience an increase of 10 percentage points or more.





Scenario S8

Net Farm Income. The water management assumptions for scenario S8 are the same as for scenario S4, except that the crop water management is assumed to average 90% of optimal compared to 80% under scenario S4. The higher utilization of water in the non-deficit years results in a substantial increase in average NFI. The improvement in financial returns is similar to the improvements for scenario S3. In the Bow Basin, only one farm had a significantly negative NFI. Compared to scenario S1, all of the farms increased NFI by more than $10,000, and nine had increases greater than $30,000.

The gains in average NFI were somewhat lower for the Oldman Basin. Still, two thirds of the farms had increases of greater than $10,000, and six of 30 farms had very large increases in NFI. As with scenario S3, farms growing higher value crops show the largest increases in NFI under the new water management scenario.

Figure 19 - Average Net Farm Income ($1000)
Scenario S1 and S8 - Bow Basin

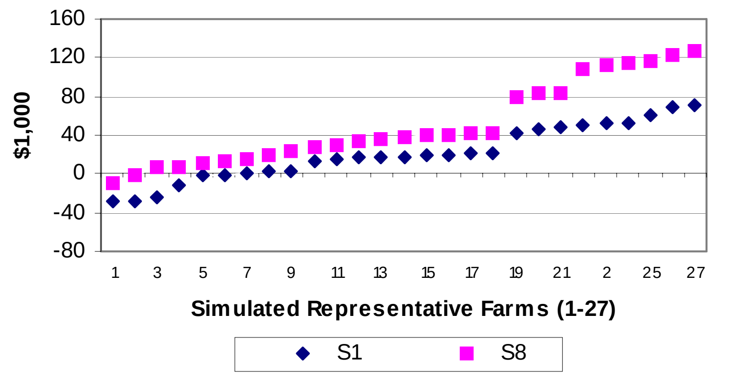
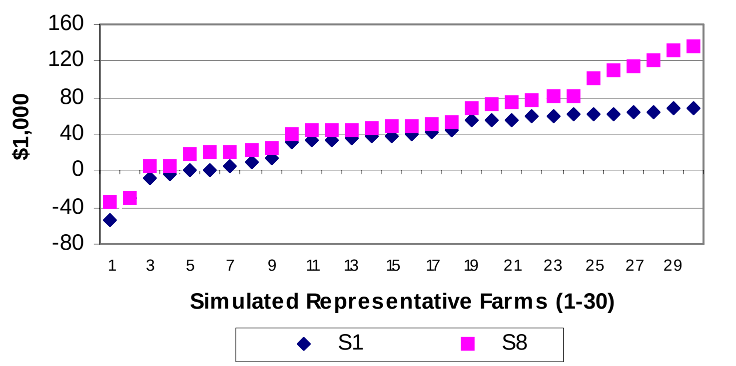
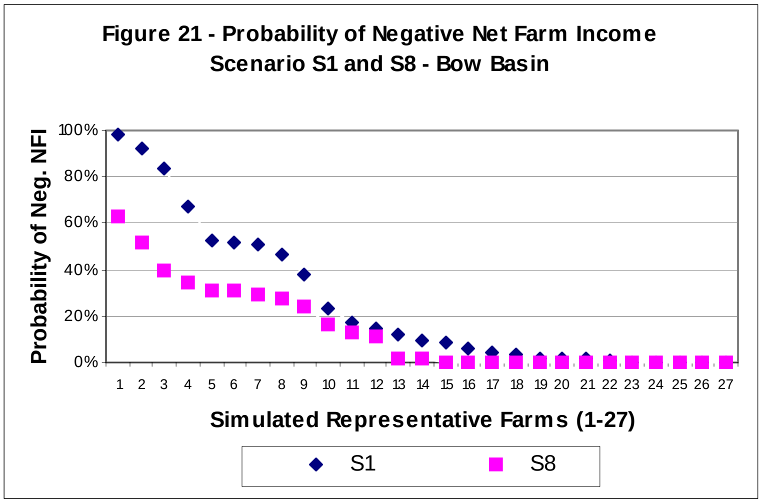


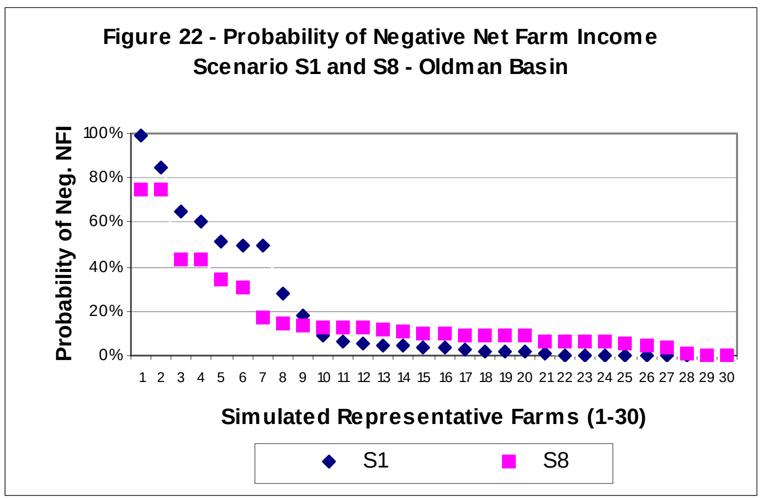
Figure 20 - Average Net Farm Income ($1000)
Scenario S1 and S8 - Oldman Basin



Probability of Negative Net Farm Income. As under scenario S3, about one third of the Bow Basin farms would have the benefit of a significantly lower probability of negative income in addition to the higher average NFI. These improvements are due to increased water application rates and efficiencies. The main beneficiaries of the significantly lower income risks are the farms that emphasize grains and oilseeds in the crop mix.

In the Oldman Basin, eight of the 30 farms had significantly lower probabilities of negative NFI. However, about half of the farms had a slight increase in the risk of negative NFI.





Scenario S9

Net Farm Income. The financial impact of scenario S9 on Bow Basin district farms would be improved compared to the base case, and would be similar to the results for scenarios S3 and S8. Two of the 27 representative farms showed a negative average NFI. As in scenario S3, the higher yields resulting from higher water application rates compensate for any declines in yield during the water deficit years.

All of the farms in the Oldman Basin also demonstrated an increase in average NFI, though the financial gains would be less than those for Bow districts. Gains in NFI would be minor for most of the 30 farms, but more significant for farms with an emphasis on specialty crops. Financial performance of some farms in the Oldman Basin declined marginally from scenario S3.

Figure 23 - Average Net Farm Income ($1000)
Scenario S1 and S9 - Bow Basin

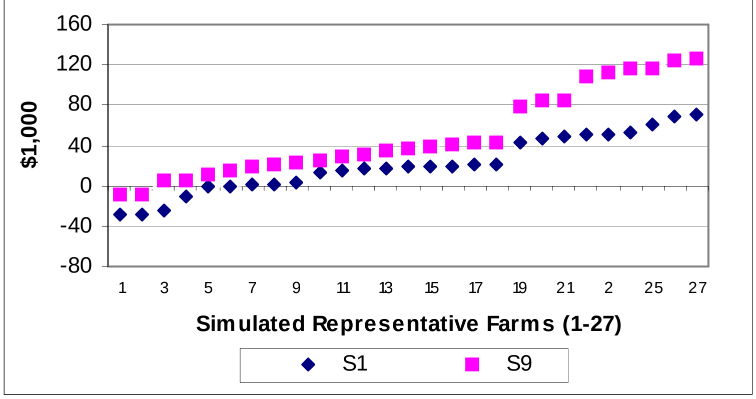
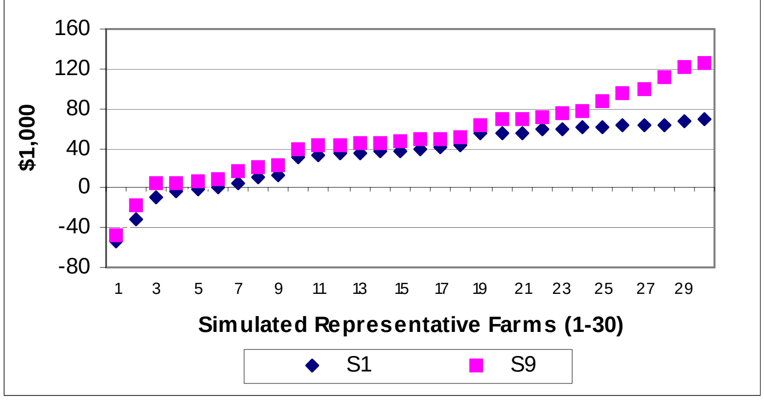


Figure 24 - Average Net Farm Income ($1000)
Scenario S1 and S9 - Oldman Basin



Probability of Negative Net Farm Income. In the Bow Basin, the risk of negative NFI was lower than scenario S1, but marginally higher than scenario S3. In the Oldman Basin, most the farms had an increased risk of negative NFI compared to scenario S1. However, the risk was still less than 20% (one in five). The increase in the probability of negative NFI in the Oldman Basin indicated an increase in the annual income variability from the current conditions. However, the long-term average NFI would be the same or higher than for scenario S1.

Figure 25 - Probability of Negative Net Farm Income Scenario S1 and S9 - Bow Basin

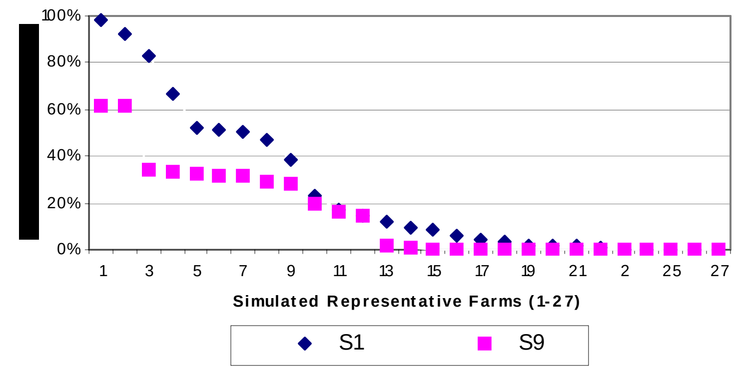
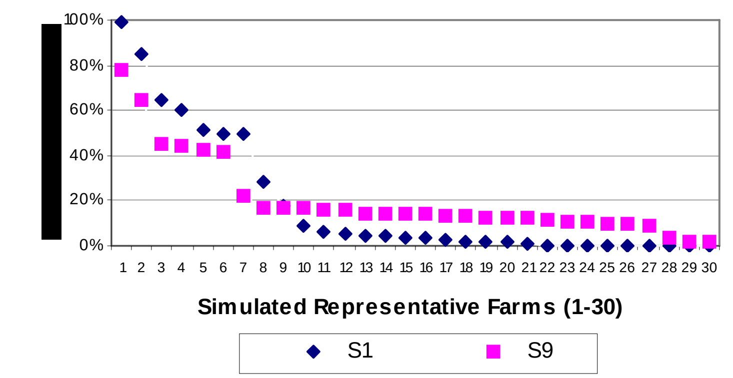


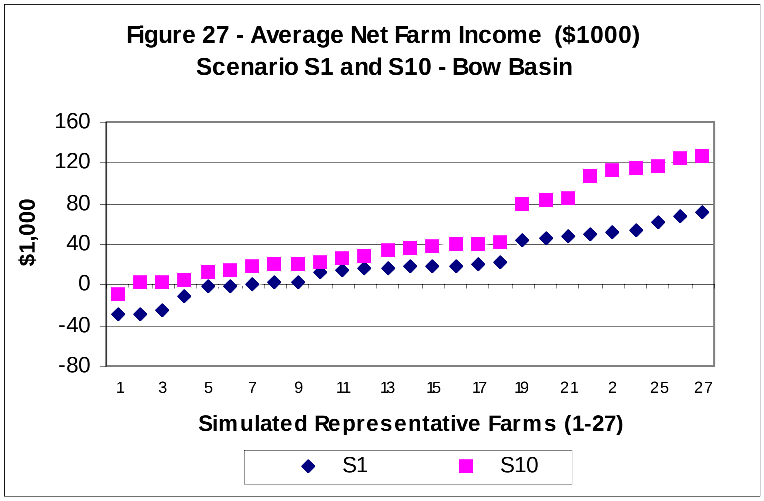
Figure 26 - Probability of Negative Net Farm Income Scenario S1 and S9 - Oldman Basin

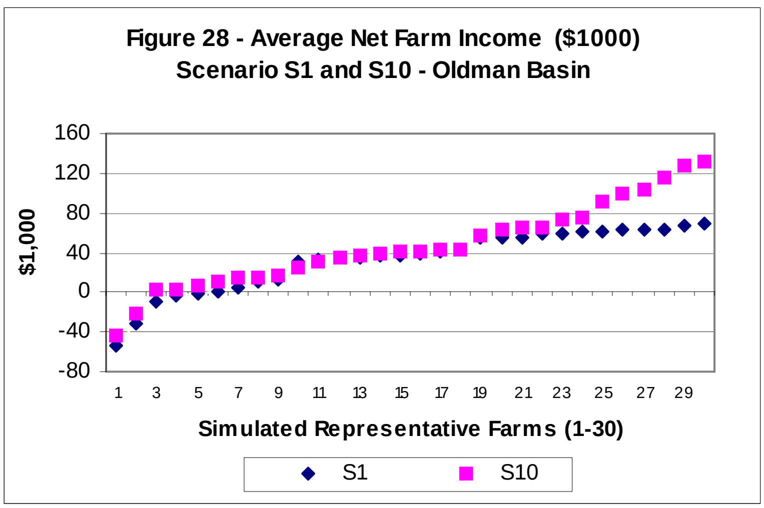


Scenario S10

Net Farm Income. Average NFI for the Bow Basin farms would be similar to scenario S9, continuing to show improvements from scenario S1. Only one farm had a negative average NFI, and only slightly negative. The largest gains were again concentrated among the higher income farms.

In the Oldman Basin, average net farm income would decline slightly from scenario S9. Compared to scenario S1, most farms had almost no change in NFI. As with the Bow districts, the largest gains were concentrated among the higher income farms.





Probability of Negative Net Farm Income. The risk of negative NFI would be significantly lower than the base case for about 35% of the farms in the Bow Basin, and about the same for the remaining 65%. In the Oldman Basin about 25% of the farms would have a decreased probability of negative NFI, but most of the others would have an increased risk, albeit still not greater than 20%.

Figure 29 - Probability of Negative Net Farm Income
Scenario S1 and S10 - Bow Basin

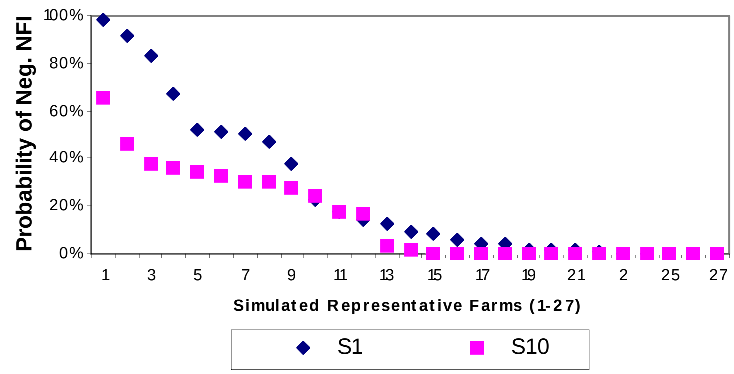
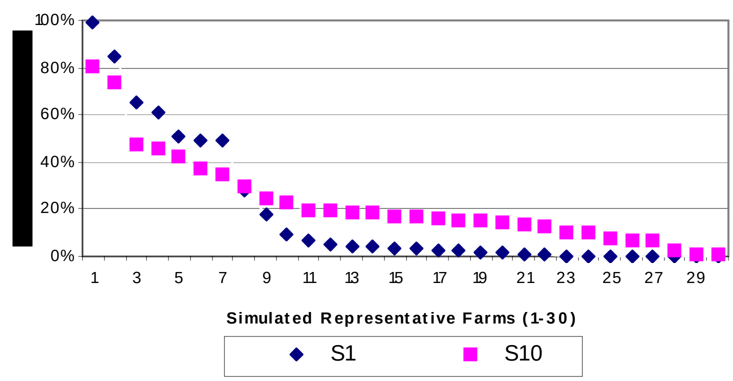


Figure 30 - Probability of Negative Net Farm Income
Scenario S1 and S10 - Oldman Basin



Average Net Farm Income Ranges by Farm Type

The average NFI results for different farm types varied considerably depending on the climate region and water management scenario. The range of results for the different farm types is provided below. While each farm type was run with three debt levels, the results below include only the base case debt level.

- Grains and Oilseeds (4 different irrigation blocks) $-10,750 to $25,500
- Specialty Crops and Grains (5 blocks) $42,000 to $141,750
- Grains and Forages (4 blocks) $-6,000 to $52,250
- Mainly Forages (6 blocks) $10,000 to 91,250

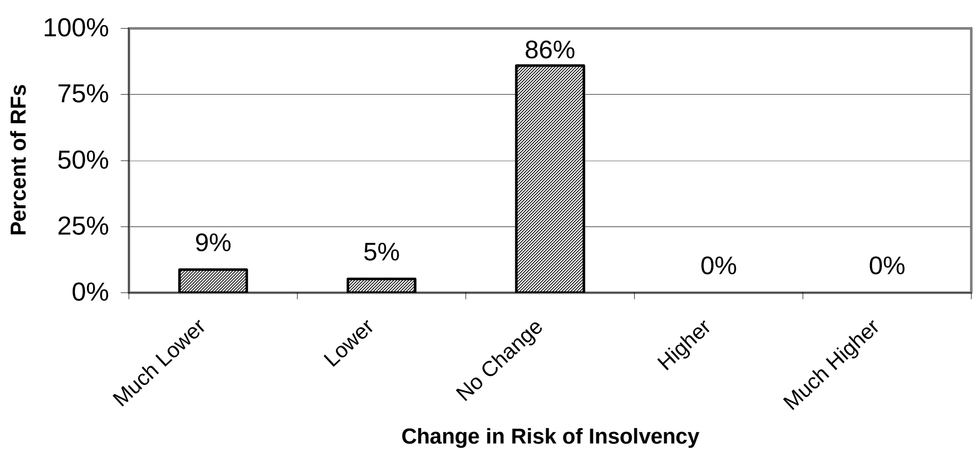
Risk of Financial Insolvency

The third financial assessment indicator of the FIRMM is the likelihood that the farm will face financial insolvency (bankruptcy). For this analysis, the alternate water management scenarios are again compared with the base case. The charts show the change in the risk of financial insolvency for representative farms under the alternative water management scenarios compared to scenario S1.

Figure 31 shows that moving to scenario S3 from the base scenario, S1, would have either no impact or a small positive impact on the financial sustainability of farms. The figure shows that 86% of the farms demonstrated no change in the financial solvency with time, while 14% of the farms demonstrated a lower (or much lower) risk of financial insolvency.

To again emphasize the importance of improving on-farm water management levels, Figure 32 shows the insolvency results for scenario S4. While the majority of farms do not experience any change in the risk of financial insolvency (88%), 13% of the farms would be expected to experience a higher risk of financial insolvency.

Figure 31 - Change in the Risk of Insolvency: Scenario S3 Compared to Scenario S1



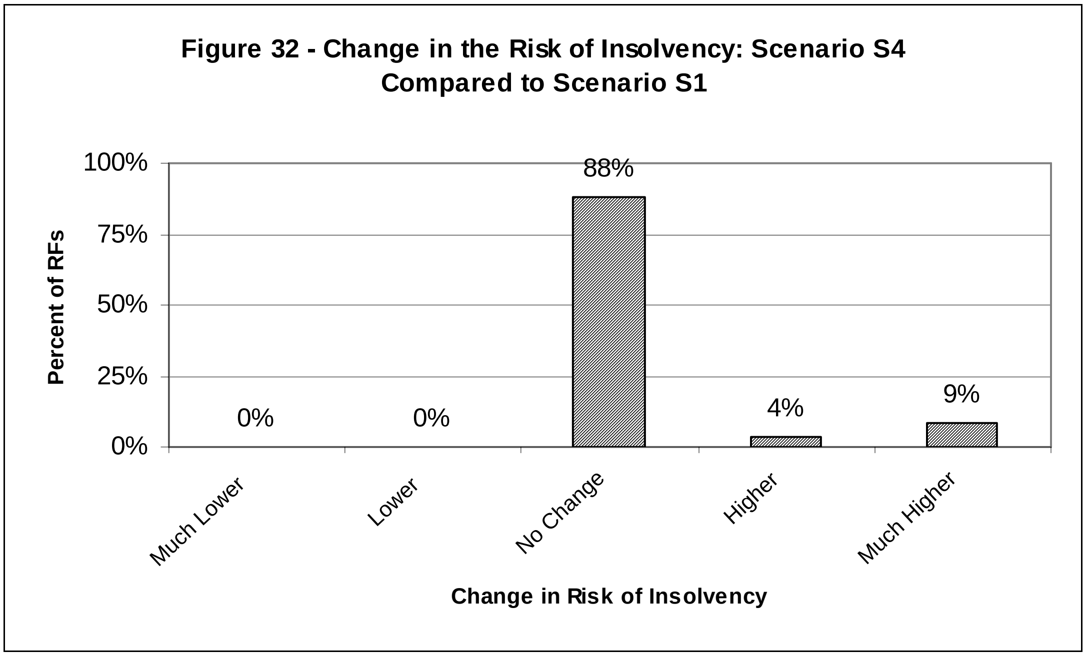


Figure 32 - Change in the Risk of Insolvency: Scenario S4 Compared to Scenario S1

Results for scenario S7 were similar to scenario S4 (Figure 33). Most farms would not experience any change in financial insolvency as a result of incorporating scenario S7 (82%), while 14% of the farms demonstrated a higher (or much higher) risk of financial insolvency. However, unlike scenario S4, a very small portion of farms would have a lower risk of insolvency.

Changes in risk of financial insolvency under scenarios S8, S9 and S10 are similar to those in scenario S3. The vast majority of farms would expect to have no change in the risk of financial insolvency due to the alternative water management scenario (84% to 89%). As well, a portion of farms would expect a lower or much lower risk of financial insolvency (10% to 13%). Only in scenario S10 do any farms risk a higher insolvency rate (4%).

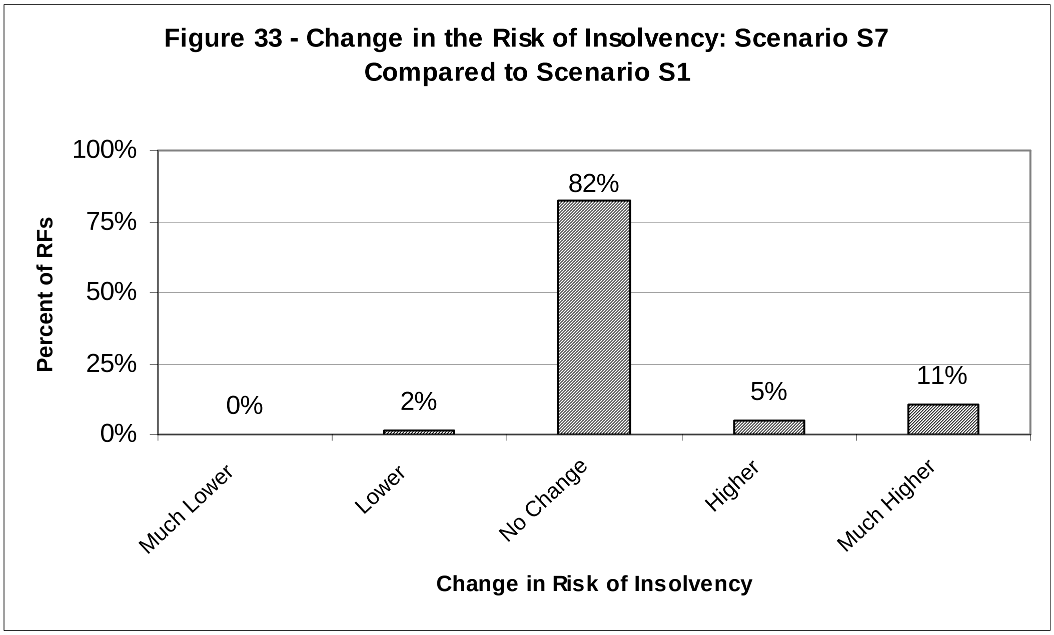


Figure 33 - Change in the Risk of Insolvency: Scenario S7
Compared to Scenario S1
100%
75%
50%
25%
0%
Percent of RFs
0%
2%
82%
5%
11%
Much Lower
Lower
No Change
Higher
Much Higher
Change in Risk of Insolvency

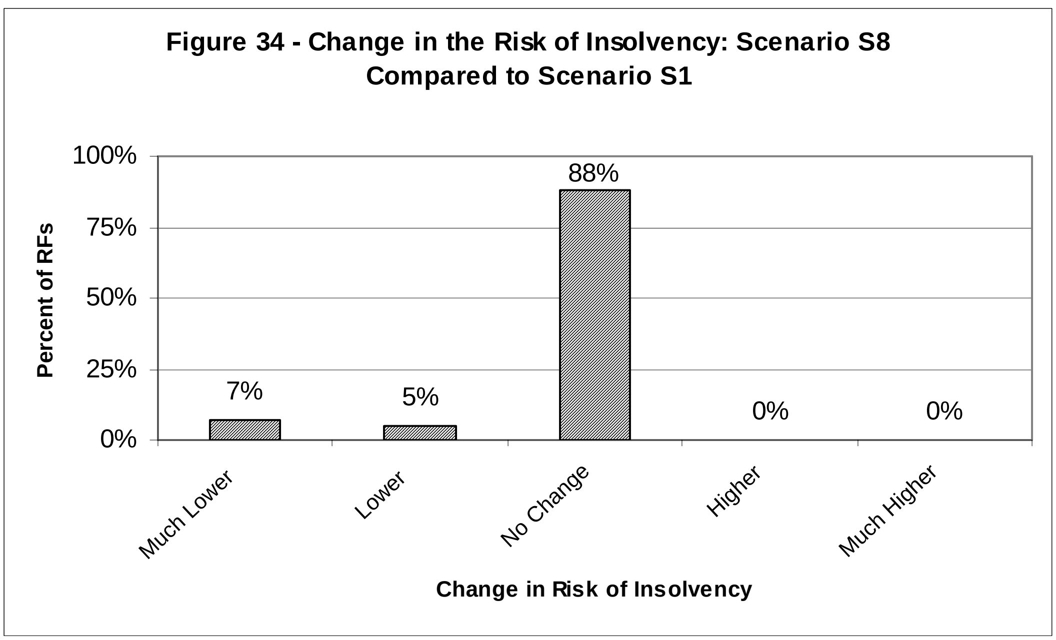
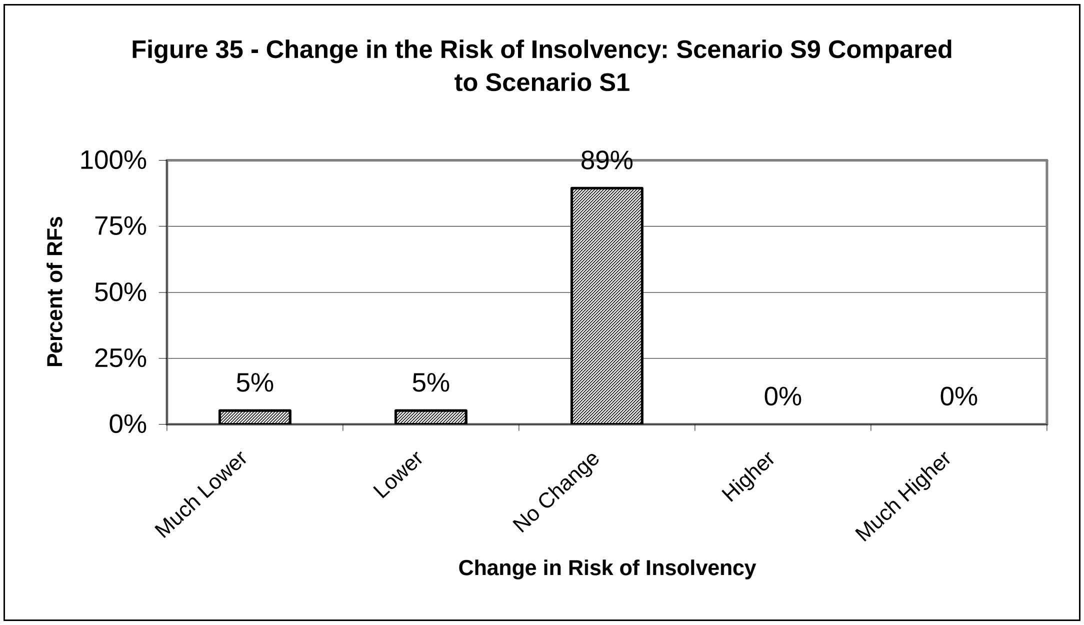
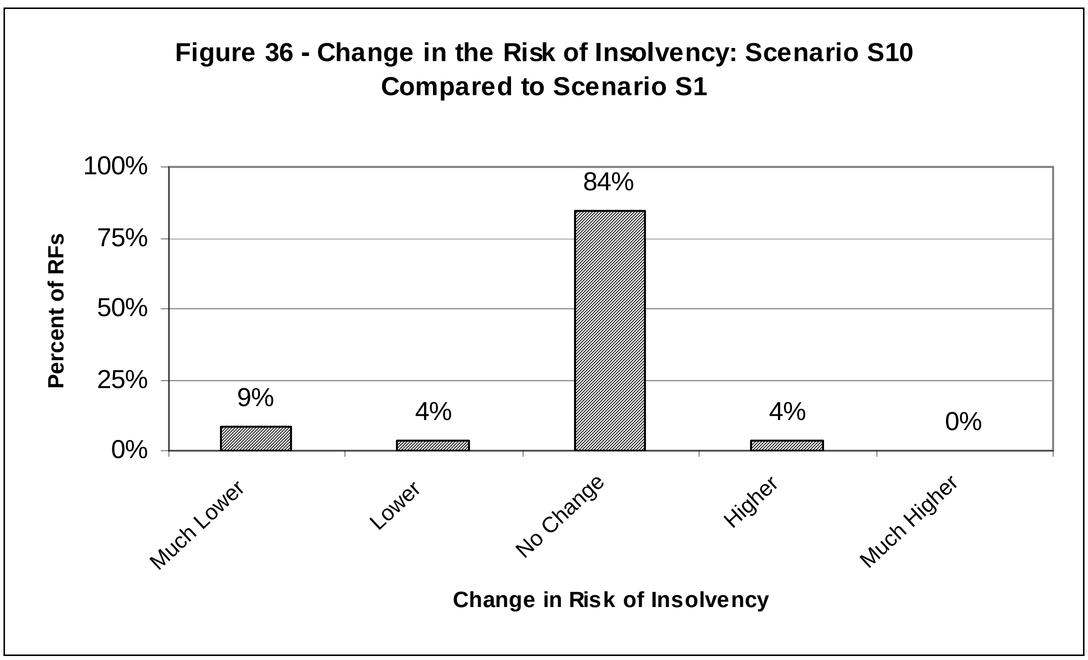


Figure 34 - Change in the Risk of Insolvency: Scenario S8
Compared to Scenario S1
100%
75%
50%
25%
0%
Percent of RFs
7%
5%
88%
0%
0%
Much Lower
Lower
No Change
Higher
Much Higher
Change in Risk of Insolvency





Summary of Farm Financial Results

This section summarizes the main financial results of the alternative water management scenarios. Four water management scenarios (S3, S8, S9 and S10) generally demonstrated positive financial results. These "better" scenarios are described in Table 14. The remaining two "worse" scenarios, S4 and S7, are described in Table 15.

Summary of "Better" Water Management Scenarios. Most farms in scenarios S3, S8, S9 and S10 demonstrated substantial gains in NFI compared to the base case scenario S1. The average NFI of farms within the Bow Basin more than doubled compared to the base case. For the Oldman Basin, average NFI also increased dramatically, although the base case NFI was significantly higher than with the Bow Basin. Only scenario S10 demonstrates any possible reductions in NFI; however, the number of farms indicating a lower NFI was very small. As well, in all scenarios, the number of farms that have a negative net farm income declined substantially compared to scenario S1.

The probability of farms experiencing a negative NFI during the 68-year assessment period differed for the Bow and Oldman Basins. In the Bow Basin, between half and two-thirds of the farms had a lower probability of negative NFI compared to the base case. The remaining farms generally had no change. In the Oldman Basin, only one-third of the farms demonstrated a lower probability of negative NFI. For scenario S3, another one-third would experience an increased probability. Scenario S10, on the other hand, would expect a higher probability for almost two-thirds of the farms.

As shown in the individual scenario results, the majority of the changes in probability of negative NFI would be relatively small. Even with an increase in probability of negative NFI, most of the time the level of risk would remain small. It is more important to consider situations that have high levels of risk. Table 14 shows the percentage of farms under each scenario that have a probability of negative NFI greater than 20%. In the Bow Basin, the percentage of farms with a 20% probability or greater remained at 37% or declined slightly. In the Oldman Basin, the probability declined four to seven percentage points from the base case of 27%.

Changes in the risk of financial insolvency were fairly consistent across all four scenarios and two basins. Between 10% and 15% of the farms would expect a lower risk of farm financial insolvency with the alternative water management scenarios. Practically all of the other farms would expect no change to the base case risk of financial insolvency. Only scenario S10 in the Oldman Basin demonstrated any farms that would expect an increase in the risk of insolvency, although the percentage of farms was small at 3%.

Table 14. Summary of main farm financial results for "better" scenarios.

Performance Indicator	Bow Basin					Oldman Basin				
	Current	Alternative Futures				Current	Alternative Futures			
	S1	S3	S8	S9	S10	S1	S3	S8	S9	S10
Irrigated area (ha)	221,526	239,170	263,086	263,086	287,003	268,859	296,230	325,853	325,853	355,476
% expansion over current		8.0%	18.8%	18.8%	29.6%		10.2%	21.2%	21.2%	32.2%
Probability of deficit > 100 mm	0.2%	2.0%	2.7%	1.8%	2.5%	0.1%	2.4%	6.3%	4.5%	8.7%
Average net farm income for modeled farms ($)	20,950	51,410	50,600	50,220	49,890	33,240	60,680	54,800	49,800	47,120
% of farms > S1 (by $2,000 or more)		100%	100%	100%	96%		100%	97%	100%	83%
% of farms = S1 (within +/- $2,000)		0%	0%	0%	4%		0%	3%	0%	13%
% of farms < S1 (by $2,000 or more)		0%	0%	0%	0%		0%	0%	0%	4%
% of farms negative	22.2%	3.7%	7.4%	7.4%	3.7%	16.7%	6.7%	6.7%	6.7%	6.7%
Probability of negative NFI in any year										
% of farms < S1 (by 3% or more)		67%	63%	59%	52%		37%	33%	33%	30%
% of farms = S1 (within +/- 3%)		33%	37%	41%	48%		33%	20%	7%	7%
% of farms > S1 (by 3% or more)		0%	0%	0%	0%		30%	47%	60%	63%
% of farms > 20% probability (1 year in 5)	37%	33%	33%	33%	37%	27%	20%	20%	23%	23%
Risk of insolvency										
% of farms < S1		15%	15%	11%	15%		13%	10%	10%	10%
% of farms = S1		85%	85%	89%	81%		87%	90%	90%	87%
% of farms > S1		0%	0%	0%	4%		0%	0%	0%	3%

48

Summary of “Worse” Water Management Scenarios. Scenarios S4 and S7 show that without an increase in on-farm water application levels, from an average of 80 percent of optimal to an average of 90 percent, financial performance declines for the majority of representative farm types. In the Bow Basin, the average NFI would be expected to decline slightly. The decrease in NFI would be much more substantial in the Oldman Basin. In both regions, the percentage of farms having a negative NFI would increase somewhat.

The probability of experiencing a negative NFI would stay roughly equal for farms in the Bow Basin. Between 19% and 26% would expect an increased probability compared to scenario S1. For most farms within the Oldman Basin, the probability of a negative NFI would rise.

The likelihood of a high risk of negative NFI increases somewhat for both basins, particularly for the Oldman Basin under scenario S10.

Changes to the risk of financial insolvency also differ compared to the “Better” scenarios. While the vast majority of farms would not expect any substantial change in the risk of insolvency, the remaining 11% and 20% of the farms would have a higher risk.

Duration of Water Shortages

Another aspect of the risk of water shortages, which has not yet been addressed, is the duration of the water shortages. Since weather has cyclical tendencies, “dry spells” or droughts that last for several years are a real concern. Multi-year droughts can severely impact farm financial results for two or more years in a row. These back-to-back financial turndowns will have greater consequences on farm financial sustainability than intermittent poor years.

Figures 37 through 42 illustrate the risks of back-to-back financial losses for three representative farm types. For each farm type, the results are charted separately for the “better” and “worse” water management scenarios.

Grains and oilseed farms would expect a significant decline in the risk of consecutive years with negative NFI with the “better” water management scenarios (e.g., scenario S3). The risk would remain the same with the “worse” scenarios (e.g., scenario S4).

Farms that grow high value specialty crops, such as sugar beets, generally have a low risk of a negative NFI in any given year. Consequently, the risk of back-to-back deficit years is practically nil.

The last two charts in the series show the results for farms that grow a combination of grains, oilseeds and forages. Only one of the irrigation regions, B71, showed significant risk of consecutive poor years. Under each of the “better” scenarios, this risk is significantly reduced. However, under the “worse” scenarios, the decline in risk is much lower. As well, farms in B33 would experience an increased risk of back-to-back negative incomes.

Table 15. Summary of main farm financial results for "worse" scenarios.

Performance Indicator	Bow Basin			Oldman Basin		
	Current	Alternative Futures		Current	Alternative Futures	
	S1	S4	S7	S1	S4	S7
Irrigated area (ha)	221,526	263,086	287,003	268,859	325,853	355,476
% expansion over current		18.8%	29.6%		21.2%	32.2%
Probability of deficit > 100 mm	0.2%	1.0%	2.7%	0.1%	3.7%	7.0%
Average net farm income for modeled farms						
Avg. for all modeled farms ($)	20,950	18,130	18,000	33,240	23,750	18,560
% of farms > S1 (by $2,000 or more)		4%	0%		0%	0%
% of farms = S1 (within +/- $2,000)		74%	70%		0%	0%
% of farms < S1 (by $2,000 or more)		22%	30%		100%	100%
% of farms negative	22.2%	29.6%	29.6%	16.7%	20.0%	20.0%
Probability of negative NFI in any year						
% of farms < S1 (by 3% or more)		0%	0%		0%	0%
% of farms = S1 (within +/- 3%)		81%	74%		10%	7%
% of farms > S1 (by 3% or more)		19%	26%		90%	93%
% of farms > 20% probability (1 year in 5)	37%	44%	44%	27%	33%	50%
Risk of insolvency						
% of farms < S1		0%	4%		0%	0%
% of farms = S1		89%	81%		87%	80%
% of farms > S1		11%	11%		13%	20%

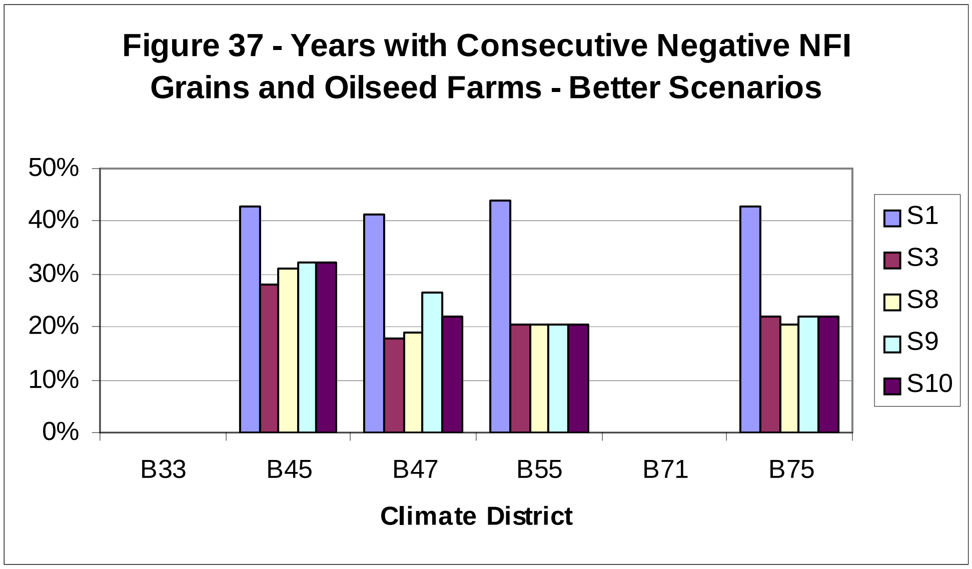


Figure 37 - Years with Consecutive Negative NFI
Grains and Oilseed Farms - Better Scenarios
50%
40%
30%
20%
10%
0%
B33
B45
B47
B55
B71
B75
Climate District
S1
S3
S8
S9
S10

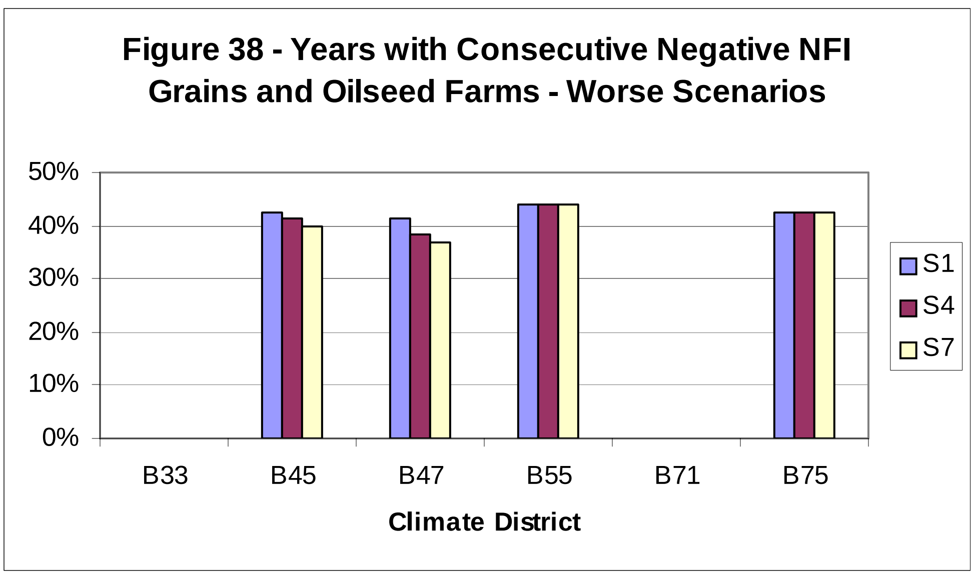


Figure 38 - Years with Consecutive Negative NFI
Grains and Oilseed Farms - Worse Scenarios
50%
40%
30%
20%
10%
0%
B33
B45
B47
B55
B71
B75
Climate District
S1
S4
S7

Figure 39 - Years with Consecutive Negative NFI Sugar Beet Farms - Better Scenarios

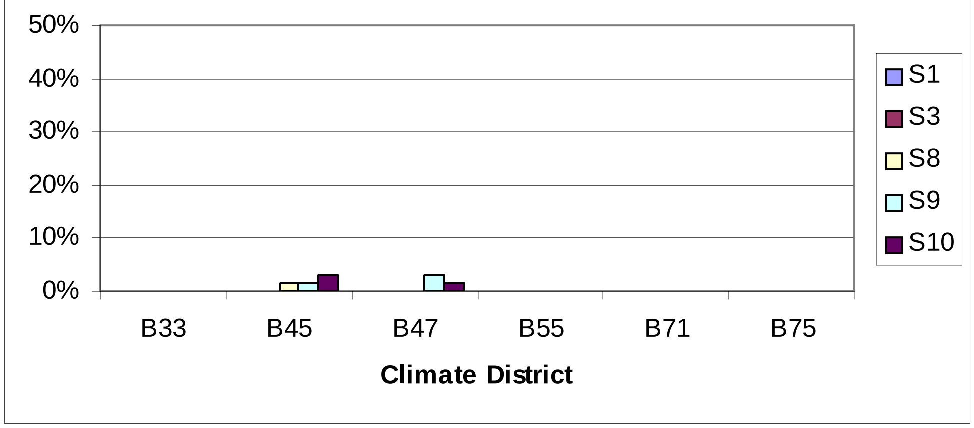
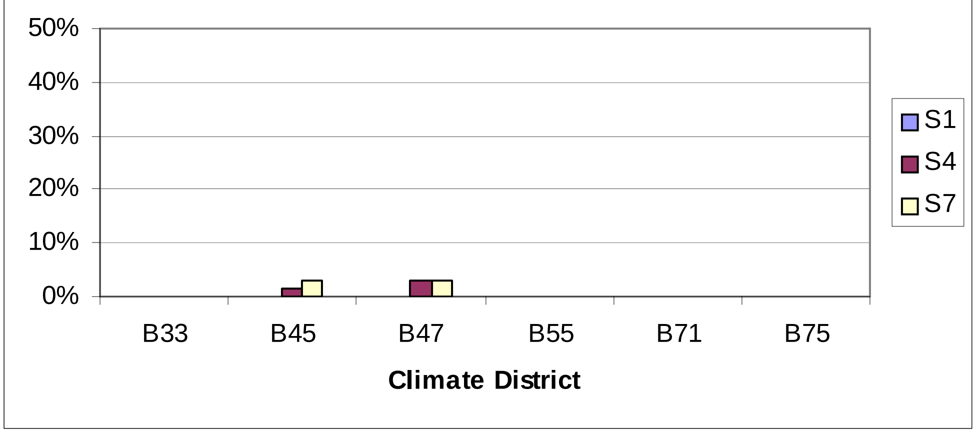
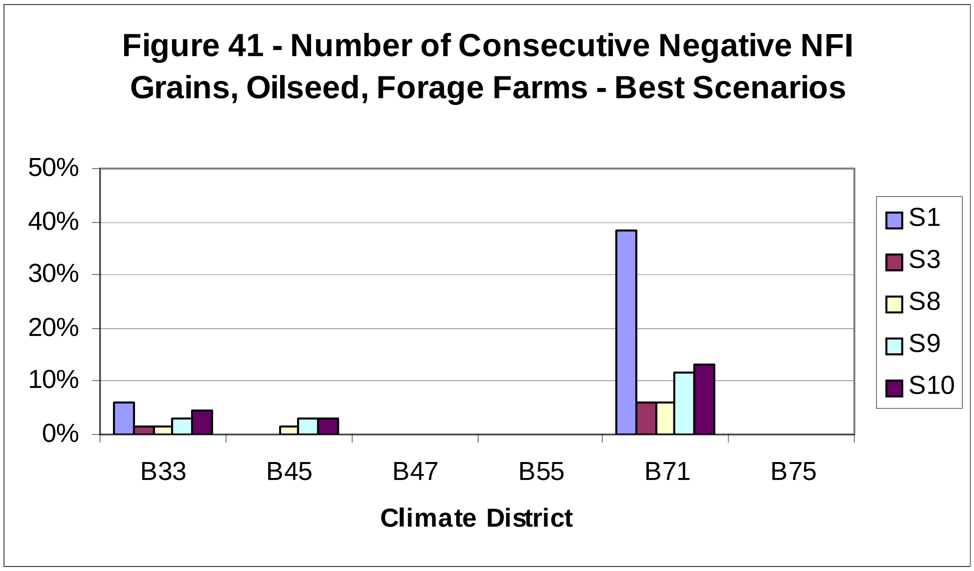
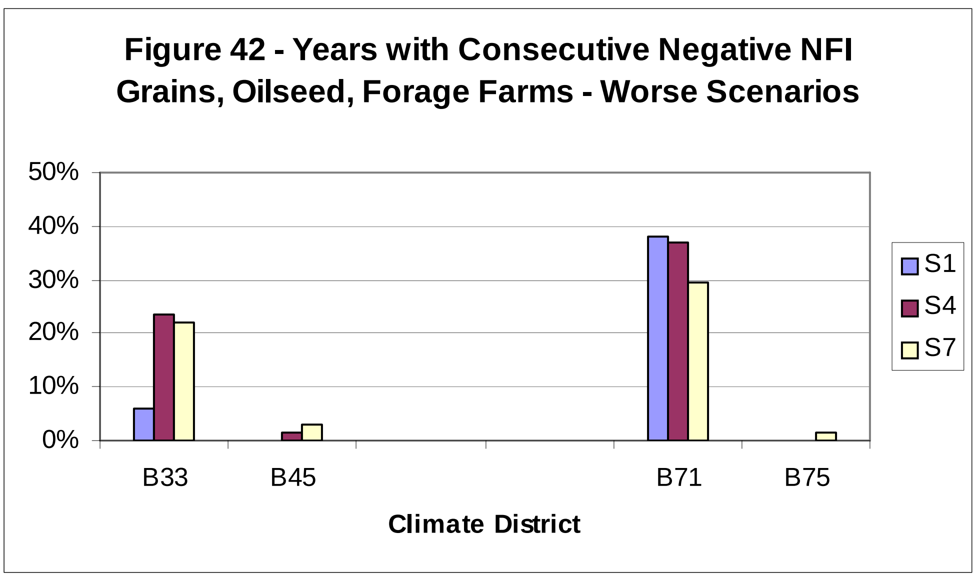


Figure 40 - Years with Consecutive Negative NFI Sugar Beet Farms - Worse Scenarios







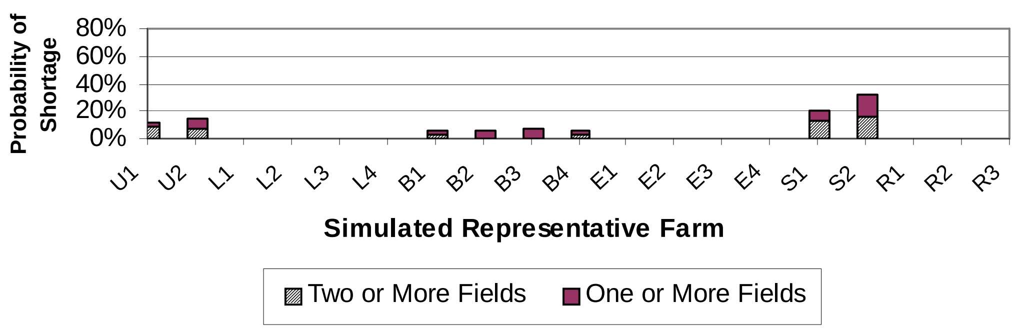
Probability of Fields Shorted Water

The FFIRM optimizes water allocation between fields (see Section I). When water deficits occur, the optimizer allocates water to specific fields in order to maximize total revenue. The type of crops grown on the representative farms was the main determinant for the number of fields that were given less than optimal amounts of irrigation water (i.e., were shorted water). Water was first allocated to the high valued crops, such as sugar beets and potatoes. The low valued crops, usually barley and wheat, were the lowest on the water allocation priority. Other factors, such as debt level, would have no impact on the water allocation process.

The following charts describe the results of the water allocation optimization procedure with respect to how many (and how often) fields were shorted water. The results show the probability of one-or-more fields shorted and the probability of two-or-more fields being shorted.

In Figure 43, the probability of one-or-more and two-or-more fields being shorted water is shown for the 19 farms assessed for scenario S1. The labels on the bottom of the chart indicate which irrigation district the farm represents. The first 10 farms are in the Oldman Basin, while the remaining nine farms are in the Bow Basin. Farms #15 and #16 show the highest probability of fields being shorted water. Most of the farms have little or no risk of any water shortages.

Figure 43 - Probability of Fields Shorted Water Scenario S1



Scenarios S3, S4 and S7 have similar risk patterns (Figures 44 – 46). Four farms have risks of water shortages of around 40 percent or more. On the other hand, farms in the Enchant area (E1 – E4) continue to show no risk of water shortages.

Also of note is that most of the farms shorted water on two-or-more fields rather than just one. An explanation is that most of the farms have two or more low-valued crops, all of which merit water reductions to permit more water being applied to the higher-valued crops. Only four farms shorted water primarily on only one field. The reason is these farms tend to emphasize forages, with perhaps only one low-valued grain crop.

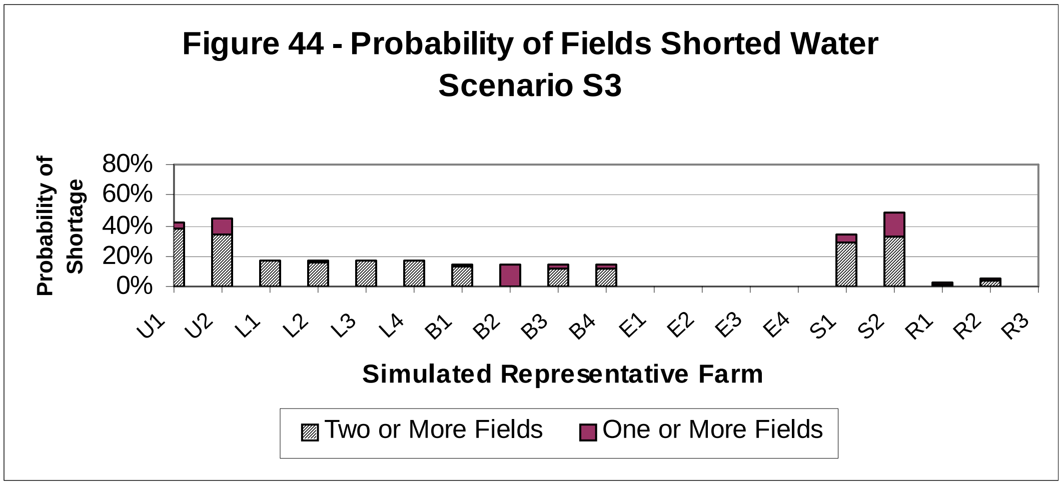


Figure 44 - Probability of Fields Shorted Water
Scenario S3
Probability of Shortage
80%
60%
40%
20%
0%
U1 U2 L1 L2 L3 L4 B1 B2 B3 B4 E1 E2 E3 E4 S1 S2 R1 R2 R3
Simulated Representative Farm
Two or More Fields
One or More Fields

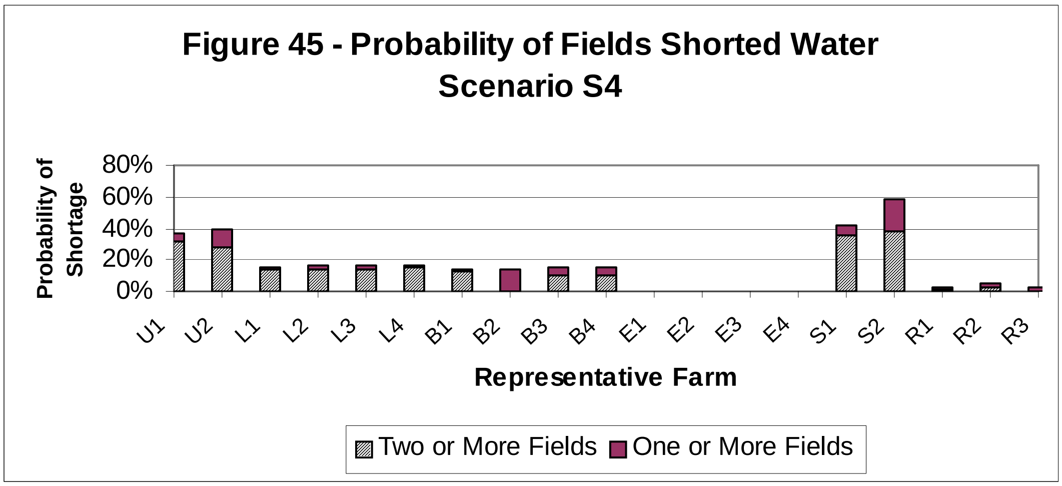


Figure 45 - Probability of Fields Shorted Water
Scenario S4
Probability of Shortage
80%
60%
40%
20%
0%
U1 U2 L1 L2 L3 L4 B1 B2 B3 B4 E1 E2 E3 E4 S1 S2 R1 R2 R3
Representative Farm
Two or More Fields
One or More Fields

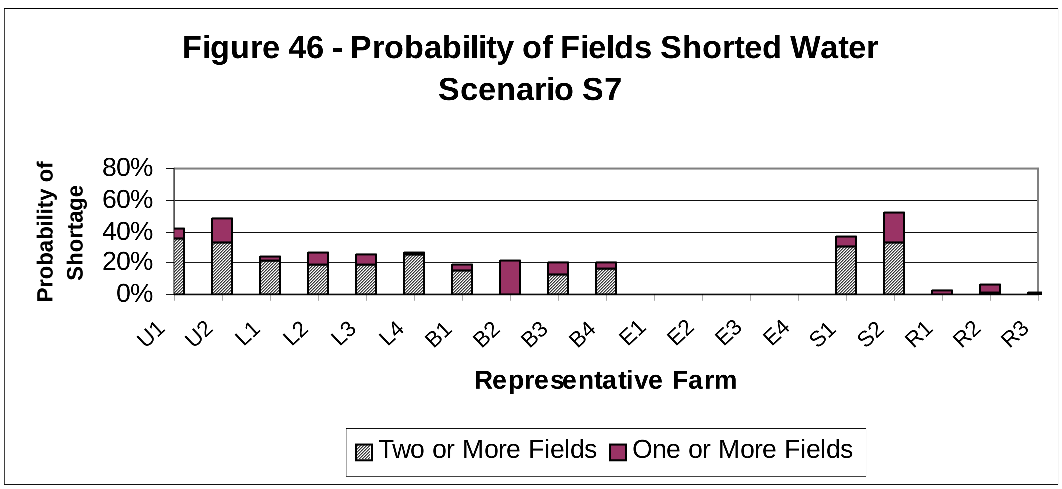
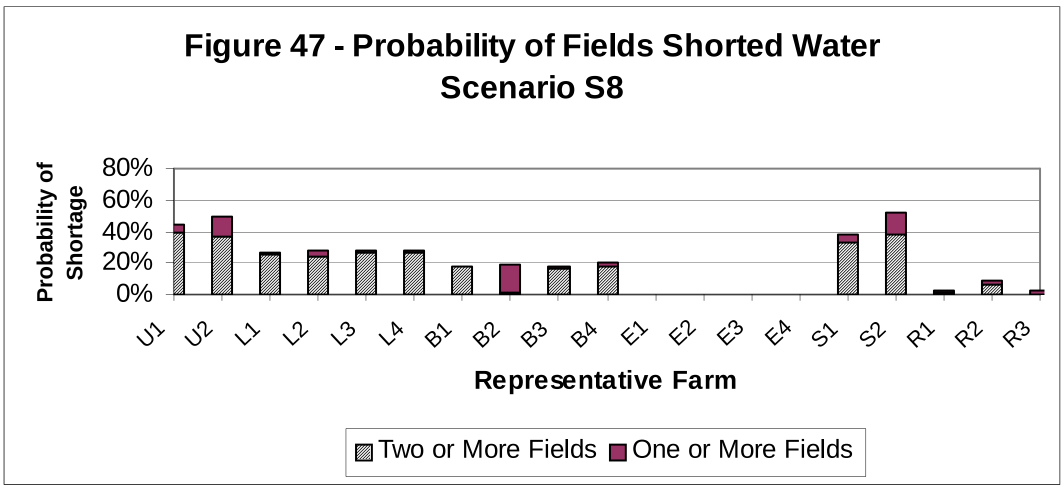


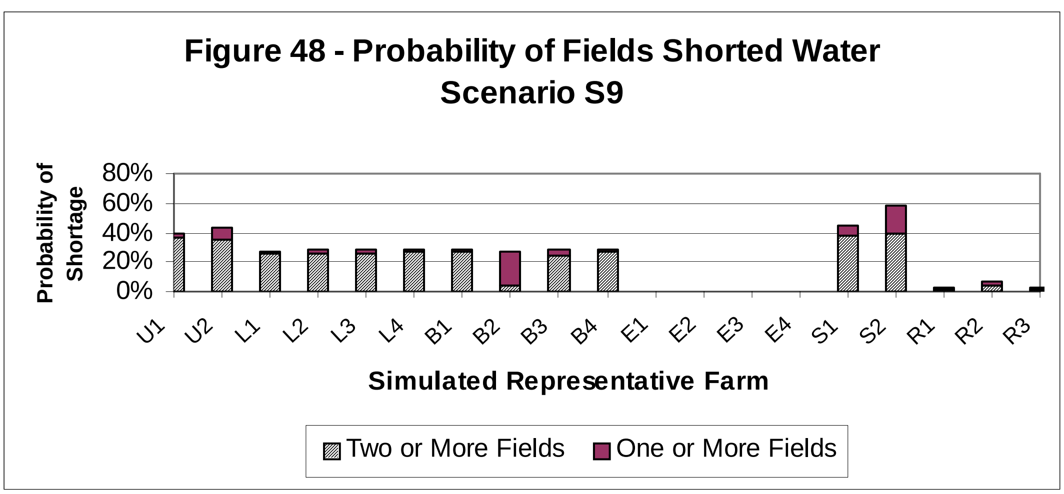
Figure 46 - Probability of Fields Shorted Water
Scenario S7
Probability of Shortage
80%
60%
40%
20%
0%
U1 U2 L1 L2 L3 L4 B1 B2 B3 B4 E1 E2 E3 E4 S1 S2 R1 R2 R3
Representative Farm
Two or More Fields
One or More Fields

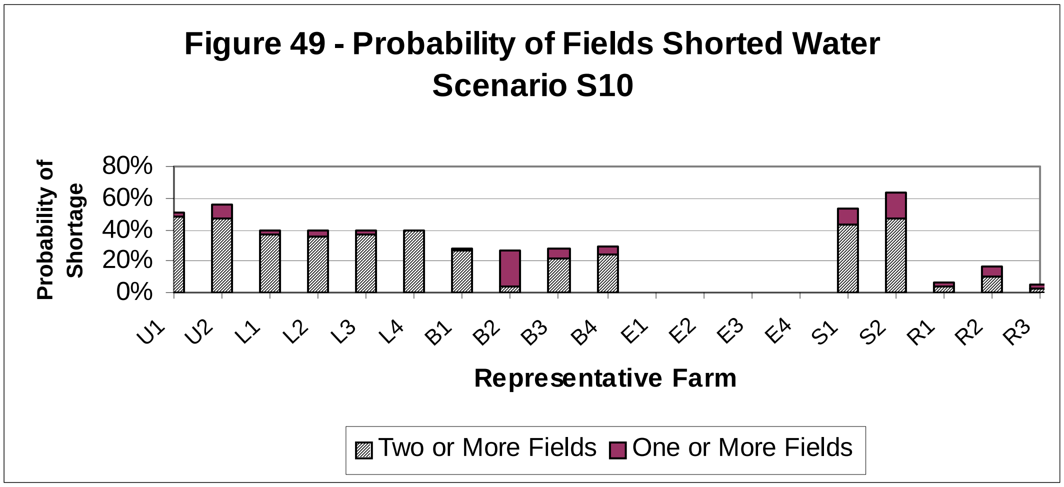
In scenarios S8, S9 and S10, the risk of a water shortage increases for most representative farms (Figures 47-49). For example, farms in the Lethbridge area (L1 – L4) in scenario S3, all had about a 20% probability of experiencing a water shortage that required water to be limited on one or two fields. In scenarios S8 and S9, the probability increased to 25% or 30%, and in scenario S10 it increased to 40%.

Most farms continue to short water on two fields. Only one farm (B2) shorts water to only one field most of the time. The reason is three of the four crops on the farm are high-valued.

Although the risk in water shortages tends to increase for many farms in the three water management scenarios above, it was shown earlier that the NFI also tended to increase. The higher water application rates on farms in the non-deficit years generally more than offset the reductions to revenue in the deficit years. Furthermore, with small deficits, the water application amounts, and consequently NFI, will often still be higher than in the base case scenario.







CONCLUSIONS

A number of general observations and conclusions were drawn from the various analyses that were performed through this component of the overall Irrigation Water Management Study.

- Farm enterprises that relied only on cereals and oilseed production were significantly less profitable than farms that also grew specialty crops or forages.

- For the scenario conditions that maintained the current on-farm water consumption level of 80%, most farm types experienced a significant decrease in average net farm income. This was due to overall lower incomes each year, particularly in the water deficit years.

- Most farm types would experience a higher average net farm income with time, under water management practices where on-farm water consumption levels were at 90% of optimum. This would contribute to increased revenue opportunities, particularly in non-deficit years, and would help to sustain enterprises through periodic deficit years.

- Regardless of farm type, the overall farm sustainability either remained the same or improved marginally for scenarios where water management levels were higher and crop water use was targeted at 90% of optimum. More specifically, the risk of farm insolvency either remained unchanged or fell marginally for these scenarios.

- Changes in the risk of negative net farm incomes differed between the Oldman and Bow River Basins.
  - In the Oldman Basin, the farm types that had a high risk of negative net farm income under the base case or current (1999) conditions had considerably reduced risk under scenarios where higher water management levels were practised. However, many of the low risk farms in the base case scenario experienced an increase in the risk of negative net farm incomes, even under improving water management scenarios. The high-risk

farms in the base case scenario were, for the most part, grain and oilseed farm-types. By increasing the application of water in all years, especially the non-deficit years, those farms were able to significantly reduce the risk of negative net farm incomes. The increase in the risk of negative net farm income for the other farms was due to the increased frequency and magnitude of water shortages that occurred under higher water demand situations arising from increasing water applications or irrigation area expansion.

  - In the Bow Basin, water supply deficits were more frequent but of a notably lesser magnitude than in the Oldman Basin. Almost all of the farms experienced a decrease in the risk of negative net farm incomes. The increased application of water in the non-deficit years and the resulting higher average net farm incomes more than offset the increased risk of negative net farm incomes in the water deficit years.

- For many of the farms in the Oldman Basin, a trade-off would need to be made between a higher average net farm income and an increase in the risk in negative net farm incomes. Some businesses may prefer to reduce their variability in income even if it means that their average net income may decline.
  - While the average net farm income generally increased for scenarios where higher water applications or improving water management were expected, the variability of net farm income when compared to the base case (1999) did not change significantly. The only exceptions were for the grain and oilseed farm types, which generally experienced a decline in variability of net farm incomes, and for forage farm types in the Oldman Basin, which generally experienced an increase in variability of net farm income.

  - For scenarios that examined simply 10% and 20% expansions, most farm types in the Oldman Basin experienced an increase in variability of net farm incomes. For the Bow Basin, only farm types that included forages in the farm mix experienced an increase in variability of net farm income.

- As the risk of back-to-back years of notable deficits increases, the risk of negative net farm incomes also increases.

- For scenario conditions where 90% of optimum crop water requirements were met, there were also conditions applied whereby water management practices, both on the farm and at the district level, were improving beyond current levels. For the analysis to be favourable from a farm financial perspective, all of the assumptions concerning improved water management would have to be fulfilled in order that net water demands would be somewhat reduced, thereby reducing the extent of deficits.

- It is projected that most farm enterprises could withstand deficits in water supply up 100 millimetres, even if they occurred relatively often. Due to water losses through the irrigation application process being a part of the water demand, only a portion of diversion deficit levels actually impact the crop directly. In addition, the ability for a farm operator to move limited supplies of irrigation water around to various fields, also allows him to move that water to those crops that can help maximize overall farm revenue under constrained supply conditions.

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Volume 5 Economic Opportunities and Impacts

II. The Economic Benefit of Growth in Alberta Irrigation Development

Prepared by:

Marv Anderson[1]
Marv Anderson & Associates Ltd.

[1] Marv Anderson is a national and international consultant who focuses on the economics of water management. Other than in Alberta, he has worked extensively in Indonesia, Honduras, Brazil, Egypt, Pakistan, Sri Lanka, India, Bangladesh, Uzbekistan, Russia, Venezuela, Bolivia, Peru, Barbados, Guyana/Caribbean, and Ghana. His principal clients are the World Bank, Asian Development Bank, IFAD/FAO and the Canadian International Development Agency. He began his career at the University of Alberta and the AERCC in Ottawa. He now resides in Sherwood Park, Alberta, still owning and operating a dryland grain/oilseed farm in northeastern Alberta.
(Contact: marvanderson@msn.com.)

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The Irrigation Water Management Study in the South Saskatchewan River Basin is a cooperative study initiated in 1996 by the Alberta Irrigation Projects Association (AIPA), Alberta Agriculture, Food and Rural Development (AAFRD) – Irrigation Branch, and Prairie Farm Rehabilitation Administration (PFRA) of Agriculture and Agri-Food Canada. The study was initiated in response to a 1991 Alberta Government regulation, which placed irrigation expansion limits on the irrigation districts (Fig. 1). When the Regulation was passed, the Alberta Government committed to a review of the irrigation expansion guidelines in the South Saskatchewan River Basin during the next decade.

The purpose of this component of the study is to document the benefits of irrigation in southern Alberta in a rigorous review but yet understandable by a non-economist. This report profiles the existing irrigation industry in Alberta, and considers the implications of further irrigation expansion of 10 to 20 percent within existing irrigation districts, based primarily on water use efficiency improvements. This requires documentation of the economic, environmental and social benefits of the irrigation industry to Alberta as of the year 2000, as well as expectations for the future.

The specific Terms-of-Reference for the report were as follows.

- Assuming no change in the existing area of irrigation development, prepare a statement and supporting material on the economic, environmental and social benefits of the irrigation industry to Alberta as of the year 2000 and expectations for the future. Quantify where possible.
- Assuming a 10 to 20% expansion, prepare a statement and supporting material on the contribution that the irrigation industry can make to achieve the economic, social and environmental objectives of the province. Quantify where possible.

METHODS

Much of this work was completed by analyzing, summarizing and extrapolating existing data, supplemented by informal interviews with AAFRD and other professionals in the irrigation industry. The second task was primarily addressed by reviewing Ministerial Business Plans (Agriculture, Economic Development and Environment) and an AAFRD Growth Strategy document, supplemented by informal "brainstorming" sessions with AAFRD and agri-industry personnel. The required work was carried-out from September to December, 1999.

The analysis is presented in three sections:

- Section II: Existing Situation – an overview of the role of existing irrigation-dependent activities in the southern Alberta economy.
- Section III: Potential Opportunities – an examination of potential growth (in terms of value-added) in irrigated farm production and related agri-processing activities in southern Alberta during 2000-2010.
- Section IV: Impacts and Implications – estimated impacts of two irrigation development scenarios and their ramifications regarding provincial policy objectives.

Figure 1. South Saskatchewan River Basin, primary sub-basins, irrigation districts and census divisions.

EXISTING SITUATION

On-Farm Production

The location and relative importance of irrigation in Alberta's agriculture industry is indicated in Table 1. The more than 517,000 hectares of irrigated agriculture within the 13 irrigation districts utilizes only 5.4 percent of the cultivated area in the province. About 8.3 percent of all Alberta farmers have land under irrigation.

Table 1. The location and importance of irrigation in primary agriculture, 1995.

Location	# of Farms	Hectares	% of All Farms	% of All Crop Land
Census Division #1:				
Cypress MD No. 1	367	29,077	35.1	13.1
Forty Mile County No. 8	247	40,314	32.0	10.7
Census Division #2:				
Warner County No. 5	169	16,641	27.4	6.3
Lethbridge County No. 26	898	102,070	73.5	44.9
Taber MD No. 14	749	116,851	78.0	47.7
Newell County No. 4	837	103,714	84.0	70.2
Census Division #3:				
Cardston MD No. 6	221	16,277	27.8	7.7
Willow Creek MD No. 26	150	13,904	16.0	6.6
Pincher Creek MD No. 9	29	1,957	4.8	2.2
Ranchland MD No. 66	3	57	4.5	2.0
Census Division #5:				
Vulcan County No. 2	151	23,876	18.9	6.3
Wheatland County No. 16	288	18,985	29.6	5.4
Starland #47Kneehill #48	31	2,677	2.2	0.6
Total Southern Alberta Irrigation	4,140	486,400	37.0	15.2
Percent of All Alberta Irrigation	84%	94%		
Other Alberta Irrigation	774	30,200	1.6	0.4
Total Alberta Irrigation	4,914	516,600	8.3	5.4

Source: AAFRD (1997).

The impacts of irrigation with regard to on-farm production are generally well-known. Irrigation basically enhances on-farm production in four important ways.

- Enhanced yields of conventional crops (crops which are grown under both dryland and irrigation);
- Opportunities for the production of "new" crops which can be successfully grown only under irrigation;
- More stable crop yields and thus, more reliable crop production; and
- Increased on-farm diversification, particularly beef production.

The extent to which yields typically increase is indicated in Tables 2 and 3. A yield increase of two to three times is common. In the more arid regions (southeastern parts of Alberta), the difference between dryland and irrigated yields is often more pronounced.

Table 2. Dryland crops enterprise analysis in southern Alberta* ($/hectare).

Item	Spring Wheat	Feed Barley	Canola	Oats**	Alfalfa Hay	Weighted
	1	2	3	4	5***	Average
Historical Dryland Pattern (%)****	56.4	25.7	5.9	2.9	9.1	100%
(A) 1. Crop Sales	309.17	261.38	316.36	147.30	231.29	290.44
2. Crop Insurance Receipts	0.00	3.46	0.00	0.00	0.00	0.89
3. Miscellaneous Receipts	6.25	21.89	3.04	3.83	0.00	9.41
4. Government Program	0.67	0.99	0.52	11.59	0.00	0.67
5. Additional Revenue from Straw/Grazing	0.42	13.79	0.00	57.67	0.00	3.78
6. GROSS RETURN	**316.51**	**301.51**	**319.92**	**220.39**	**231.29**	**305.19**
(B) 1. Seed	17.20	16.75	21.55	35.04	0.00	15.91
2. Fertilizer	41.93	44.13	76.63	0.00	15.72	43.17
3. Chemicals	38.33	33.56	32.67	0.96	0.00	33.11
4. Hail/Crop Insurance	20.11	11.32	10.55	0.00	0.00	15.17
5. Trucking and Marketing	0.77	1.21	1.24	0.00	0.00	0.84
6. Fuel	13.54	16.58	14.48	21.40	6.97	13.81
7. Irrigation Fuel and Electricity	0.00	0.00	0.00	0.00	0.00	0.00
8. Repairs – Machinery	21.65	36.69	19.25	17.15	11.79	24.41
9. Repairs – Buildings	1.19	8.77	2.99	1.38	4.99	3.63
10. Utilities & Misc. Expenses	11.44	17.17	11.24	31.36	7.24	12.50
11. Custom Work/Special	1.06	16.11	12.53	0.00	4.08	6.20
12. Operating Interest Paid	5.51	3.71	0.00	0.07	0.40	4.10
13. Paid Labour & Benefits	5.46	16.85	9.07	14.78	5.49	8.70
14. Unpaid Labour	24.76	22.29	17.00	32.42	8.48	21.97
15. VARIABLE COSTS	**202.94**	**245.15**	**229.19**	**154.56**	**65.14**	**203.54**
(C) 1. Cash/Share Rent & Land Lease	31.55	18.04	11.59	0.32	86.29	31.31
2. Taxes, Water Rights, License & Insurance	9.37	11.05	11.29	8.38	1.06	9.22
3. Equipment & Bldg: a) Depreciation	45.81	44.85	34.84	36.18	26.76	42.87
b) Lease Payments	3.06	0.00	10.80	0.00	21.35	4.62
4. Paid Capital Interest	21.67	24.54	5.46	3.73	3.11	19.30
5. TOTAL CAPITAL COSTS	**111.47**	**98.47**	**73.98**	**48.60**	**138.57**	**107.32**
(D) CASH COSTS (B15+C5-B14-C3)	**243.84**	**276.48**	**251.33**	**134.57**	**168.47**	**246.01**
(E) TOTAL PRODUTION COSTS (B15+C5)	**314.41**	**343.62**	**303.17**	**203.17**	**203.71**	**310.85**
(F) GROSS MARGIN (A6-D)	**72.67**	**25.03**	**68.59**	**85.82**	**62.81**	**59.18**
RET'N TO UNPAID LABOUR (A6-E+B14)	**26.86**	**-19.82**	**33.75**	**49.64**	**36.05**	**16.31**
RETURN TO INVESTMENT (A6-E+C4)	**23.77**	**-17.57**	**22.21**	**20.95**	**30.69**	**13.64**
Percent Return to Investment	1.17%	-0.90%	1.28%	1.68%	6.27%	0.74%
RETURN TO EQUITY (A6-E)	**2.10**	**-42.11**	**16.75**	**17.22**	**27.58**	**-5.66**
INVESTMENT						
Land	1436.32	1345.01	1284.03	767.32	150.90	1282.47
Buildings	167.24	196.15	157.45	176.65	53.69	163.48
Machinery	423.50	402.77	300.55	304.35	285.15	394.77
Irrigation Machinery	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	**2,027.06**	**1,943.94**	**1,742.03**	**1,248.32**	**489.75**	**1,840.72**
MANAGEMENT						
Yield per Hectare (tonnes)	2.10	2.28	0.96	2.00	3.85	
Expected Market Price ($ per tonne)	147.00	114.84	330.75	73.50	60.00	
LABOUR						
Hired Labour (hours)	0.57	1.36	0.96	1.68	0.69	0.82
Unpaid Labour (hours)	2.47	2.22	1.70	3.24	0.84	2.20
Total Labour (hours/hectare/year)	**3.04**	**3.58**	**2.67**	**4.92**	**1.53**	**3.01**

* All crops are on stubble, implicitly charging for the cost of summerfallow or the no-fallow option in the crop rotation.
Product prices have been adjusted to more accurately reflect long-term average real prices.
Weighted average based on historical land use.

** Typical of the Brown Soil Zone (on fallow).

*** Crop insurance receipts adjusted downward to reflect a more typical revenue scenario.

**** Based on historical data for 1971-1991 for ARA II.

Sources: AAFRD (1998a, 1998b).
(NOTE: These are actual "consensus" yields and costs-of-production derived from an annual survey of representative farmers).

Table 3. Irrigated crops enterprise analysis in southern Alberta* ($/hectare).

Item	Soft Wheat 1	Feed Barley 2	Alfalfa Hay 3	Grain Silage 4	Corn Silage** 5	Canola 6	Dry Beans 7	Sugar Beets 8	Alfalfa Seed 9	Weighted Average
Irrigated Land Use Pattern (%)	22.8	11.7	27.5	13.3	2.1	10.3	5.0	5.6	1.7	
(A) 1. Crop Sales	791.53	607.20	758.37	892.54	1651.90	893.84	1324.12	2223.95	1538.75	922.42
2. Crop Insurance Receipts	9.71	0.00	0.00	71.88	0.00	0.00	19.25	11.37	0.00	13.37
3. Miscellaneous Receipts	6.30	0.96	15.57	6.82	0.72	8.99	16.16	67.51	49.17	13.10
4. Government Program	5.58	1.75	0.00	0.20	0.00	6.97	1.73	1.98	49.57	3.26
5. Additional Revenue from Straw/Grazing	32.59	39.31	0.00	3.85	0.00	0.00	0.00	2.77	0.00	12.70
6. GROSS RETURN	**845.72**	**649.23**	**773.93**	**975.30**	**1,652.62**	909.80	**1,361.26**	**2,307.57**	**1,637.49**	**964.85**
(B) 1. Seed	29.60	26.76	30.37	35.01	125.26	55.60	112.24	161.36	10.53	46.09
2. Fertilizer	110.78	120.29	35.58	130.05	154.44	106.75	97.61	121.58	0.00	92.34
3. Chemicals	59.26	37.56	9.51	40.03	54.63	88.22	189.11	225.51	137.79	60.52
4. Hail/Crop Insurance	21.72	19.10	0.00	9.17	5.39	30.94	60.79	17.25	45.54	16.48
5. Trucking and Marketing	21.20	10.01	1.88	0.89	2.52	9.07	0.00	22.04	6.15	8.97
6. Fuel	28.61	26.00	20.78	45.86	43.24	33.93	49.74	101.83	79.92	35.19
7. Irrigation Fuel and Electricity	37.21	24.04	48.61	39.27	63.16	41.37	28.94	46.16	16.38	39.78
8. Repairs – Machinery	52.09	49.59	71.76	57.43	44.28	64.30	98.10	179.10	64.87	68.65
9. Repairs – Buildings	7.41	11.91	2.69	12.36	5.73	4.70	5.31	11.02	16.26	7.24
10. Utilities & Misc. Expenses	31.75	25.18	34.42	35.95	35.66	38.50	37.12	153.67	185.21	42.75
11. Custom Work/Special	15.86	39.29	29.45	51.55	0.00	19.27	19.50	122.71	20.63	33.36
12. Operating Interest Paid	8.35	6.33	6.97	3.95	1.11	10.35	18.78	20.24	0.79	8.25
13. Paid Labour & Benefits	16.46	36.18	37.88	67.04	118.88	42.95	45.62	104.15	50.98	43.22
14. Unpaid Labour	69.98	46.68	47.52	51.97	64.59	37.61	113.94	240.43	107.47	67.66
15. VARIABLE COSTS	**510.30**	**478.91**	**377.43**	**580.52**	**718.90**	**583.54**	**876.78**	**1527.06**	**735.51**	**570.49**
(C) 1. Cash/Share Rent & Land Lease	42.50	67.26	0.00	91.85	107.96	52.19	75.96	177.62	0.00	51.18
2. Taxes, Water Rights, License & Insurance	45.29	36.92	28.74	34.00	54.76	45.84	50.29	51.08	80.14	39.69
3. Equipment & Bldg: a) Depreciation	139.39	118.39	141.29	114.11	156.64	132.18	165.54	245.85	161.43	141.37
b) Lease Payments	3.21	1.43	0.00	0.00	0.00	8.20	0.00	2.47	0.00	1.88
4.-Paid Capital Interest	70.50	48.93	57.38	47.32	53.18	54.61	96.12	51.62	29.48	58.81
TOTAL CAPITAL COSTS	**300.90**	**272.93**	**227.41**	**287.28**	**372.54**	**293.02**	**387.91**	**528.63**	**271.05**	**292.92**
(D) CASH COSTS (B15+C5-B14-C3)	**601.82**	**586.78**	**416.03**	**701.73**	**870.21**	**706.77**	**985.21**	**1569.42**	**737.66**	**654.38**
(E) TOTAL PRODUTION COSTS (B15+C5)	**811.20**	**751.84**	**604.84**	**867.81**	**1,091.44**	**876.56**	**1,264.68**	**2,055.69**	**1,006.56**	**863.41**
(F) GROSS MARGIN (A6-D)	**243.89**	**62.46**	**357.91**	**273.57**	**782.41**	**203.03**	**376.05**	**738.15**	**899.83**	**310.46**
RETURN TO UNPAID LABOUR (A6-E+B14)	**104.50**	**-55.93**	**216.61**	**159.46**	**625.77**	**70.86**	**210.52**	**492.31**	**738.40**	**169.09**
RETURN TO INVESTMENT (A6-E=C4)	**105.02**	**-53.68**	**226.47**	**154.81**	**614.35**	**87.86**	**192.70**	**303.49**	**660.41**	**160.25**
Percent Return to Investment	2.51%	-1.57%	6.25%	3.94%	12.22%	2.22%	5.12%	6.53%	13.81%	4.09%
RETURN TO EQUITY (A6-E)	**34.52**	**-102.61**	**169.09**	**107.49**	**561.18**	**33.25**	**96.57**	**251.87**	**630.93**	**101.44**
INVESTMENT										
Land	2463.39	2024.11	2075.76	2547.83	3085.38	2292.32	1848.30	1857.24	2670.44	2250.88
Buildings	338.11	218.14	167.34	289.71	331.37	326.65	161.38	342.09	721.18	267.24
Machinery	792.81	721.99	749.42	737.54	677.83	924.79	1375.88	1962.41	1059.61	875.62
Irrigation Machinery	593.08	465.37	633.03	354.57	932.60	422.70	378.05	482.89	332.58	525.64
TOTAL	**4,187.40**	**3,429.62**	**3,625.55**	**3,929.64**	**5,027.18**	**3,966.46**	**3,763.61**	**4,644.64**	**4,783.81**	**3,919.38**
MANAGEMENT										
Yield per Hectare (tonnes)	6.15	5.29	8.43	25.50	33.04	2.70	2.40	49.42	0.47	
Expected Market Price ($/tonne)	128.63	114.84	90.00	35.00	50.00	330.75	551.25	45.00	3307.50	
LABOUR										
Hired Labour (hours/hectare/year)	1.63	3.34	3.66	5.93	9.66	3.71	4.45	9.32	4.99	3.98
Unpaid Labour (hours/hectare/year)	7.02	4.67	4.74	5.19	6.45	3.76	11.39	24.07	10.75	6.77
Total Labour (hours/hectare/year)	**8.65**	**8.01**	**8.40**	**11.12**	**16.11**	**7.46**	**15.84**	**33.38**	**15.74**	**10.75**

* The selected crops are considered representative of the cereals (34.5%), forages (42.9%), oilseeds (10.3%) and specialty crops (12.3%) grown under irrigation in southern Alberta. (Table 4)
There are actually more than 50 irrigated crops in southern Alberta. These particular crops represent about two-thirds of the total irrigated area.
Product prices have been adjusted to more accurately reflect long-term average real prices.

** Crop insurance receipts adjusted downward to reflect a more typical revenue scenario.

Sources: AAFRD (1998c, 1999a)
(NOTE: these are actual “consensus” yields and costs-of-production derived from an annual survey of representative farmers).

Irrigation also allows for the introduction of a large number of "new" crops. These crops include, in particular, corn (grain and silage), beans, peas, vegetables, fruits, potatoes and sugar beets. The areal extent of these crops is indicated in Table 4. Since these are typically higher-value crops, their economic impacts are much greater than their areas suggest; probably twice that of conventional crops.

The third important benefit is the fact that crop yields are much more stable. This results in: 1) greater farm income stability and, thus, greater on-farm sustainability; 2) much lower crop insurance costs, both public and private; and 3) greater assurance in meeting production targets and contracts.

The "bottom line" at the farm level is a relatively large incremental increase in net farm income per hectare. Some comparative figures are provided in Table 5 and illustrated in Fig. 2.

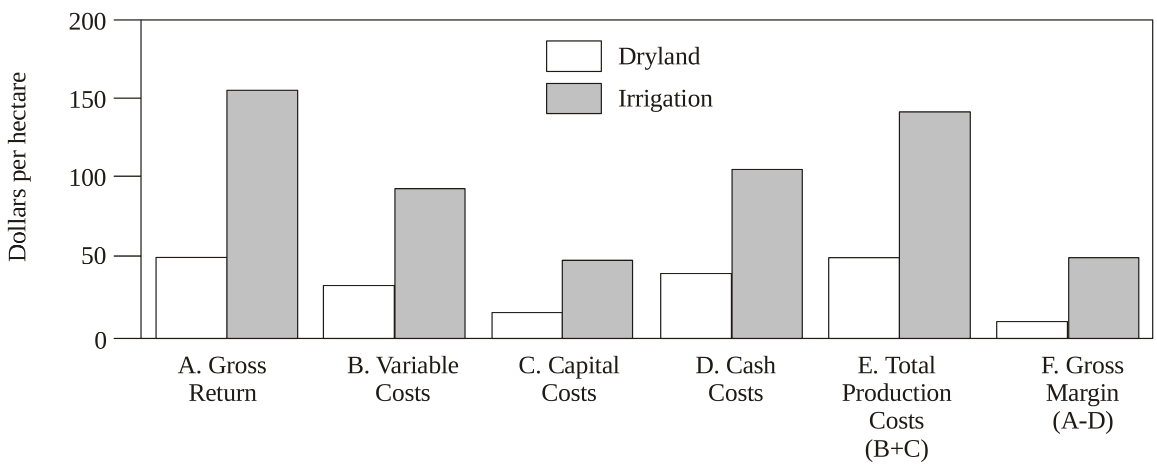

Figure 2. Comparative costs and benefits of irrigation and dryland agriculture – southern Alberta, 1999.

Gross returns on irrigated lands are typically more than three times that of non-irrigated lands, and the gross margin is often more than five times. The gross margin is approximately equivalent to value-added (Fig. 3). Gross value-added includes compensation to employee labour and management, interest, rent, profits, taxes, and reserves for depreciation. Net value-added excludes depreciation. The Gross National Product (GNP) is the total gross value-added by all the productive enterprises in the economy. On a per-hectare basis, the return to on-farm labour and investment is estimated to be 10 to 11 times as large (Fig. 4). Total investment per hectare (about one-half of which is locally-purchased machinery and equipment which must periodically be replaced) approximately doubles and labour requirements per acre, on average, climb 3.6 times, most of which must be hired. This alone augments local investment by perhaps $100 million per year, as well as generates on-farm employment for some 15,000 people (in terms of full-time equivalents) (Fig. 4). Employment of 15,000 is in the order of 18 percent of all employment in primary agriculture.

Table 4. Distribution of crops grown within the thirteen irrigation districts – 1998. (All values are in HECTARES)

CROP	CROP CODE		AID		BRID		EID		LID		LNID		MID		MVID		RID		RCID		SMRID-W		SMRID-E		TID		UID		WID		TOTAL HECTARES
			A*	N**	A*	N**	A*	N**	A*	N**	A*	N**	A*	N**	A*	N**	A*	N**	A*	N**	A*	N**	A*	N**	A*	N**	A*	N**	A*	N**	
Barley	BAR	a		276	11,291	325	14,259	304	202		7,076	3,870	1,157	1,577			3,814	2,895	65		14,476	1,390	5,091	132	4,544	202	1,953	3,319	4,628	989	83,831
CPS Wheat	WCP	b			1,680	25					451	89									438	44									2,726
Durum	WDU	c			4,484	306	821				1,369	252	24	109							2,879	149	13,218	298	751	23	114	116			24,913
Grain Corn	COR	d					63														123		812								998
Hard Spring Wheat	WHD	e			4,901	165	7,689	93			834	324	85	54			263	314			1,628	464	3,097	337	729		279	1,271			22,527
Malt Barley	BAM	f																													0
Oats	OAT	g			348	3	1,291				106	57	61				81	30			74		464	28	193		6	74	238		3,055
Rye	RYW	h					107				56		28								104	38	47			20			79		479
Soft Wheat	WSO	I			11,782	154	3,797	203			1,818	170	180						106		6,305	167	9,984	161	4,427	344			1,862	1,451	42,912
Triticale	TRI	j			46		11				208												81								345
Winter Wheat	WWT	k					102				65										115	38	222		38			61			641
Alfalfa - Two cuts	AL2	l	364	127	12,167	172	29,759	28	749	20	2,441	67	962	120		473	3,814	150	200		6,287	241				459	1,387	340	5,748	366	66,442
Alfalfa - Three cuts	AL3	m									5,705	1,973											11,926	250	4,450						24,303
Barley Silage	BAS	n			1,622	113	8,594	35			17,909	3,299	150	72			1,664	364			5,005	212	1,749	46	448	243	185	62	1,870		43,643
Brome Hay	BRO	o									358	41					32	71			174	24	160	23							884
Corn Silage	COS	p			812	5	1,817				1,906	14	83						46		215		1,064	24	807						6,793
Grass Hay	GRH	q	81	68	215	76	1,936	28	324	24	932	112				364	354	212			1,322	223	801	62	460		620	413	2,768	235	11,631
Green Feed	GFD	r	153	95	640	75	3,628				123	14	325	287		81	91				58		1,363	188	36				247		7,403
Milk Vetch	MVH	s									49										4										53
Native Pasture	PAN	t			70	236					179	102									236	46	4,248	588	883	81					6,669
Oats Silage	OAS	u																													0
Sorghum/Sudan Grass	SOR	v																			32										32
Tame Pasture	PAT	w	184	28	5,778	724	18,406	1,190	445	24	2,235	609	945	119	426	162	1,315	425	10	63	1,950	210			1,700	77	2,112	612	5,059	609	45,417
Timothy Hay	TIM	x			493	13	394				177	5					40				1,348	21	235		486		60				3,273
Canola	CAN	y		49	8,907	215	9,566	42	142	0	2,874	541	497	524			1,477	911			7,474	478	10,030	211	815		236	381	1,870	777	48,016
Flax	FLX	z			408		443				6	16									28		963	17	26						1,906
Hyola	HYO	aa			1,618																24										1,642
Linola	LIN	ab			96		33																								129
Mustard	MUT	ac															85						77								163
Alfalfa Seed	ALE	ad			514	68	4,286	14			36																				4,919
Canary Seed	CNY	ae																													0
Caraway Seed	CWY	af					24																111								136
Carrots	CAR	ag			61		212														18		12		43						346
Dill	DIL	ah																					164								164
Dry Beans	BEA	ai			2,881	7	799				17										650		8,801	61	1,697						14,912
Dry Peas	PED	aj			1,428	64					110										428	2	674	5	253						2,964
Faba Beans	FAB	ak																													0
Fresh Peas	PEF	al			464		557						32								602								191	135	1,982
Grass Seed	GRE	am			30		102				18										2	1									153
Lawn Turf	SOD	an					8				30										142		53						134		367
Lentils	LEN	ao																				53									53
Market Gardens	MKT	ap			11		319	3			6			16			4				326		8		21		27	61	276		1,078
Mint	MNT	aq																					779								779
Monarda	MNA	ar																													0
Nursery	NUR	as			4		85				78										107		27						276		577
Onions	ONI	at			16																3				54						74
Potatoes	POT	au			2,587		1,340				189										960		1,858	13	2,597		8		113		9,665
Safflower	SAF	av																													0
Seed Potatoes	POE	aw																							255						255
Small Fruit	FRT	ax					1										2				9						4				16
Sugar Beets	SBT	ay			4,645	2	385				1,843	2									3,049		2,895	6	3,925						16,752
Sunflower	SUN	az					91																187	7							285
Sweet Corn	COT	ba			104	11															247				1,383						1,745
Miscellaneous	MIS	bb			85	291	171				251	764					16				271	36	102	36	6			7	1,851	2,671	6,558
Summer Fallow	FAL	bc			20	2,005	167	339	0	0	71	219									144	308	151	658	80			194	164	507	5,026
Total			**781**	**643**	**80,208**	**5,056**	**111,265**	**2,279**	**1,862**	**68**	**49,525**	**12,540**	**4,528**	**2,878**	**426**	**1,080**	**13,055**	**5,372**	**427**	**63**	**57,253**	**4,144**	**81,456**	**3,149**	**31,109**	**1,450**	**6,991**	**6,911**	**27,374**	**7,740**	**519,632**
Total Assessed Hectares			**1,424**		**85,263**		**113,544**		**1,930**		**62,065**		**7,406**		**1,506**		**18,427**		**490**		**61,398**		**84,605**		**32,559**		**13,902**		**35,115**		**519,632**

*A = Actual Irrigated Area – That area defined within the district's assessment role as "to be irrigated" that Actually received irrigation water.
**N = Not Irrigated – That area defined within the district's assessment role as "to be irrigated" that did Not receive irrigation water.

Prepared by: Alberta Agriculture, Food and Rural Development, Irrigation Branch, Lethbridge.

Table 5. Financial crop production characteristics: irrigation vs. dryland, 1998 ($/hectare).

Item		Dryland	Irrigation	Intensity Factor**
A.	Gross Return	305.19	964.85	3.2
B.	Variable Costs	203.54	570.49	2.8
C.	Capital Costs	107.32	292.92	2.7
D.	Cash Costs (B+C- Unpaid Labour-Depreciation	246.01	654.38	2.7
E.	Total Production Costs (B+C)	310.85	863.41	2.8
	Gross Margin* (A-D)	59.18	310.46	5.2
	Return to Unpaid Labour (A-E+Un-paid Labour)	16.31	169.09	10.4
	Return to Investment (A-E+Interest Paid)	13.64	160.25	11.8
	Percent Return to Investment	0.74%	4.09%	5.5
	Return to Equity (A-E)	-5.66	101.44	
	Total Investment ($/hectare)	1,840.72	3,919.39	2.1
	Total Labour (hours/hectare/year)	3.01	10.75	3.6

* Approximately equivalent to value-added; the return to land, labour, capital and management.
** Irrigation/Dryland
Source: Tables 2 and 3.

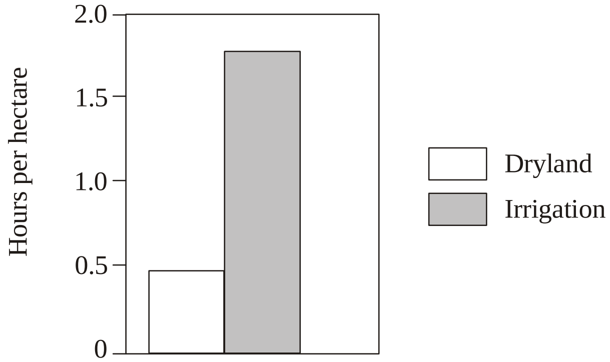

Figure 3. Labour requirements: Irrigation vs. dryland - southern Alberta, 1999.

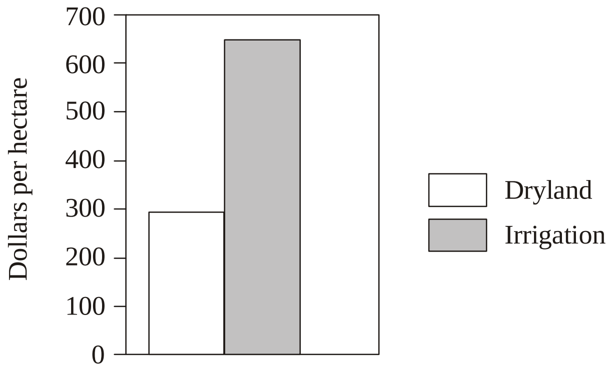

Figure 4. Investment requirements: Irrigation vs. dryland - southern Alberta, 1999.

At the same time, there is a marked increase in the extent to which on-farm production is diversified, particularly into beef operations. Table 6 indicates that nearly 60 percent of all Alberta beef is fattened in the irrigated area of southern Alberta. The ten largest feedlots in southern Alberta alone fatten more than 40 percent of all finished cattle. Beef feedlots in southern Alberta also tend to be larger than elsewhere in the province. Direct employment by feedlots is also very significant, averaging approximately one person per 1000 head of capacity (Fig. 5).

Table 6. Major beef feedlot operations in Alberta, by region, 1999.

Operations*	Number	Capacity**	Average Size	Employment***	% Alberta
Southern Alberta Irrigation	**27**	**462,000**	**17,111**	**462**	**57.3**
Top 10 Feedlots	10	334,000	33,400	334	41.4
Other Feedlots	17	128,000	7,529	128	15.9
Other Alberta:	**33**	**344,000**	**10,424**	**344**	**42.7**
Top 10 Feedlots	10	168,000	16,800	168	20.8
Other Feedlots	23	176,000	7,652	176	21.8
Alberta Total	**60**	**806,000**	**13,433**	**806**	**100**
Top 10 Feedlots	10	351,000	35,100		

* All of the feedlots immediately south of Calgary, i.e. Okotoks, Nanton and High River are not considered in the "irrigation umbrella". (Identical to that of the Agri-Processing analysis – see following). Everything east of Calgary, on the other hand (like Strathmore, Bassano, Carseland) is considered within the "irrigation umbrella".
** One-time capacities.
*** Very approximate. Assumes one FTE per 1000 head capacity.
Source: ACFA (1995, 1996).

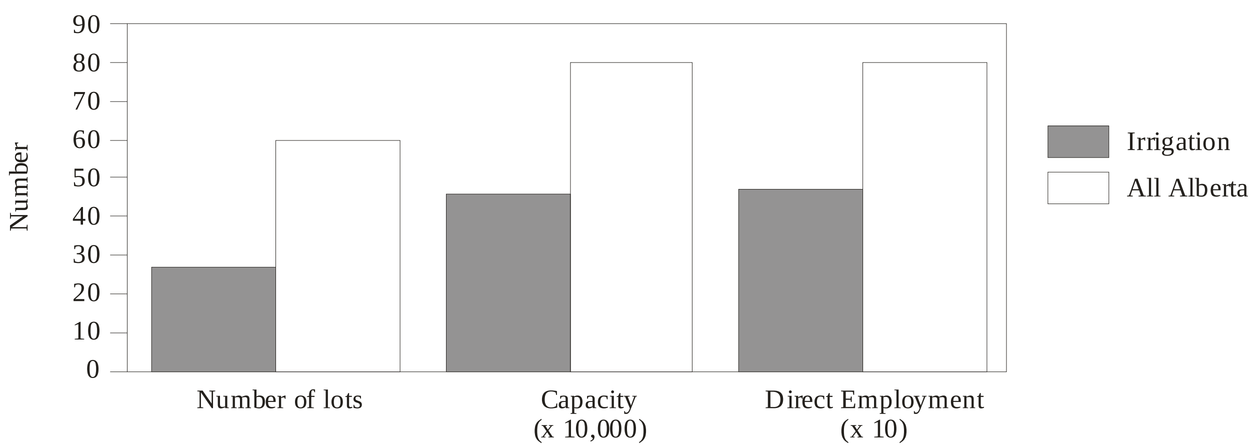

Figure 5. Beef Feedlots: Irrigation areas and all Alberta, 1999.

The net result is that the economic role of irrigated agriculture in Alberta is much greater than its area or farm numbers would suggest. Although the area is only represented by about 8 percent of Alberta farmers and 5 percent of the cropland (Table 1), irrigated agriculture generates more than 14 percent of farm cash receipts, about 11 percent of the agricultural value-added, and 19 percent of the direct agricultural employment in the province (Table 7; Fig. 6).

Table 7. Alberta farm cash receipts and value-added, irrigated and other Alberta, average 1994-1998 ($/thousands).

Item	Farm Cash Receipts*					Value-Added**				
	Alberta	North	S. Dry	S. Irrigated	% Irrigation	Alberta	North	S. Dry	S. Irrigated	% Irrigation
Livestock/Products	**3,314,275**	**2,271,463**	**480,479**	**562,333**	**17.0**	**734,922**	**539,085**	**101,184**	**94,652**	**12.9**
Cattle and Calves	2,408,263	1,609,442	357,868	440,953	18.3	312,568	231,921	41,799	38,848	12.4
Hogs	379,099	270,942	56,031	52,126	13.8	242,585	173,376	35,854	33,355	13.8
Sheep and Lambs	14,444	9,211	2,403	2,830	19.6	-3,073	-1,943	-519	-611	19.9
Dairy	288,505	225,034	20,311	43,160	15.0	91,600	71,448	6,449	13,703	15.0
Poultry and Eggs	169,822	114,851	39,229	15,742	9.3	69,169	46,779	15,978	6,412	9.3
Honey	21,918	19,726	0	2,192	10.0	10,795	9,715	0	1,079	10.0
Other	32,224	22,257	4,637	5,330	16.5	11,278	7,790	1,623	1,865	16.5
Field Crops	**2,605,210**	**1,959,118**	**357,956**	**288,136**	**11.1**	**1,573,488**	**1,226,996**	**188,392**	**158,100**	**10.0**
Total Crops and Livestock	**5,919,485**	**4,230,581**	**838,435**	**850,469**	**14.4**	**2,308,410**	**1,766,081**	**289,576**	**252,753**	**10.9**

* Market receipts. Excludes $234 million in miscellaneous transfer payments.

** Value-added = Farm cash receipts less intermediate costs. Similar to Gross Domestic Product (GDP) at factor cost.
Intermediate costs include: seed, fertilizer, chemicals, fuel, irrigation fuel, building and machine maintenance and repairs, utilities and overhead, custom work, feed, livestock replacement, veterinary and medicine costs, supplements, trucking, marketing and commissions.
Value-added = residual costs, including operating interest, wages, unpaid labour, taxes, rent, depreciation, capital interest and operating surplus adjustments.

Sources: Russell et al. (1993). AAFRD (1999c)

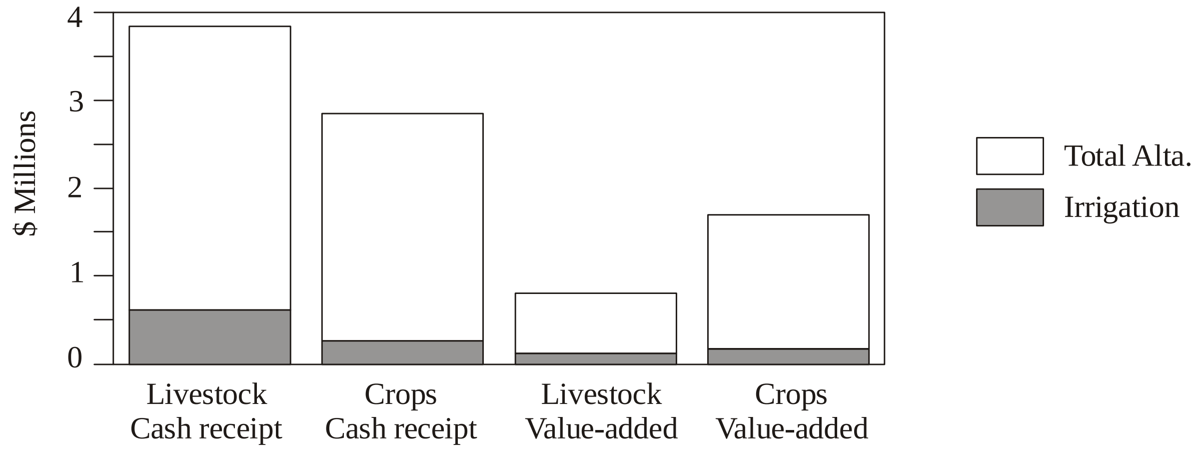

Figure 6. Farm cash receipts and value-added: Irrigation areas and all Alberta, 1994 to 1998 averages.

Farm Supply Implications (Backward Linkages)

More intensive irrigated agricultural production generates an increase in input requirements: fertilizer, pesticides, machinery, equipment, center pivots, related services, and so on. For example, there were a reported 680 people employed in the Lethbridge area manufacturing agricultural and related machinery These backward "linkages" are indirect economic activities that ripple throughout the local economy to generate additional employment and incomes. The absolute size of this ripple-effect depends upon: 1) agricultural production intensities; 2) technological sophistication; 3) the level of inter-industry interdependencies; and 3) the extent of trade "leakages". The latter are defined as imports (the most important and often the only leakage), withdrawals from inventory, and government production. If industrial or commodity production has a high import content, the spin-offs (and benefits) are reduced accordingly. (At the same time, these values are also a function of how an "industry" is defined. As the level of aggregation increases, the absolute size of the respective multipliers typically increases also.)

The relative size of these backward-linked economic activities is quantified using "multipliers". Multipliers are derived from inter-industry relationships of production activities that describe how much output each industry bought from and sold to other industries in the economy. The multiplier provides the tool whereby the total impact of an activity on the economy - on income, employment, gross domestic product (GDP), and gross output can be measured.

Conventional economic multipliers measure indirect impacts[2] only through backward linkages. These are generally presented as total (absolute) output multipliers, with and without leakages[3] (Tables 8a and 8b). Tables 8a and 8b highlight four points.

- The current gross output multiplier for the agricultural sector in Alberta is (in terms of a change in final demand) in the range of 2.5 to 2.7, climbing gradually with time. This is generally characteristic of both irrigated agriculture (Kulshreshtha et al. 1993) and dryland agriculture, although there are significant differences between sub-sectors within the agriculture industry (Manning and Anderson 1978; MAA 1978)

- The accompanying GDP (or value-added) multiplier is between 0.8 and 1.0; the income multiplier is between 0.45 and 0.55; the employment multiplier is about 0.3 (per $10,000 change in final demand); and the import multiplier is about 0.33. This means that if the irrigation sector produces $1.1 B worth of produce (Table 7) and ships $800 million to various final demand sectors, backward technological linkages dictate a corresponding expansion in all other linked industries. Thus, it will be found that in order to meet these irrigation requirements, all industries, including irrigation, must increase their output to, say $2 B, which generates a total income in the region of, say, $400 million. This would imply a conventional output multiplier of $2 B/$800 M = 2.5. The conventional GDP and income multipliers would be $800 M/$800M = 1.0 and $400 M/$800 M = 0.5, respectively.

- Section 4 of this report simulates the expected change in agricultural sales (not the change in final demand). For ease of calculation, the following estimates are employed.
  - Backward agricultural supply sales levels = direct agricultural sales levels (i.e. 1:1).
  - Backward agricultural supply value-added % = (forward) agricultural processing value-added, i.e. about 25 percent.
  - Backward agricultural supply employment = 1 person per $100,000 in value-added.

- Table 8 also highlights to what extent existing import requirements into Alberta (a leakage) presently reduce the respective multipliers. If an industry has a much higher multiplier without leakages than it does with leakages, this means that any increase in final demand is largely satisfied by out-of-province suppliers rather than by domestic (Alberta) production. For irrigated agriculture, the conventional import multiplier is presently about 0.33 (Kulshreshtha et al. 1993).

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[2] Indirect impacts are also sometimes referred to as “secondary” impacts or spin-offs.

[3] A “total” economic multiplier is also called a “closed” or Type II multiplier. This is synonymous with what is sometimes called a full inter-industry final demand multiplier. Employing this method, households are included as an “industry”, thus incorporating both the industry effect and the induced income effect in the calculation of the multiplier. That is to say, when an industry increases its output, it must obtain more inputs which are provided by other industries. The expansion of these industries means increased demands are placed on their suppliers, and so on through a chain of interdependent industries. This is referred to as the industry effect. In addition, as industries increase their production, they increase staff and thus pay more wages. This increased income in the hands of consumers can generate additional consumption and, thus, further increase industry outputs. This is referred to as the income effect. (The alternative is a simple, open, Type I multiplier.) The denominator in these ratios is always the final demand change for the industry in question.

Table 8a. Total final demand multipliers, existing Alberta situation (absolute form, with leakages), by major industry.

Industry	Household Income	GDP at Factor Cost	Employment	Gross Output
1. Agriculture	0.546	0.995	0.287	2.692
2. Forestry	0.614	1.018	0.150	2.551
3. Fishing, Hunting and Trapping	10368	1.922	0.394	5.308
4. Mines, Quarries and Oil Wells	0.344	0.985	0.079	1.982
5. Manufacturing	0.514	0.956	0.159	2.866
6. Construction	0.666	0.966	0.194	2.672
7. Trade	1.001	1.318	0.408	2.971
8. Transportation and Storage	0.653	1.075	0.221	2.597
9. Communications	0.766	1.247	0.220	2.513
10. Utilities	0.573	1.495	0.117	2.231
11. Finance, Insurance and Real Estate	0.559	1.135	0.094	2.101
12. Comm., Bus. and Personal Services	0.933	1.276	0.380	2.888
13. Dummy Industry I	0.304	0.460	0.114	2.193
14. Dummy Industry II	0.443	0.686	0.159	2.636
15. Transportation Margins	0.276	0.455	0.093	2.095
16. Households	0.370	0.602	0.125	2.282

Table 8b. Total final demand multipliers, potential Alberta situation (absolute form, without leakages), by major industry.

Industry	Household Income	GDP at Factor Cost	Employment	Gross Output
1. Agriculture	1.028	1.857	0.452	4.970
2. Forestry	1.039	1.757	0.288	4.450
3. Fishing, Hunting and Trapping	2.179	3.345	0.659	8.978
4. Mines, Quarries and Oil Wells	0.568	1.390	0.147	2.969
5. Manufacturing	0.984	1.797	0.314	5.062
6. Construction	1.159	1.836	0.355	4.954
7. Trade	1.387	1.995	0.534	4.702
8. Transportation and Storage	1.072	1.804	0.359	4.457
9. Communications	10.86	1.806	0.325	3.951
10. Utilities	0.790	1.876	0.187	3.198
11. Finance, Insurance and Real Estate	0.766	1.497	0.161	3.018
12. Comm., Bus. And Personal Services	1.321	1.953	0.508	4.625
13. Dummy Industry I	1.043	1.778	0.355	5.762
14. Dummy Industry II	1.043	1.706	0.361	5.248
15. Transportation Margins	1.070	1.805	0.358	5.447
16. Households	0.768	1.297	0.255	4.070

Source: Alberta Bureau of Statistics/Alberta Treasury (1991).

In general, these indirect impacts should not be considered when evaluating alternative public investment options because similarly defined multipliers are similar for any given economy at any point in time. Supposed differences can often be traced to methodological differences (definitions, time-frame, industry or spatial resolution). Multipliers help quantify the total regional impact of irrigation on the Alberta economy.

Agri-Processing (Forward Linkages)

Forward-linked activities are defined as all production activity generated downstream of primary, on-farm agricultural production. They include processing activities, local transpiration, storage, and so on. In agri-processing, once again, the actual "value-added" component includes the additional return to labor, management and capital (wages, salaries and a return to the investment).[4]

A profile of Alberta's rapidly growing agricultural processing industry is provided in Table 9. According to these data, in 1996 the agri-processing industry in Alberta was already a $6.8 billion business with nearly 18,000 employees. Table 10 decomposes and updates these data into irrigation-dependent agri-processing and other Alberta processing (although the database is slightly different. Observations are as follows.

- Province-wide, the estimated value of all shipments is now (1999) almost $9 billion, of which an estimated $2.6 billion is value-added by the agri-processing industry. This compares to farm cash receipts of some $5.9 billion (estimate) and an on-farm value added of approximately $2.3 billion. Agri-processing employment is estimated to now exceed 22,000 – already one-quarter as many people as employed in all of primary agriculture on some 59,000 farms.

- Agri-processing in Alberta has a relatively large meat and poultry component (33%), followed by beverage products (11%), dairy and vegetable products (each at 9%) and flour products (8%).[5]

- Agri-processing in Alberta is heavily concentrated in the irrigation-dependent south. In terms of value-added, about 46 percent of the meat and poultry processing and 58 percent of the vegetable and vegetable product processing is done in the irrigated south. The overall percentage is 26 percent (Table 10). The comparable figures in primary agriculture are 12.9% and 10.0% for livestock and crops, respectively (Table 7).

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[4] More formally: Gross value-added includes compensation to employee labour and management, interest, rent, profits, taxes, and reserves for depreciation. Net value-added excludes depreciation. The Gross National Product (GNP) is the total gross value-added by all the productive enterprises in the economy (Dictionary of Economics).

[5] Meat/Poultry & Products = federally inspected meat plants, provincially inspected meat plants, other meat processors, poultry products, egg and egg products, and animal by-products.
Beverage Products = non-alcoholic and alcoholic beverages.
Feed Products = processed forages, feed, specialty feeds, oats and pet foods.
Flour, Breads and Pasta = grain and cereal products, bakery products and pasta/pasta products.
Vegetables and Related Products = vegetables and vegetable products, potato processing, sugar beet processing, and specialty crops.
Oilseeds and Edible Oil Products = canola oil, meal and products.
Other Food Products = confections, snack foods, fish products, honey and by-products, specialty foods and miscellaneous food processing.

Table 9. Alberta's agricultural processing industry - 1991, 1996 and 1997.

Product Category	1991			1996**					1997		
	Employees No.	Value of Shipments $M	Value-Added* $M	No. of Operations	Employee No.	Value of Shipments $M	Value-Added* $M	Employees No.	Value of Shipment s $M	Int. Exports $M 1997 Data
Meat & Poultry Products	5,392	2311.5	419.3	80	8,412	3,344.3	756.0		3,515.2	963.9
Dairy Products	2,532	454.9	65.8	24	1,106	696.2	197.6		613.1	17.3
Beverage Products	2,017	442.2	253.3	19	1.472	550.3	258.7		650.3	48.3
Feed Products	1,250	317.2	59.7	67	1,479	494.7	132.9		466.7	139.9
Fruit & Vegetables	600	113.0	36.5	13	600	150.0	48.8		151.0	11.1
Other Food Products	5,270	1099.0	421.6	102	4,527	1,584.6	514.6			461.6
Canola Oil, Meal & Products	404	273.7	50.9	6	400	272.0	50.6			210.2
Beet Sugar Industry				1	140	55.0	17.0			
Flour, Cereals, Bread, Pasta				46	1,374	276.2	104.2			
Potato Chip, etc. Industry				5	800	390.0	120.0			251.4
Other Food Industries	4,866	825.3	370.7	44	1,813	591.4	222.8			
Total	**17,061**	**4,737.8**	**1,256.2**	**305**	**17,596**	**6,820.1**	**1,908.6**	**19,300**	**7,249.3**	**1,642.1**

* Value-added = the value of shipments of goods manufactured, less the cost of materials and supplies (i.e essentially salaries, wages and a return to capital).
** Includes some author estimates employing fixed I/O ratios and value-added ratios.

Sources: Statistics Canada (1997); AAFRD (1999b).

Table 10. Alberta's agri-processing industry in irrigation-dependent areas and all Alberta, 1999.

Category*	Establishments	Employment FTE's**	$M Shipments	$M Value-Added
Irrigation –Dependent:				
Meat/Poultry and Products	16	4,400	1,749	395.4
Dairy Products	2	60	38	10.8
Beverage Products	4	160	60	28.2
Feed Products	21	330	110	29.5
Flour, Cereals and Pastas	7	190	38	14.3
Fruit and Fruit Products	2	20	5	1.6
Vegetables and Vegetable Products	26	1,270	446	133.8
Oilseeds and Edible Oil Products	2	285	109	20.3
Other Food Products	9	310	111	41.8
Total	**89**	**7,025**	**2,666**	**675.8**
All Alberta:				
Meat/Poultry and Products	158	9,540	3,793	857.6
Dairy Products	35	1,240	781	221.6
Beverage Products	38	1,600	598	281.1
Feed Products	76	1,570	525	141.0
Flour, Cereals and Pastas	28	2,820	567	213.9
Fruit and Fruit Products	14	180	45	14.6
Vegetables and Vegetable Products	67	2,400	764	229.2
Oilseeds and Edible Oil Products	8	605	326	60.6
Other Food Products	164	2,720	1,540	580.1
Total	**588**	**22,625**	**8,939**	**2,599.9**
% Irrigation/All Alberta:				
Meat/Poultry Products	10	46	46	46
Vegetables	39	53	58	58
Average	**15**	**31**	**30**	**26**
Adjusted Totals:***				
Irrigation Dependent		**5,971**	**2,266**	**574**
Dryland		**13,260**	**5,332**	**1,635**
Alberta Total		**19,231**	**7,598**	**2,210**

* Categories are not identical to those used by Statistics Canada, Census of Manufacturing (see Table 9).
** Authors estimates based on average establishment size, by size category.
*** Adjusted downward 15% to approximate "official" agri-processing estimates to calculate the respective multipliers (see text).
Source: AAFRD (1999b).

- A more detailed breakdown of the regional employment figures in agri-processing (Table 11) further highlights the heavy concentration of particular agri-processing activities in the irrigated south. This includes, in particular, federally inspected meat plants (56.8% of province-wide employment), vegetable processing (34.5%), potato processing (75%), sugar beet processing (100%), special crops production (78.3%), canola oil and meal production (59.4%), and snack food manufacture (38.5%). Most of these crop-related agri-processing activities are highly dependent upon nearby irrigated crop production. Much of the meat processing is tied to irrigated forage production and the numerous/large beef feedlots in the region (Fig. 7).

Table 11. Agri-processing employment - Irrigation-dependent and all Alberta, 1999.

Agri-Processing Category	Total Alberta FTE's	S. Irrigation FTE's	S. Irrigation Percent of Total
Meat/Poultry and Products:	**9,540**	**4,400**	**46.1**
Meat (Federally Inspected)	7,130	4,050	56.8
Meat (Provincially Inspected)	580	70	12.1
Meat (Other Processors)	560	20	3.6
Poultry Products	770	200	26.0
Egg and Egg Products	200	10	5.0
Animal By-Products	300	50	16.7
Dairy Products:	**1,240**	**60**	**4.8**
Beverage Products:	**1,600**	**160**	**10.0**
Non-Alcoholic Beverages	1,200	110	9.2
Alcoholic Beverages	400	50	12.5
Feed Products:	**1,570**	**330**	**21.0**
Processed Forages	450	120	26.7
Feed and Specialty Feeds	790	190	24.1
Oats	80	0	0.0
Pet Foods	250	20	8.0
Flour, Breads and Pastas:	**2,820**	**190**	**6.7**
Grains and Cereal Products	570	110	19.3
Bakery Products	2,000	30	1.5
Pasta and Pasta Products	250	50	20.0
Fruit and Fruit Products:	**180**	**20**	**11.1**
Vegetables and Related Products:	**2,400**	**1,270**	**52.9**
Vegetables and Vegetable Products	1,420	490	34.5
Potato Processing	600	450	75.0
Sugar Beet Processing	150	150	100.0
Special Crops	230	180	78.3
Oilseeds and Edible Oil Products:	**605**	**285**	**47.1**
Canola Oil, Meal and Products	605	285	47.1
Other Food Products:	**4,720**	**310**	**6.6**
Confections	190	0	0.0
Snack Foods	390	50	38.5
Fish Products	100	10	10.0
Honey and By-Products	290	20	6.9
Specialty Foods	1,220	100	8.2
Miscellaneous Food Processing	530	30	5.7
TOTAL	**22,625**	**7,025**	**31.0**

Source: Table 10 (author's estimates, unadjusted).

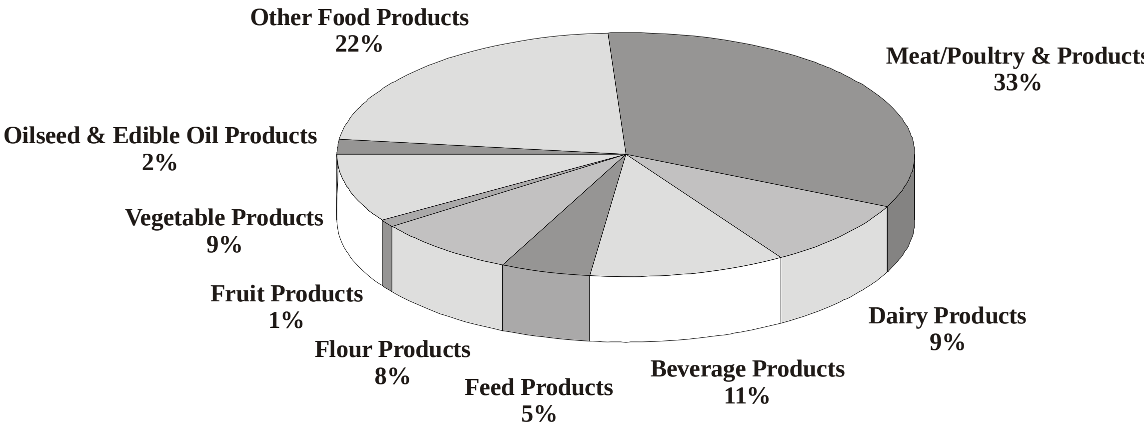

Figure 7. Sub-sectors in the Alberta agri-processing industry, 1999.

It is particularly important to note the growing importance of the agri-processing industry in irrigation-dependent southern Alberta (Table 12).

Table 12. Comparison of impacts of agri-processing in irrigated and non-irrigated areas.

Criteria	Irrigation Area	Other Alberta	All Alberta
Ratio: $ Agri-Processing Shipments/$Farm Receipts	2.66	1.05	1.38
Ratio: $ Agri-Processing V.A./Farm V.A.	2.27	0.80	0.94

Sources: Tables 7 and 10 (adjusted).

These ratios are indicative of how extensive and sophisticated the agri-processing sector in Alberta has already become. The larger the ratio, the more sophisticated the economy. Note, in particular, that the ratios for the irrigated south are more than twice as large as for the rest of Alberta.

The specific benefit of value-added agricultural production in the province is that it allows Alberta residents to capture additional incomes from primary production. Instead of exporting raw materials (as was done historically), processed agricultural products can both substitute for previously imported agricultural-based commodities and be exported, leaving more of the incremental benefits in Alberta.

The differences between backward linkages and forward linkages is also noteworthy when considering a sustainable growth strategy for the agricultural sector. Backward linkages are largely determined by prevailing industrial technologies. These are relatively fixed at any point in time and fairly similar (intensities aside) for both irrigated and dryland crop and livestock production (Tables 2, 3 and 5). Thus, conventional economic multipliers that track backward linkages also tend to be fairly similar for different agricultural enterprises, and even for different industries. This is not true of forward linkages. The magnitude of forward linkages depends upon a large number of socio-economic variables, some of which can be affected by the political decision-making process. The regional-provincial variables that make southern Alberta particularly attractive as an agri-industrial location include (CWRA et al 1999):

- adequate water for the industrial process itself;
- unique source of nearby raw material (crop or livestock production);
- reliable , dependable, high quality, and relatively low cost raw material;
- strong institutions and "people-support" – highly skilled and highly motivated people (farmers, irrigation district personnel, etc.);
- focus on the latest technology at the farm level, as well as at the industrial level (thus, lower units costs, etc.);
- focus on the environment and long-term sustainability (thus reduced waste, high recovery rates, recycling, etc.);
- excellent physical infrastructure(roads, power, natural gas, water, etc.);
- excellent social infrastructure (good schools, hospitals, recreation centers, access to recreational opportunities, religious freedom, etc.);
- suitable location with respect to markets (Pacific NW, etc.); and
- the overall Alberta Advantage (relatively low personal and corporate taxes; relatively low property taxes; no sales tax; generally business-friendly; etc.).

There is no upper limit to agri-industrial development, and hence, no rigid upper limit on the magnitude of the "multipliers" associated with these forward linkages. Considerable more growth is possible if the prerequisites (immediately above) remain in place.

This conceptual framework also acknowledges that the economic development process in Alberta is now largely market-driven and often trans-national. Primary agriculture in Alberta, therefore, generally responds to agri-industrial requirements – not the other way around.

Complementary Benefits and Synergies

Irrigation is integral to the entire socio-economic fabric of southern Alberta. It affects the quality of life of virtually every resident in the Palliser Triangle. Yet it has become such an accepted way-of-life that many of the day-to-day benefits of irrigation are simply taken for granted, particularly those regarding the basic ambiance created by the overall irrigation network. Aside from agriculture-related activities, there are very real direct benefits associated with: 1) environmental sustainability; 2) industrial-municipal water requirements; 3) recreation; 4) wildlife; 5) fishing; and 6) tourism.

Environmental Sustainability (Byrne 1999; MAA 1989) Irrigation greatly affects bio-mass production, the local climate, long-term soil productivity, and water and air quality (AIPA 1993):

> *"Irrigation makes possible the growth of trees, small fruits, flowers, and vegetables…One cannot over-estimate the importance of these factors in the everyday existence of a strip of territory which was, at one time, prior to irrigation, treeless, waterless, drought-scorched prairie."*

Commercial bio-mass (agricultural crop production) increases by at least 2.5 times.[6] This denser green cover reduces the average daily summer temperature by four to five percent (say 1 degree C) and modulates day and night temperature fluctuations. Without this additional vegetation, there would be more rapid heat absorption and radiation making the temperature fluctuations similar to desert conditions. In turn, with less vegetation and cloud formation, less rain would create an even more arid environment. With more vegetation, there is also less erosion of the fertile topsoil and, thus, reduced silting. Additionally, the groundwater table is enhanced, thus maintaining local potable water sources. (New Indian Press 1999). For local residents, at least, these direct and very real benefits are almost incalculable.

More intense resource use, however, naturally exposes the resource base to more environmental disruption. Water quality (especially in waters impacted by feedlot runoff and soluble nitrates), potential soil erosion (especially wind), soil pH, and soil salinity are four principal concerns that require constant monitoring.

Industrial-Municipal. Irrigation is also linked to industry and communities through both a) the provision of industrial and potable water; and b) waste disposal through irrigation.

One of the most important variables in locating industries is an ample supply of good quality water for the industrial process itself. Almost equally important is the opportunity to efficiently dispose of industrial waste. The sophisticated irrigation systems in southern Alberta already accommodate and support both of these industrial requirements. Even the City of Lethbridge is now (1999) investigating the possibility of waste disposal through irrigation.

In terms of municipal requirements, about 42,000 people in 47 southern Alberta communities now rely on irrigation districts for their municipal water supply (AENV 1989) (Table 13). This is about two-thirds as much potable water as is required by the City of Lethbridge. With the introduction of increasingly more underground piping for irrigation purposes, even more communities will likely tap into the convenience and efficiency of these pressurized systems. For example, this is currently (1999) being considered by the Town of Coaldale.

Recreation. "Recreation" generally refers to the recreational activities of Alberta residents. Recreational activities that are tied to the 89 major water bodies in the irrigation area include: 1) day-use recreation; 2) overnight camping/recreation; 3) observing wildlife; 4) hunting; and 5) fishing. In addition to fishing, water-based activities include boating, swimming, water skiing and motor skiing. There are three provincial parks that are closely tied to irrigation district operations, and four additional nearby provincial parks. These seven parks contain 895 camping sites and numerous day use facilities. Annual-user days total about 200,000; annual camping user-nights total about 100,000.

Alberta Environment also administers 13 day-use recreation sites on irrigation reservoirs or along canals that accommodate perhaps 100,000 more recreational user-days per year. In addition, there are some 26 municipal parks and recreation areas in the region that provide for about another 100,000 recreational user-days per year.

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[6] Based on wheat yields, adjusted for qualitative differences, calculated from Tables 2 and 3. This is AAFRD's proxy variable to track long-term land productivity.

Table 13. Municipal, industrial, recreational, and other users in the irrigation districts, 1999.

Irrigation District	Area* (km^2)	Municipal Users		No. of Major Industrial Users	Number of Other Users			Recreational Characteristics			
		Number Commun.	Population 1986		Livestock (major)	Golf Courses	Other (major)	Size (km^2)	Shoreline (km)	Prov. Parks	Other Sites**
Eastern Irrigation District	1,135.5	10	11,763	3	n/a	3	n/a	266.8	648	1	1
Western Irrigation District	351.2	5	4,590	2	6	0	6	41.4	90		2
Taber Irrigation District	325.6			n/a	n/a	n/a	n/a	15.5	45		
Bow River Irrigation District (Alberta Environment)	852.6	11	1,422	2	217	0	15	38.9 75.1	98 122	1	2
St. Mary Irrigation District (Alberta Environment)	1,460.0	11	18,021	3	40	3	43	114.0 75.1	327 122		8
Lethbridge Northern Irrigation District	620.6	7	2,397	2	150	0	10	18.1	29	1	5
Raymond Irrig. District – Within Raymond Irrig. Dist.-Downstream	184.2	0		n/a	n/a	n/a	n/a	5.2 137.3	16 200		
Magrath Irrigation District	74.1	0		n/a	n/a	n/a	n/a	0	0		
United, Mountain View, Leavitt, & Aetna Irrigation District	187.5	3	3,740	0	0	0	0	11.3	26		3
Ross Creek Irrigation District	4.9	0		0	0	0	2	2.6	5		1
Total	**5,196.2**	**47**	**41,933**	**12**	**413**	**6**	**76**	**801.3**	**1,728**	**3**	**22**

* Based upon assessed area.
**Developed sites with facilities.
n/a = not applicable
Sources: AENV (1989); Berrien Environmental Inc. (1993), McNaughton (1993.

Wildlife. The linear open canal systems (nearly 9,000 km) afford significant habitat for pheasants and other upland game birds during the summer and fall. More than 60 percent of Alberta's pheasant population exists within the 13 irrigation districts. Provincially, more than one-half of the total pheasant harvest occurs within the irrigation district boundaries.

Without offsetting mitigation measures, canal rehabilitation to improve water use efficiencies is estimated to reduce previously enhanced wildlife populations by about 10 percent (UMA 1993.

Fishing. Some 20 irrigation district reservoirs are also relatively good fishing areas, especially for Whitefish, Northern Pike and Walleye. The number of angler days at irrigation reservoirs is estimated to be about 250,000 days per year (Berrien Environmental Inc. 1993). The total annual commercial yield is typically about 300 tonnes, valued at about $500,000.

Tourism. "Tourism" generally refers to recreational use by out-of-province and international visitors. In the early 1990s, it was estimated that out-of-province visitors spent about $40 M/year in southern Alberta, with about $2 M of this being spent on water-based recreation in the irrigation region (McNaughton 1993).

Other Water Uses of Irrigation Infrastructure. There are literally hundreds of other water users that benefit from irrigation infrastructure, including, in particular: 1) beef feedlots; 2) livestock dugouts; 3) golf courses; 4) oil companies; 5) farm domestic users; 6) market gardens, tree farms and sod farms; and 7) at least 15 co-operative farm water supply projects (Table 12).

Measurable Direct Benefits and Regional Impacts. With respect to recreation, the net benefit of irrigation to the region is essentially that of improved access to water-based recreational facilities. Facilities with specific desirable attributes are closer to the user. Irrigation reservoirs are particularly important in southern Alberta because there are so few natural standing water bodies in the region. Directly comparable alternatives only exist outside the region in Montana, the foothills region, and northern Alberta. The general magnitude of this benefit is measured by the time and money that is saved by not having to travel to a similar more distant recreation site. The approximate value of this benefit is estimated to be:

Average Value/Trip/Person	=	$4.00[7]
Approximate User-Days/Year	=	400,000
Site Recreational Benefit	=	$1.6 million/year

The monetary impact of these activities on the regional economy, however, is much greater (Table 14) (McNaughton 1993).

To put this into context, the total value is equal to about 3.4 percent of irrigated farm cash receipts (Table 7), or about 1 percent of the value of irrigation-dependent agri-processing (Table 10).

[7] Approximate. Assumed to be about twice the value (to reflect twice the distance) calculated in AENV and Adamowicz (1995).

Table 14. Economic impact of recreational activities based within irrigation infrastructure.

Activity	No. Days/Yr	Expenditures/Day	Total
Day Use/Campers	400,000	$44.44	$17.8 M
Observing Wildlife	270,000	$16.47	$ 4.5 M
Fishing	250,000	$13.89	$ 3.5 M
Hunting	135,000	$20.99	$ 2.8 M
TOTAL			**$28.6 M**

FUTURE OPPORTUNITIES

Introduction

During the 1970s, agricultural policy in Alberta emphasized the need to increase traditional crop and livestock production by both expanding the cropped area/basic herd and increasing yields. This was still basically a raw material export strategy. To enhance and stabilize farm incomes during the 1980s, the emphasis switched to on-farm crop and livestock diversification. Once again, this was usually unprocessed agricultural production destined for the export market. Then in the 1990s yet another agricultural development strategy emerged that focused on adding value[8], a strategy aimed at generating more income and employment in the agricultural and agri-processing sectors. This strategy focuses on net income rather than gross revenue.

Irrespective of the policy focus during the last 30 years, the irrigation sector has been able to thrive:

- During the twenty-year period from 1970 to1990, the irrigated area approximately doubled, climbing from about 240,000 hectares to nearly 486,000 hectares.

- During the twenty-year period from 1978 to 1998, both the number and area of irrigated "specialty" crops increased dramatically. The number of crops increased from maybe a dozen to more than fifty[9], and the total area in specialty crops increased by about 20,000 hectares. In the irrigated area, special crops make up 13 percent of the cropped area while in the rest of Alberta the corresponding percentage is 2.5 percent, most of which is dry peas. About 20 percent (61,000 out of 283,000 hectares) of all Alberta "specialty crops" are grown within the 13 irrigation districts.

- During the 1990s, the growth in agri-processing in the irrigated south was particularly strong, climbing from a sales level of about $1 billion/annum (Kulshreshtha et al. 1993) to about $2.5 billion/annum at the end of the decade. Perhaps even more impressive is the

[8] Recall again that value-added is essentially the return to all the incremental land, labour, management and capital requirements utilized at any stage of the production process. Approximately the same as the underlying calculation of the Gross Domestic Product; the incremental value upon which the GST is applied. The basic component of value-added is wages and salaries, i.e. gross income.

[9] Specialty crops include (in descending order of area): sugar beets, dry beans, potatoes, alfalfa seed, dry peas, fresh peas, sweet corn, lentils, market gardens, mint, nursery crops, lawn turf, carrots, sunflower, small fruits, caraway seed, dill, grass seed, onions and small fruit. The 1998-1999 Special Crops Directory (AAFRD, Edmonton, 1999) lists seven major special crops and 33 minor special crops.

fact that the relative importance of irrigation-dependent agri-processing continued to climb: 23% in 1990; 30% in 1999.

Irrigation, in short, is central to the successful execution of both a provincial crop/livestock diversification strategy and a provincial agricultural strategy that focuses on augmenting value-added industry. Agro-climatic conditions in the irrigated south favor irrigated agricultural diversification into "specialty crops" as many of these crops must have the moisture (with irrigation) and heat units only southern Alberta can provide. At the same time, major considerations in industrial location include: 1) ready access to a stable supply of high-quality raw material; 2) ready access to other production requirements, such as a talented and dedicated labour force and an adequate industrial water supply; and 3) supporting infrastructure and related businesses, as well as a generally business-friendly public/government environment. These complementary strategies are structurally and institutionally linked to one another. This synergy and internal dynamic is a chicken-and-egg phenomenon.

What follows is a brief overview of what is most likely to evolve in the irrigated agri-industrial sector during the next 10 years (2000-2010), assuming the absence of random events or newly introduced growth constraints. It is assumed that final demand (in this case, the raw materials required by agri-processors) generally determines the direction and rate of change in the future.

Projected Agri-Processing

There are a number of ways to project the future development of the agri-processing industry in Alberta and its relationship to irrigated agriculture.

One indication of what might happen in the future is simply to extrapolate the past. This procedure suggests that future growth in the provincial agri-processing sector will likely be between three and five percent per annum, generating the following production levels (Table 15).

Table 15. Projected value of value-added commodity shipments ($B).

Year of Growth Projection	Growth Rate/Year Projection #1*	Growth Rate/Year Projection #2**
2000	7.3	8.7
2005	8.5 (+18%)	11.2 (+56%)
2010	9.8 (+36%)	13.7 (+90%)
Annual Growth Rate	**3.0%/year**	**5.0%/year**

*Based on data for 1984-97. **Based on data for 1992-97.

The slow rate represents the average rate of growth during 1984 to 1997, while the faster rate represents the average rate of growth in the agri-processing sector in the mid-1990's (Fig. 8).

Table 16. Impact of irrigation on agricultural production intensities and agri-processing (value-added), selected States, 1996.

Western United States	Irrigated Land (M ha)	Total Cropland (M ha)	Percent Irrigated Col. 2/3	Value of Ag. Products Sold (US$M)		Value Food/Bev. Shipments*	Ratio Food & Bev. Value of Farm Receipts	Food & Beverage Value-Added US$M	Percent Value-Added/Value of Shipments
				Total	$/ha				
				US$M		US$M	Col. 7/Col. 5		Col. 9/Col. 7
Arizona	0.410	0.517	79.4%	1903	3,682	1689.4	0.9	683.4	40.5%
California	3.526	4.372	80.6%	23032	5,268	49250.4	2.1	20264.8	41.1%
Colorado	1.388	4.253	32.6%	4534	1,065	7771.8	1.7	2918.5	37.6%
Idaho	1.414	2.553	55.4%	3346	1,310	3924.2	1.2	1466.5	37.4%
Kansas	1.095	12.149	9.0%	9207	759	11947.9	1.3	2136.1	17.9%
Montana	0.807	7.134	11.3%	1871	262	495.8	0.3	164.8	33.2%
Nebraska	2.808	8.941	31.4%	9832	1,100	12237.8	1.2	2548.5	20.8%
Nevada	0.310	0.343	90.3%	356	1,038	782.4	2.2	397	50.7%
New Mexico	0.326	0.882	36.9%	1618	1,836	1086.8	0.7	332.5	30.6%
North Dakota	0.073	10.937	0.7%	2869	262	1600.6	0.6	537	33.5%
Oklahoma	0.205	6.007	3.4%	4146	689	3622.2	0.9	1395.8	38.5%
Oregon	0.788	2.139	36.9%	2969	1,389	4901.7	1.7	2064	42.1%
South Dakota	0.139	7.833	1.8%	3570	455	2094.5	0.6	674.4	32.2%
Texas	2.220	15.241	14.6%	13767	904	29452.7	2.1	11777.5	40.0%
Utah	0.490	0.838	58.6%	877	1,048	3115.8	3.6	1031.7	33.1%
Washington	0.690	3.203	21.5%	4768	1,488	9828.2	2.1	3582.2	36.4%
Wyoming	0.696	1.201	57.9%	899	749	307.8	0.3	147.7	48.0%
NW USA (3 states)	**2.892**	**7.895**	**36.6%**	**11083**	**1,404**	**18654.1**	**1.7**	**7112.7**	**38.1%**
West USA (17 states)	**17.385**	**88.543**	**19.6%**	**89564**	**1,011**	**144110**	**1.6**	**52122.4**	**36.2%**

* Food and kindred products. Excludes tobacco.
Source: U.S. Government (1998).

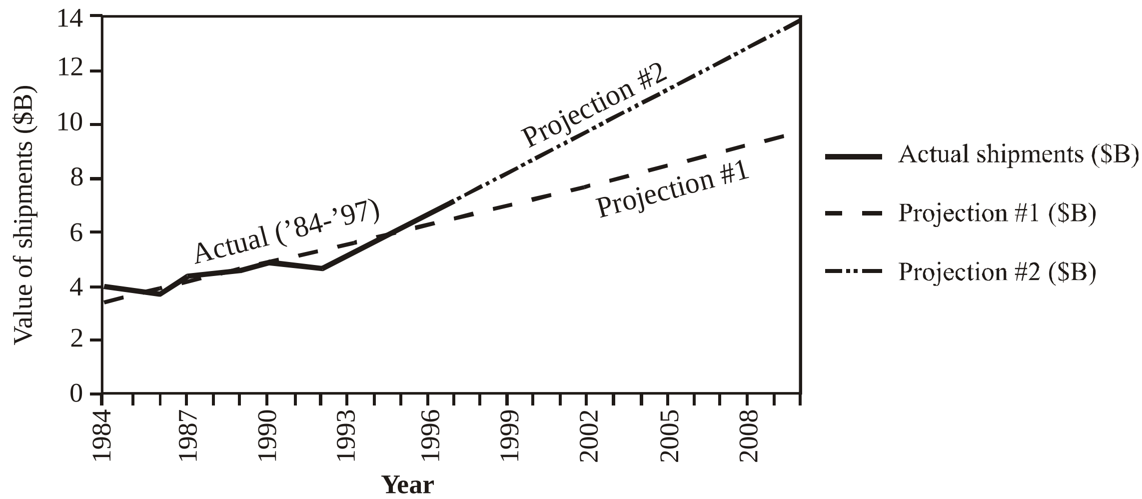

Figure 8. Actual and projected Alberta agri-processing, 1984-2010.

Even if irrigated agriculture was just expected to maintain its existing share of all agri-processing in Alberta in the future (30% as per Table 10), this sub-sector would have to grow 18 to 56 percent by 2005 and 36 to 90 percent by the 2010. These two projections likely bracket real growth rates.

A second way of projecting future growth in the irrigation sector and its attendant implications is to link projected food and beverage shipments to projected farm cash receipts. For example, Alberta Agriculture, Food and Rural Development estimates that the present Alberta Agri-Processing Shipments/Farm Receipts ratio is 1.2 and anticipates that this ratio could climb to 2.0 by 2005 (P. Woloshyn, personal communication; AAFRD 1999). The logic behind this is that Alberta should be able to develop its agri-processing sector to the same ratios as other jurisdictions in Canada.[10] Similar ratios for the western United States (Table 16) are also instructive. The average ratio in the NW USA is 1.7; the average for 17 western states is 1.6. Washington State is 2.1 (similar to B.C. at 2.3); the Dakotas are 0.6 (similar to Manitoba at 0.9); and Montana-Wyoming are 0.3 (identical to Saskatchewan). But what these ratios still disguise is the relative importance of irrigation and dryland in generating this composite ratio. In Alberta, the following is the current condition (Table 17).

Table 17. Comparison of value-adding contribution from the irrigation sector.

Criteria	Irrigation Area	Other Alberta	All Alberta
Ratio: $Agri-Processing Shipments/$Farm Receipts*	2.66	1.05	1.28
Ratio: $Agri-Processing V.A./Farm V.A.	2.27	0.80	0.80

* Calculated on the basis of average farm receipts during the last five years and estimated 1999 agri-processing shipments.
Sources: Section 2.3 and Tables 7 and 10 (adjusted).

[10] The corresponding ratios in various other Canadian provinces in 1998 were: Ontario 3.6; Quebec 2.8; B.C. 2.3; Manitoba 0.9; and Saskatchewan 0.3 (see internal AAFRD data).

Clearly, irrigation-dependent agri-processing augments the overall Shipment/Receipts ratio considerably. Future agri-processing development will be concentrated in the irrigation areas. A second qualification is that the focus is really on value-added rather than shipments. It is value-added that is indicative of employment and income generation in Alberta. Focusing on value-added also facilitates looking at two additional ways to further strengthen agri-processing in Alberta, namely 1) a higher level of product transformation (processing); and 2) an increasingly competitive cost structure , such as lower direct and indirect taxes. This is illustrated in Figures 9 and 10 with respect to canola and beef. The Value Added/Value of Shipments ratios for various jurisdictions also underscore this point. This aggregate ratio is presently about 0.25 in Alberta (Table 10), whereas the Canadian average is about 0.32 (Table 18) and the western U.S. average is about 0.36 (Table 16). On average, even though there may be a processing facility in Alberta, the degree of product transformation is still relatively limited.

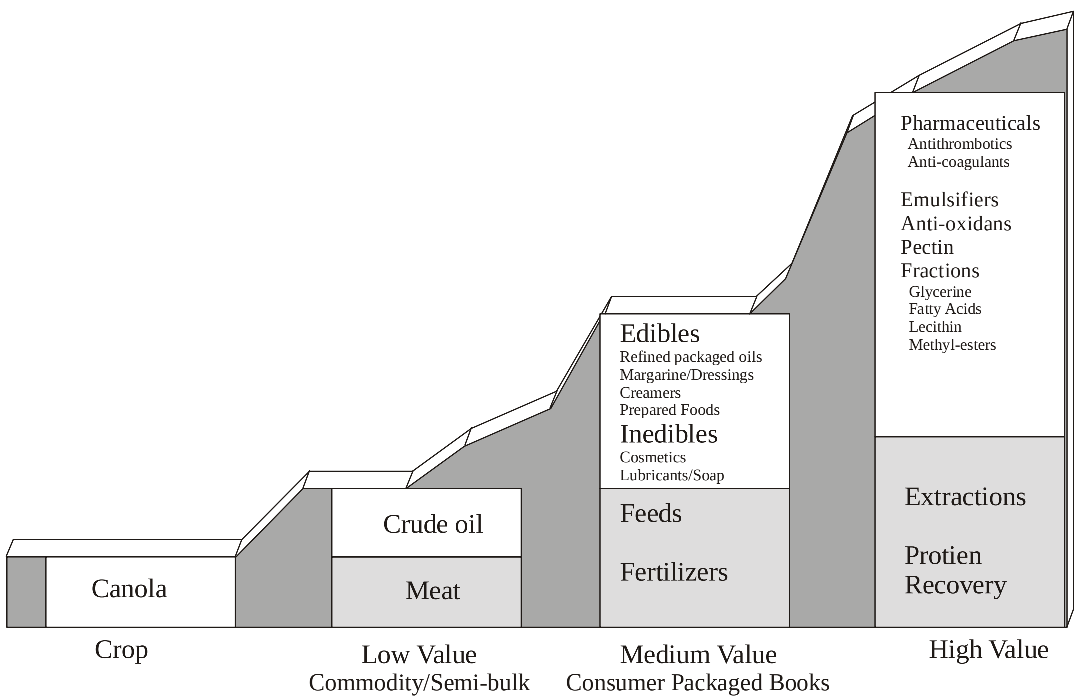

Figure 9. Potential value-added processing in the canola industry.

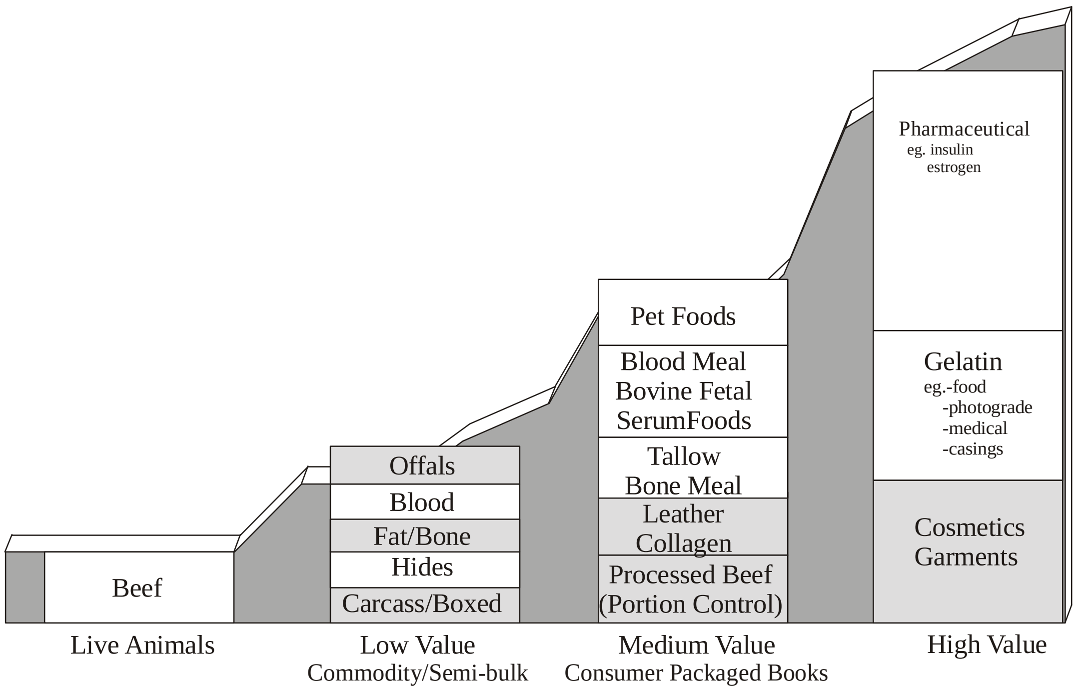

Figure 10. Potential value-added processing in the beef industry.

The third and most detailed procedure that can be utilized to estimate future agri-processing developments in Alberta (focusing on the irrigation-dependent region) is an analysis of each sub-sector based on the most current "insider" information regarding anticipated future investments. "Insiders" include both industry and government personnel. This procedure utilized the 1999 Directory of Alberta's Agricultural Processing Industry (AAFRD 1999b), identifying 588 businesses, to first estimate employment, shipments and value-added in the agri-processing industry in both irrigation-dependent areas and other areas of Alberta (Table 10 and 11). Sub-sector projections for 2005 and 2010 were then made after carefully considering the regional growth potential of each one of these sub-sectors. Particular attention was given to anticipated future investment levels for major existing agri-businesses in the province, including:

- IBP/Lakeside (Brooks) and Cargill (High River) – both world class beef slaughter and beef processing operations;
- Hostess-Frito, Old Dutch, Lamb Weston (Conagra) and McCain – all major potato processing facilities in the Lethbridge-Taber area;
- Agricore – a major pulse processor in the province, and
- Roger's Sugar (Beet) Refinery, Taber.

Table 18. Performance and structure of Canadian food and beverage industries, 1977 – 1979.

	1 Average Profit Margin	2 Profit Hetero-geneity	3 Fringe Profit-ability	4 Index of Natural Entry Barriers	5 4-Firm Seller Concentra-tion Ratio, 1979	6 Relative Size of Low-Profitability Firms	7 Average Firm Size $Millions 1979	8 Number of Firms, 1979	9 Capital/ Output Ratio	10 % Tariff Rate 1978	11 % Advertising Sales Ratio 1977	12 Share of Market 1979 Imported	13 Share of Output Exported	14 Value Added Shipments Ratio
Slaughtering and Meat Processors	6.9 (40)	0.23	L	0.58	44	0.61	15.2	469	0.29	2.0	0.0	0.06 (75)	0.10	0.173
Poultry Processors	8.1 (32)	0.25	L	0.60	38	2.03	14.7	71	0.40	10.0	0.0	0.03 (85)	0.00	0.256
Fish Prod. Ind.	12.6 (33)	0.32	L	0.93	45	0.39	7.3	277	0.54	4.0	0.0	0.22 (46)	0.53	0.377
Fruit & Veg. Canners & Pres.	16.9 (45)	0.35	L	0.95	41	0.18	8.6	154	0.93	5.0	3.0	0.24 (66)	0.04	0.379
Frozen Fruit & Veg. Proc.	17.8 (49)	0.37	M	0.09	61	0.23	11.1	30	1.19	5.0	3.0	0.34 (61)	0.13	0.365
Dairy Prod. Ind.	11.1 (46)	0.18	L	0.28	36	0.49	14.6	303	0.49	4.0	1.0	0.02 (100)	0.03	0.242
Flour & Breakfast Cereal Prod. Ind.	15.5 (51)	0.33	L	0.36	66	2.33	33.5	31	1.46	7.0	4.0	0.05 (94)	0.29	0.303
Feed Industry	9.7 (49)	0.26	L	0.33	26	0.41	4.4	485	0.56	3.0	1.0	0.02 (71)	0.04	0.198
Biscuits Mfrs.	16.8 (34)	0.18	M	0.30	74	1.27	19.8	23	0.73	5.0	2.0	0.06 (54)	0.05	0.492
Bakeries	15.5 (29)	0.34	L	1.06	33	0.61	0.8	1551	1.17	8.0	1.0	0.02 (57)	0.02	0.543
Confectionery Mfrs.	27.8 (57)	0.55	M	0.99	50	0.32	7.0	104	0.77	7.0	4.0	0.19 (62)	0.05	0.486
Cane and Beet Sugar Processors	12.6 (51)	0.22	L	0.19	85	--	65.2	8	0.30	1.0	0.0	0.38 (13)	0.11	0.245
Veg. Oil Mills	5.1 (46)	0.06	L	0.10	70	3.00	90.9	9	0.69	2.0	0.0	0.32 (15)	0.17	0.172
Soft Drink Mfrs.	17.6 (36)	0.35	L	0.95	48	1.22	6.2	200	1.16	6.0	5.0	0.01 (50)	0.00	0.488
Distilleries	39.1 (62)	0.25	H	0.86	77	0.49	4.4	16	1.64	50.0	4.0	0.25 (9)	0.24	0.632
Breweries	34.3 (49)	0.20	M	0.10	99	2.03	138.7	8	2.48	16.0	6.0	0.01 (9)	0.06	0.701
All Food and Beverage, Average	16.7 (53)	0.27		0.54	56	0.61	30.0	234	0.93	5.3*	2.1	0.14	0.13	0.315
All Manufacturing Average	16.5 (41)	0.50	0.7	0.80	53	0.82	31.5	174	1.17	9.6	1.2	0.23	0.18	0.401

Table presented only to provide value-added / shipments ratio for Canadian food and beverage industry (Col. 14).

Source: Cahill and T. Hazledine (1980).

The resulting simulations are provided in Table 19 and highlight the following.

1. Throughout Alberta, the agri-processing sector is expected to grow an average of 4 percent per annum, with only a slightly higher growth rate anticipated for the irrigation sector. This is almost exactly midway between the preceding Projection #1 and Projection #2. This would mean that agri-processing shipments from the irrigation-dependent area would climb from about 2.7 billion (1999) to $4.2 billion in 2010. Province-wide, total agri-processing shipments are expected to climb from $8.9 B to $13.2 B by 2010, about 25% of which would be value-added.[11]

2. The irrigation sector already accounts for 30% of agri-processing shipments. This is expected to climb slightly with time - to 31% in 2005 and 32% in 2010. Projected employment is expected to remain relatively flat at about 30%. At the same time, the percentage of value-added contributed by the irrigation sector is expected to gradually climb over time as well, increasing from the current 26% to about 29% by 2010.

3. The composition of agri-processing in the irrigated south is unique. About 46% of meat/poultry products and 58% of the vegetables are already processed in the south. Vegetable processing (which is closely tied to the location of irrigated farm production) is expected to become even more concentrated in the south during 2000-2010.

4. Agri-processing plants in the south tend to be much larger than a typical agri-processing facility in other parts of the province – in fact, almost three times as large. Thus, although the irrigated south only has about 15% of all agri-processing establishments in the province, this region presently accounts for about 30% of provincial shipments. A few big (mostly trans-national) plants greatly affect the regional averages.

Agri-processing requirements in the irrigation-dependent south, as well as in the remainder of the province, will increasingly impact on the production patterns, production technology and market structure of primary agriculture. Commodity contracting specifying both an input package and an output requirement (vertical integration) will become increasingly common. This will be the economic “driver”. Some of the more likely production implications for irrigated agriculture during the period 2000 to 2010 are tracked in the following section.

Irrigated On-Farm Production Trends

Of particular importance here are the expected changes that will probably arise with respect to both crops (especially potatoes, sugar, forages, oilseeds, pulses, and “specialties”) and livestock (especially beef).

Crops. Expected irrigated cropping trends during 2000-2010 for the existing irrigation area are provided in Table 20. Highlights include:

[11] The value-added is projected using constant VA/Shipment ratios that will probably be inaccurate.

Table 19. Alberta's agri-processing industry in irrigation-dependent areas and all Alberta, actual 1999, and projected 2005 and 2010.

Category*	1999 Actual (Est.)				2005 Projected			2010 Projected		
	No. of Establishments	Employment (FTE's)**	$M Shipments	$M Value-Added	Employment (FTE's)	$M Shipments	$M Value-Added	Employment (FTE's)	$M Shipments	$M Value-Added
Irrigation-Dependent:										
Meat/Poultry & Products	16	4400	1749	395.4	5675	2256	510.1	6736	2678	605.5
Dairy Products	2	60	38	10.8	81	51	14.5	97	61	17.3
Beverage Products	4	160	60	28.2	187	70	32.9	211	79	37.1
Feed Products	21	330	110	29.5	451	151	40.6	550	184	49.4
Flour, Cereals & Pastas	7	190	38	14.3	224	45	17.0	254	51	19.2
Fruit & Fruit Products	2	20	5	1.6	36	9	2.9	48	12	3.9
Vegetables & Veg. Products	26	1270	446	133.8	1653	661	198.3	2123	849	254.7
Oilseeds & Edible Oil Products	2	285	109	20.3	160	109	20.3	160	109	20.3
Other Food Products	9	310	111	41.8	402	131	49.3	451	147	55.4
Total	89	7025	2666	675.8	8868	3482	885.8	10629	4170	1062.9
All Alberta:										
Meat/Poultry & Products	158	9540	3793	857.6	12302	4891	1105.9	15701	6242	1411.3
Dairy Products	35	1240	781	221.6	1660	1045	296.6	1714	1079	306.2
Beverage Products	38	1600	598	281.1	1872	700	329.1	1945	727	341.8
Feed Products	76	1570	525	141.0	2144	717	192.6	2467	825	221.6
Flour, Cereals, & Pastas	28	2820	567	213.9	3328	669	252.4	3418	687	259.2
Fruit & Fruit Products	14	180	45	14.6	324	81	26.3	368	92	29.9
Vegetables & Veg. Products	67	2400	764	229.2	2645	1058	317.4	3283	1313	393.9
Oilseeds & Edible Oil Products	8	605	326	60.6	479	326	60.6	479	326	60.6
Other Food Products	164	2720	1540	580.1	5567	1816	684.1	5730	1869	704.1
Total	588	22625	8939	2599.9	30322	11303	3265.0	35103	13159	3728.6
% Irrigation/All Alberta:										
Meat/Poultry Products	10	46	46	46	46	46	46	43	43	43
Vegetables	39	53	58	58	62	62	62	65	65	65
Average	15	31	30	26	29	31	27	30	32	29
Adjusted Totals:* **										
Irrigation-Dependent		5971	2266	574	7538	2960	753	9035	3545	903
Dryland		13260	5332	1635	18236	6648	2022	20802	7641	2266
Alberta Total		19231	7598	2210	25774	9608	2775	29837	11185	3169

*Categories are not identical to those used by Statistics Canada, Census of Manufacturing (see Table 9).
**Authors estimates based on average establishment size, by size category.
***Adjusted downward 15% to approximate "official" agri-processing estimates to calculate the respective multipliers. See text.
Source: AAFRD (1999b).

Table 20. Irrigated cropping patterns, Alberta, actual and projected, 1992 – 2010 (hectares).

Crop Kind	1992 Actual	1998 Actual	2005 Projected		2010 Projected	
			Same Area	Area Change***	Area Same	Area Change*****
Sugarbeets	13,018	16,752	21,044	23,148	22,662	27,195
Dry Beans	13,052	14,912	16,997	18,696	17,806	21,367
Dry Peas	(incl. in Other)	2,964	4,047	4,452	4,047	4,856
Forage Seeds**	7,662	4,919	8,094	8,903	8,094	9,712
Potatoes	7,153	9,665	15,378	16,916	17,401	20,882
Vegetables, Fresh & Processed*	3,901	5,480	7,284	8,013	8,094	9,712
Other Specialty	9,201	2,000	4,047	4,452	4,856	5,827
All Horticulture & Specialty	53,985	56,691	76,890	84,579	82,961	99,553
				0	0	0
All Cereals****	194,373	159,716	123,429	135,772	105,218	126,262
All Oilseeds	24,382	47,694	77,700	85,470	84,984	101,981
All Forages***	166,703	198,608	244,026	268,428	248,882	298,658
Summerfallow / Misc.	1,630	3,551	4,047	4,452	4,047	4,856
Total Irrigated Area (ha)	**441,073**	**466,260**	**526,092**	**578,701**	**526,092**	**631,310**
				(+ 10%)		(+ 20%)

*For 1998, includes carrots (346 ha), fresh peas (1,982 ha), market gardens (1,078 ha), onions (74 ha), seed potatoes (255 ha), and sweet corn (1,745 ha).
**In 1998, only includes alfalfa seed.
***Alfalfa and timothy hay, silage, greenfeed, and tame pasture.
****Excludes barley and corn silage, currently (1998) about 48,600 hectares.
*****Proportional land use assumed.
Basic Sources: For 1992 data, see: AAFRD (1993).
For 1998 data, see Table 4. For some earlier projections for 2002, also see: Johnson and Macyk (1994)

FRACTIONS:	Specialty	0.1462	0.1462	0.1577	0.1577
	Cereals	0.2346	0.2346	0.2000	0.2000
	Oilseeds	0.1477	0.1477	0.1615	0.1615
	Forages	0.4638	0.4638	0.4731	0.4731
	Misc.	0.0077	0.0077	0.0077	0.0077
	Total	**1.0000**	**1.0000**	**1.0000**	**1.0000**

- The potato irrigated area is expected to expand fairly rapidly, paralleling expansion of the new world-class potato processing facilities in southern Alberta (especially Lamb Weston and McCains). The irrigated area in potatoes is expected to reach 17,400 hectares by 2010.

- The sugar beet irrigated area increased in the late 1990s and it is expected to climb another 6000 hectares by 2010. Rogers Sugar is already (1999) in the midst of a $50 million expansion.

- The irrigated area in vegetables (excluding potatoes) is also expected to continue to expand during the next decade. Fresh vegetables, such as Taber sweet corn, are increasingly grown throughout the irrigated south. The irrigated area for processing vegetables should also continue to expand in the south in response to a growing demand by Lucerne, Vauxhall Foods and numerous smaller processors. Some researchers suggest that a five-fold increase in processing vegetable irrigated area (from 2000 to 10,000 hectares) is possible within the next decade (Johnson and Macyk 1994). At least 8,000 hectares of irrigated vegetables is expected by 2010.

- The area seeded to pulse crops, especially dryland pea and lentil production, increased dramatically during 1985-95. Researchers now expect three other crops to experience very high rates of growth in Western Canada, at least some of which should spill over into irrigated areas: dry beans, chickpea and fababean (Slinkard and Vandenberg). Agricore is already expanding their pulse facilities at Bow Island.

- There is also the potential for additional forage seed production. Some researchers think that this irrigated area could almost triple, climbing to 20,000 hectares during the next decade (Johnson and Macyk 1994). The Blood Tribe is now expanding into timothy seed production on their newly-irrigated Big Lease.

- Forage production will also continue to increase. Irrigated barley and corn silage (some 48,500 hectares) are key feed ingredients for local feedlots. Barley-based beef is, in effect, the regions largest and most important "specialty crop". By 2010 it is expected that the total area of irrigated forage will amount to almost half of all irrigated land. This will imply a shift away from cereal grain production which will eventually be restricted to grains that are processed locally – particularly high-yielding feed barley for the beef industry and wheat for the local flour milling industry (Ellison Milling Co.).

- The oilseed area, primarily canola, is also expected to climb and may exceed 81,000 hectares by 2010. Increasingly high-yielding canola varieties (both natural and GMO) with relatively good profit margins, and the presence of a local processing facility will likely augment the irrigated area of canola. Canbra Foods, now controlled by Richardson/Pioneer, will likely become a more aggressive buyer/processor during the next decade.

Virtually all of these anticipated production shifts will further increase land use intensities (productivity) and input requirements (fertilizer, pesticides, water, etc.) during the 2000 to 2010 period. They will also reflect a gradual shift to capture more value-added within Alberta, both on-farm and in the agri-processing sector.

Livestock. Additional beef production and beef finishing in southern Alberta is also expected during the next 5 to 10 years. There is now an internal dynamic in play that will almost certainly result in a further concentration of beef feeding and slaughter operations in Alberta (and particularly south and southeast Alberta) that will serve all of western Canada. However, in southern Alberta, it is likely that feedlots, in particular, will become somewhat more dispersed. For environmental reasons, very little additional feedlot capacity in County 26 (Lethbridge) is expected. In addition, increasingly strong north-south trade ties, particularly with the Pacific Northwest, will likely emerge (Smith 1981; MAA 1996; Carter and Schmitz 1983; Rosaasen and Schmitz 1984). This dynamic is a function of at least five crucial factors.

- The presence of two world-class slaughter plants (IBP and Cargill).
- Increasingly strong N-S trade links (following the NAFTA free trade agreement).
- The world beef trade (especially for value-added products) is growing very quickly.
- The value-added processing possibilities are very extensive.
- Southern Alberta has numerous unique attributes: major feedlots, easy feed and feeder cattle access, climate, proximity to U.S., supporting physical-institutional infrastructure, and so on.

A 50 percent increase in the meat processing industry of the irrigation-dependent south is expected by 2010 and this would still represent about 60 percent of agri-processing in the irrigated south and 43 percent of all meat processing in the province (Table 6 and Table 19). Feedlot capacity in the irrigated south (although increasingly more dispersed) should, therefore, also expand about 50 percent during the next decade.

IMPACTS AND IMPLICATIONS

Impacts

The terms-of-reference for this study focus on two potential impacts:

- Socio-economic impacts assuming no change in the existing irrigated area.
- Socio-economic impacts assuming a 10 to 20% expansion in the existing irrigated area.

On the basis of the preceding analyses, these two scenarios have been developed in Table 20 (crop composition) and Table 21 (composite productivity and profitability), and then simulated in Table 22 and Table 23.

Table 22 simulates two cases: gradual crop/livestock intensification without any change in the irrigated area, and intensification accompanied by a ten percent increase in the irrigated area (increase of 52,700 hectares). Either case could occur by about 2005.

Table 23 simulates two parallel cases: gradual crop/livestock intensification without any change in the irrigated area, and intensification accompanied by a 20 percent increase in the irrigated area (increase of 105,200 hectares). Either case could occur by about 2010.

Each of these simulations is developed with the data presented in preceding sections of this report, such that there is an internal consistency between all the extrapolated data. Even the micro-data (crop budgets in Tables 2 and 3) are generally consistent with the macro-data (GNP accounting framework, Table 7). In addition, since it is expected that the agri-processing sector will, in the future, largely determine the structure of the irrigated farm sector, these two sub-sector extrapolations are also generally consistent with one another. Additional cross-references are provided in the respective Tables.

Table 21. Actual and projected crop enterprise analysis with irrigated crop intensification, with and without irrigation expansion, 1999, 2005, and 2010 ($/hectare).

		Dryland 1999	Irrigation 1999	Irrigation 2005	Irrigation 2010
		1	2	3	4
(A)	Gross return	305.19	964.85	992.62	1,007.45
(B)	Variable costs	203.5	570.49	584.01	592.31
(C)	Total capital costs	107.32	292.92	292.75	294.08
(D)	Cash costs	246.01	654.38	666.64	674.65
(E)	Total production costs	310.85	863.41	876.75	886.37
(F)	Gross margin	59.18	310.46	325.98	332.80
	Return to unpaid labour	16.31	169.09	183.97	190.00
	Return to investment	13.64	160.25	173.54	178.61
	Percent Return to Investment	0.74%	4.09%	4.50%	4.60%
	Return to equity	-5.66	101.44	115.84	121.08
Investment					
	Land	1,282.47	2,250.88	2,222.51	2,217.82
	Buildings	163.48	267.24	263.88	263.78
	Machinery	394.77	875.62	895.02	905.34
	Irrigation Machinery	0.00	525.64	513.11	509.98
	Total	1,840.72	3,919.38	3,894.52	3,896.92
Labour					
	Hired labour (hours/hectare/year)	0.82	3.98	4.20	4.30
	Unpaid labour (hours/hectare/year)	2.20	6.77	6.82	6.89
	Total labour (hours/hectare/year)	3.01	10.75	11.02	11.19

Sources: Column (1): Table 2. Column (2): Table 3. Columns (3)-(4): Simulated from Table 3 and Table 20.

Table 22. Projected impacts of gradual irrigation intensification and a 10% area increase in southern Alberta by about 2005 ($ Million).

	Item	Data Source	Current Impact (526,000 ha)				Projected Impact: Constant Area (526,000 ha)				Projected Impact: Current Area +10% (578,700 ha)			
			Gr Value	Gr Sales	Value-add	Employ	Gr Value	Gr Sales	Value-add	Employ	Gr Value	Gr Sales	Value-add	Employ
	Crops:													
1	Irrigation	Table 17 & Note 1	508	298	163	3142	522	313	171	3222	574	344	189	3544
2	Dryland	Table 17 & Note 1	161	59	31	881	161	59	31	881	177	65	34	969
	Livestock:													
3	Irrigation	Table 7 & Note 2		562	95	1821		647	109	2047		712	120	2251
4	Dryland	Table 7 & Note 2		78	16	464		90	19	534		99	21	588
	Crops + Livestock:													
5	Irrigation	Row 1 + Row 3		860	258	4963		959	280	5268		1055	308	5796
6	Dryland	Row 2 + Row 4		137	48	1345		149	50	1415		164	55	1557
7	Difference (Direct)	Row 5 – Row 6		723	211	3617		811	230	3853		892	253	4239
	Backward Linkages:													
8	Irrigation	Note 3		860	215	2150		959	240	2398		1055	264	2638
9	Dryland	Note 3		137	34	343		149	37	372		164	41	409
10	Difference			723	181	1807		811	203	2026		892	223	2229
	Forward Linkages:													
11	Irrigation	Table 15 (adjusted)		2266	574	5971		2691	684	6852		2960	753	7538
12	Dryland	Table 15 (adjusted)		144	38	308		156	40	324		172	44	357
13	Difference			2122	536	5663		2534	644	6528		2788	709	7181
	Grand Total:													
14	Irrigation	Row 5 + Row 8 + Row 11		3986	1047	13084		4609	1205	14519		5071	1325	15972
15	Dryland	Row 6 + Row 9 + Row 12		418	120	1996		454	127	2111		499	140	2323
16	Difference (Direct + Indirect)	Row 14 – Row 15		3568	927	11088		4155	1078	12407		4571	1185	13649
	Impact With and Without Area Expansion													
17	Direct (on-farm)							88	20	236		169	43	621
18	Percent change							12	9	7		23	20	17
19	Backward (suppliers)							88	22	219		169	42	422
20	Forward (Agri-Processing)							412	109	865		666	173	1519
21	Total (Direct + Indirect)	Note 4						587	150	1319		1003	258	2562
	Percent change							16	16	12		28	28	23

Note 1: Assumes 1 person-year = 1800 hours. Note 2: Assumes a rate of growth of 4%/annum; about 50% through 10 years. (Consistent with text and Table 19.)
Note 3: Approximately the same as Direct Sales. Value-added approx. 25% (like forward linkages). Employment is about 1 person/$100,000 in sales.
Note 4: This Value-added estimate is approximately equivalent to projected changes in Agri-Food GDP. AAFRD excludes backward linkages from their own internal calculations.
Sources: See respective Tables.

Table 23. Projected impacts of gradual irrigation intensification and a 20% area increase in southern Alberta by about 2010 ($ Million).

	Item	Data Source	Current Impact (526,000 Hectares)				Projected Impact: Constant Area (526,000 ha)				Projected Impact: Current Area + 20% (631,200 Hectares)			
			Gr Value	Gr Sales	Value-add	Employ	Gr Value	Gr Sales	Value-add	Employ	Gr Value	Gr Sales	Value-add	Employ
	Crops:													
1	Irrigation	Table 17 & Note 1	508	298	163	3142	530	319	175	3273	636	383	210	3928
2	Dryland	Table 17 & Note 1	161	59	31	881	161	59	31	881	193	71	37	1057
	Livestock:													
3	Irrigation	Table 7 & Note 2		562	95	1821		721	121	2271		866	146	2725
4	Dryland	Table 7 & Note 2		78	16	464		100	21	596		120	25	715
	Crops + Livestock:													
5	Irrigation	Row 1 + Row 3		860	258	4963		1040	297	5544		1249	356	6653
6	Dryland	Row 2 + Row 4		137	48	1345		159	52	1477		191	63	1772
7	Difference (Direct)	Row 5 – Row 6		723	211	3617		881	244	4067		1058	293	4881
	Backward Linkages:													
8	Irrigation	Note 3		860	215	2150		1040	260	2601		1249	312	3121
9	Dryland	Note 3		137	34	343		159	40	398		191	48	477
10	Difference			723	181	1807		881	220	2203		1058	264	2644
	Forward Linkages:													
11	Irrigation	Table 15 (adjusted)		2266	574	5971		2954	752	7529		3545	903	9035
12	Dryland	Table 15 (adjusted)		144	38	308		167	42	338		200	50	406
13	Difference			2122	536	5663		2787	711	7191		3345	853	8629
	Grand Total:													
14	Irrigation	Row 5 + Row 8 + Row 11		3986	1047	13084		5035	1309	15674		6042	1571	18809
15	Dryland	Row 6 + Row 9 + Row 12		418	120	1996		485	134	2212		582	160	2655
16	Difference (Direct + Indirect)	Row 14 – Row 15		3568	927	11088		4550	1175	13461		5460	1411	16154
	Impact With and Without Area Expansion													
17	Direct (on-farm)							158	34	450		335	83	1264
18	Percent change							22	16	12		46	39	35
19	Backward (suppliers)							158	40	396		335	84	837
20	Forward (Agri-Processing)							665	175	1528		1222	317	2966
21	Total (Direct + Indirect)	Note 4						982	248	2374		1892	483	5067
	Percent change							28	27	21		53	52	46

Note 1: Assumes 1 person-year = 1800 hours. Note 2: Assumes a rate of growth of 4%/annum; about 50% through 10 years. (Consistent with text and Table 19.)
Note 3: Approximately the same as Direct Sales. Value-added approx. 25% (like forward linkages). Employment is about 1 person/$100,000 in sales.
Note 4: This Value-added estimate is approximately equivalent to projected changes in Agri-Food GDP. AAFRD excludes backward linkages from their own internal calculations.
Sources: See respective Tables.

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The simulated incremental impacts compared to the current base year, 1999, are summarized in Table 24.

Table 24. Simulated incremental impacts of potential irrigation development, 2000-2010*.

Item	Scenario I			Scenario II		
Approximately 2005	Intensification on 526,000 ha (Current Area)			Intensification on 579,000 ha (10% expansion)		
	Gross Sales ($M)	Valued Added ($M)	Employment (FTE)	Gross Sales ($M)	Value Added ($M)	Employment (FTE)
Impact with and without Area Expansion						
DIRECT (on-farm)	**88**	**20**	**236**	**169**	**43**	**621**
Current Impact Year 2000 Baseline	723	211	3,617	723	211	3,617
Direct Percent Increase	12.1%	9.4%	6.5%	23.3%	20.4%	17.2%
Backward (suppliers)	88	22	219	169	42	422
Forward (Agri-Processing)	412	109	865	666	173	1,519
TOTAL (Direct + Indirect)**	**588**	**150**	**1,320**	**1,004**	**258**	**2,562**
(Current Yr. 2000 Impact = Baseline)	3,568	927	11,088	3,568	927	11,088
Total Percent Increase	16.5%	16.2%	11.9%	28.1%	27.8%	23.1%
Approximately 2010	Intensification on 526,000 ha (Current Area)			Intensification on 631,000 ha (20% expansion)		
	Gross Sales ($M)	Value Added ($M)	Employment (FTE)	Gross Sales ($M)	Value Added ($M)	Employment (FTE)
Impact with and without Area Expansion						
DIRECT (on-farm)	**158**	**34**	**450**	**335**	**83**	**1,264**
Current Impact Yr. 2000 Baseline	723	211	3,617	723	211	3,617
Direct Percent Increase	21.9%	16.0%	12.4%	46.3%	39.2%	34.9%
Backward (suppliers)	158	40	396	335	84	837
Forward (Agri-Processing)	665	175	1,528	1,222	317	2,966
TOTAL (Direct + Indirect)**	**981**	**249**	**2,374**	**1,892**	**484**	**5,067**
(Current Yr. 2000 Impact = Baseline)	3,568	927	11,088	3,568	927	11,088
Total Percent Increase	27.5%	26.8%	21.4%	53.0%	52.2%	45.7%

* Theoretical impact of an area increase only is equal to the difference between the two simulated incremental impacts.
** Approximately equal to projected incremental increase in Agri-Food GDP.
Source: Extracted directly from Tables 22 and 23.

The pure "intensification" scenario (Scenario I) tracks the economic impact of an increasingly intensive irrigated cropping pattern, characterized by a gradual shift to more specialty crops (including livestock) in response to growing agri-processing requirements in the region. In about 10 years, this direct (on-farm) value-added (VA) should climb by about $34 M (+16 percent), and employment about 450 people (+12 percent). This, essentially, requires an increasingly efficient water delivery system. But even with this scenario, the total provincial impact would be much, much larger, climbing by a projected $249M (+27 percent). The spin-offs are expected to "multiply" at even a faster rate than irrigated agriculture itself (+28% versus +16 percent).

Alternatively, development could also involve an irrigated area expansion of 10 to 20 percent in addition to the largely endogenous intensification process. Expansion would have an additional stimulative effect on irrigated farm production, farm supply industries, and related agri-processing industries (Scenario II). The impact of the demand-driven crop production shifts would more than double. After about 10 years (with a 20 percent irrigation expansion), the VA would climb an estimated $83 M (+39 percent) instead of $34 M, while direct employment would climb by about 1264 people (+35 percent) instead of 450 people. In this case, the total provincial (incremental) VA impact is estimated to climb to $484 M (+52 percent) while total direct and indirect employment increases by more than 5,000 people. Once again, it is expected that the indirect impacts (spin-offs) would "multiply" at even a faster rate than irrigated agriculture itself (+52% versus +27%). This total direct + indirect value-added impact is approximately equivalent to what is sometimes referred to as the agri-food GDP (gross domestic product) (Fig. 11).

The approximate net impact of 10 to 20 percent irrigation expansion can also be determined from these simulations by simply taking the difference between Scenarios II and I (Table 25).

Table 25. The net impact of different levels of irrigation area expansion.

Variable	Expansion of 10% (579,000 ha)	Expansion of 20% (631,000 ha)
Gross Sales ($M)	416	911
Value-Added ($M)	108	235
Employment	1,242	2,693

These differences represent a theoretical "pure" expansion impact (Fig. 11).

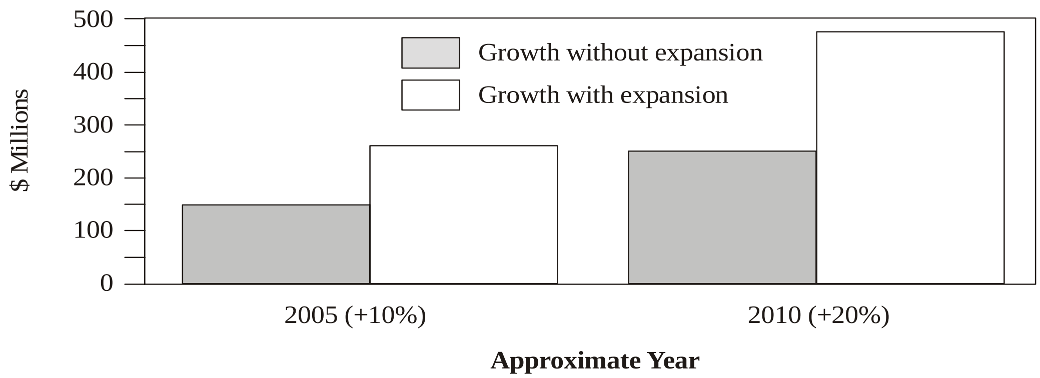

Figure 11. Change in Agri-Food GDP with and without irrigation expansion.

To put these estimates into context, the total cash receipts for primary agriculture in Alberta are presently (Year 2000) about $6 billion per year, with a value-added component of about $2.3 B (Table 7). At the same time, the Alberta agri-processing industry presently has sales of about $7.5 B per year, generating a value-added of about 2.2 B (Table 19). A value-added (or GDP) expansion of $484 million (see above) would represent an approximate 10 percent increase in the total Alberta agri-food GDP. Additional details are provided in accompanying Tables 22 and 23.

Policy Implications

Finally, what are the policy ramifications of the alternative irrigation development scenarios simulated in the preceding? To what extent are anticipated outcomes consistent with the government's provincial objectives?

The principal goals, performance measures, and targets of the Government of Alberta are indicated in Table 26.

Table 26. 1999-2002 Government Business Plan – goals, performance measures, and targets.

Goals	Measures	Targets
People		
1. Albertans will be healthy.	• Life Expectancy at Birth • Health Status	• 77.0 years for males and 83.0 years for females. • Reduce the percentage of Albertans who rate their health as only fair or poor.
2. Our children will be well cared for, safe, successful at learning and healthy.	• Economic Status of Children	• To be developed.
3. Alberta students will excel.	• Educational Attainment	• To be developed.
4. Albertans will be independent.	• Literacy and Numeracy Levels • Family Income Distribution	• 85 percent of Grade 9s meet the acceptable standards in math and language arts. • Reduce the percentage of families with income under $20,000 to 5 percent by 2007.
5. Albertans not expected to support themselves fully will receive help.	• Under construction	• To be developed.
Prosperity		
6. Alberta will have a prosperous economy.	• Gross Domestic Product • Job Growth	• Long-term GDP growth rate of 4 to 6 percent. • 155,000 new jobs from December 1996 to December 2000.
7. Our workforce will be skilled and productive.	• Skill Development	• 90 percent of employers satisfied with recent graduates' skill levels.
8. Alberta businesses will be increasingly innovative.	• Under construction	• To be developed.
9. Alberta's value-added industries will lead economic growth.	• Value-Added Industries GDP	• Alberta's value-added industries will account for an increasing percentage of GDP.
10. Alberta will have effective and efficient infrastructure.	• Infrastructure Capacity	• To be developed.
11. Alberta will have a financially stable, open and accountable government.	• Cost of Government • Taxation Load • Provincial Credit Rating • Net Debt (Accumulated Debt)	• Remain 5 percent below the average of the other nine provinces. • Maintain the lowest tax load on persons and the lowest provincial income tax rate in Canada. • The highest credit rating among the provinces. • Eliminate net debt by 2009-10. • (Fiscal Responsibility Act milestones).
12. Alberta will have a fair and safe work environment.	• Workplace Climate	• Minimize the amount of time lost owing to workplace disputes and injuries.
13. Alberta businesses will increase exports.	• Export Trade	• Increase exports to $39.6 billion by 2000.
Preservation		
14. Alberta will be a safe place to live and raise families.	• Crime Rate	• Reduce Alberta's crime rates below the national average by 2000.
15. Alberta's natural resources will be sustained.	• Resource Sustainability	• Prolong the reserve life of oil and gas; keep timber harvest below the annual allowable cut; increase crop yields to 2.42 tonnes per hectare by 2000.
16. The high quality of Alberta's environment will be maintained.	• Air Quality • Water Quality • Land Quality	• Maintain air quality levels that are considered good or fair at all times. • Maintain river quality downstream of developed areas in line with upstream conditions. • Increase crop yields to 2.42 tonnes per hectare by the year 2000.
17. Albertans will have the opportunity to enjoy the province's natural, historical and cultural resources.	• Heritage Appreciation	• 1.1 million visitors per annum to historic sites and museums. Targets to be developed for parks visitation and libraries, arts and recreation activities.
18. Alberta will work with other governments and maintain its strong position in Canada.	• Intergovernmental Relations.	• Maintain Alberta Government's public approval rating in federal-provincial relations equivalent to the average approval rating of four nearest provinces.

Source: Alberta Treasury (1998).

There are a total of 26 core performance measures tracking 18 major goals. A strong irrigation sector directly contributes to the quantitative indicators of at least seven of these goals.

- Gross Domestic Product (GDP): Contribution of agricultural industries to provincial GDP.
- Job Growth: Agri-food industry employment relative to total provincial employment.
- Value-Added Industries GDP: Contribution of agricultural processing to agri-food GDP.
- Infrastructure Capacity: Quality of irrigation infrastructure.
- Export Trade: Primary agriculture and agri-good export level.
- Environmental Quality: Land productivity.
- Family Income Distribution: Enhancing below average family incomes.

The quantitative indicators associated with each of these performance measures are provided in Table 27. The specific projections and targets established by the Department of Agriculture, Food and Rural Development for the period 1999-2002 are indicated in Table 23.

These goals and targets generally focus on the need to add in-province value to all raw material production, including commodities that might initially be considered “low-value” commodities, such as barley silage. Irrigation is a key element in this strategy and as the growth in value-added production continues, it will gradually take on an increasingly important role.

Table 28, in particular, highlights the extent to which the agricultural development strategy in the province is dependent upon very vibrant future growth in the agri-processing sector. In sharp contrast to the very low (or even negative) growth projected for primary agriculture (even though employment in primary agriculture is expected to grow about 3.5 percent per year), the value of shipments in the agri-processing sector is targeted to grow about 10 percent per year, with agri-processing employment growing about 8 percent per year.

Comparing the targeted values (Table 28) with projected values (Table 19), the targeted projections imply growth rates for agri-processing output and employment that are about two times those projected in Table 19 (8 to 10 percent/year versus 3 to 4 percent/year). Furthermore, if primary agriculture’s contribution to GDP is projected to decrease (as it is) it is clear that the only way agri-food’s contribution to GDP can then increase is if this accelerated agri-processing development is somehow successful. This would facilitate additional import substitution and a corresponding increase in exports (Goal #13).

To be successful, prevailing technical and economic parameters essentially dictate that a disproportionate amount of projected growth in the agri-processing sector come from the irrigation-dependent south. This region is characterized by an inherent high processing production to primary production ratio. This ratio is about 2.66, compared to a ratio of perhaps 1.05 for other regions of Alberta (giving an all-Alberta ratio of 1.28). This difference largely arises because:

- The existing agro-genetic characteristics of many of the “specialty” crops that are amenable to extensive processing dictate they simply must be grown under irrigation in the southern part of the province where the growing season, heat units and stable, high-quality outputs are production and processing prerequisites. Additionally, since this production is typically sophisticated, high-input, capital-intensive production, the backward linkages to agricultural suppliers and related industries are particularly strong.

Table 27. Irrigation development in support of Government of Alberta goals.

Government Goals	Performance Measures	Primary Agricultural Measure Regarding Irrigation	Quantitative Indicators
People			
4. Albertans will be independent.	• Family Income Distribution	• Disposable family income distributions in agriculture and related industries	• Percentage of farm families and other ag-dependent families with incomes in excess of $20,000/yr*
Prosperity			
6. Alberta will have a prosperous economy.	• Gross Domestic Product	• Contribution of agricultural industries to provincial GDP	• Alberta farm cash receipts* • Alberta food & beverage industries value of shipments, re: value-added* • Agri-foods contribution to GDP*
	• Job Growth	• Agri-food industry employment to total provincial employment	• ARC job creation estimates*
9. Alberta's value-added industries will lead economic growth.	• Value-Added Industries GDP	• Contribution of ag. processing to agri-food GDP	• Ratio of value of food and beverage shipments to value of farm receipts
10. Alberta will have an effective and efficient infrastructure.	• Infrastructure Capacity	• Quality of irrigation infrastructure	• Operationally effective and efficient irrigation infrastructure (financial & physical)
13. Alberta business will increase exports.	• Export Trade	• Primary agriculture and agri-food export level	• Value of out-of-province shipments of agriculture and food products*
Preservation			
16. The high quality of Alberta's environment will be maintained.	• Land Quality • Water Quality • Air Quality	• Land productivity indicator	• Crop production index (average tonnes/hectare)*

*Specific AAFRD targets indicated in accompanying Table 28.
Source: Adapted from Table 24 and related Departmental documents.

Table 28. Projections and targets for the Department of Agriculture, Food & Rural Development, 1992–2002.

	Item	1989-1993 Benchmark	*1996 Actual	*1997 Actual	*1998 Actual	*1999 Forecast	*2000 Forecast	*2002 Target
1.	Alberta Farm Cash Receipts ($M)	4,604	6,460	6,370	6,448	6,635	6,500	6,800
2.	Farm Net Cash Income ($M)	1,030	1,768	1,545	1,589	1,713	1,500	1,600
3.	Alberta Food & Beverage Industries Value of Shipment ($M)	4,867	6,620	7,249	7,500	8,300	9,500	11,000
4.	Value of Out-of-Province Shipments of Agriculture & Food Products ($M)	4,141	7,447	7,964	7,500	7,600	8,000	9,000
5.	Agri-Foods Contribution to GDP (%)	4.8	5.2	4.9	5.1	5.2	5.3	5.4
6a.	Employment in Primary Agriculture (FTE's)	88,000	96,000	85,900	84,400	88,000	90,000	98,000
6b.	Employment in Food/Bev. Industry (FTE's)	17,300	20,200	19,300	19,800	21,000	23,000	26,000
7.	Output (tonnes/hectare)	1.93	2.29	2.28	2.28	2.42	2.40	2.42

Source: AAFRD (1999).

- Conversely, given existing technologies, historical location patterns, domestic consumption levels, and existing institutional factors, from an international market-driven perspective there is limited potential for additional value-added processing of traditional crops.

- There is already a vibrant, rapidly growing and sustainable agri-industrial complex in southern Alberta which has reached a "critical mass" capable of growing indefinitely, assuming that the high-quality raw materials continue to be readily available at internationally competitive prices. This generates synergies in the region such that one agro-economic activity stimulates the development of yet another. Most world-class agri-processing facilities in Alberta are located in the south and average plant size is relatively large.

Further irrigation development is also consistent with three other government goals: 1) maintaining the high quality of Alberta's environment (Goal #16); 2) maintaining an effective and efficient infrastructure (Goal #10); and 3) enhancing below-average family income levels (Goal #4).

There are few initiatives that have such a profound net positive impact on the environment (see Section 2.4). Potentially negative impacts are almost always linked to overly-intensive resource use that eventually exceeds the sustainable carrying capacity of the irrigation-enhanced resource base. Long-term land productivity (measured as average tonnes of grain or bio-mass per hectare) can most easily be enhanced through sustainable irrigation development. With irrigation, physical land productivity climbs 250-300 percent (Tables 2, 3 and 5).

Maintaining government-owned irrigation infrastructure such that it remains effective and efficient is also responsible stewardship of public resources (one aspect of government Goal #10). The total estimated value of all capital works either owned or supported by the provincial government is $72 billion. The government-owned irrigation infrastructure, operated by Alberta Environment, is made up of some 53 dams, 26 weirs and 500 km of canals. It is valued at $4.3 billion dollars. This, in conjunction with Irrigation District assets of $1.3 billion (made up of 7,386 km of canals, pipelines, etc.), totals a relatively large 7.8 percent of all capital, either owned or supported by the provincial government (Colgan 1999).[12] Optimizing the socio-economic benefit of this existing investment is just good business.

Finally, consider the implications of additional irrigation on farm family income. From Tables 2 and 3, it is apparent that both the return to unpaid labour (i.e. the farm family) and the return to investment and equity are typically much better under irrigation (Table 29).

[12] The total estimated value of all capital works either owned or supported by the provincial government is $72 billion.

Table 29. Comparison of economic returns between irrigation and dryland farms.

Financial Performance	$ per hectare per Yr.		$ per Typical Farm per Yr.*	
	Dryland	**Irrigation**	**Dryland**	**Irrigation**
Gross Margin	$59.18	$310.51	$47,900	$125,660
Return to Unpaid Labour	$16.31	$169.17	$13,200	$ 68,460
Return to Investment	$ 13.64	$ 160.35	$11,040	$ 64,890
Percent Return to Investment	0.74%	4.09%	0.74%	4.09%
Return to Equity	-$ 5.66	$ 101.54	-$ 4,580	$ 41,090

* 800 ha of dryland; 400 ha of irrigation (approximately equal capital investments).
Source: Tables 2, 3 and 5.

Under prevailing conditions, a “typical” dryland crop operation would generate a return to family labour, management and equity of less than $9,000 per year ($13,200 + (-$4,580)), whereas a comparable operation with irrigation would make about $109,000 ($68,460 +$41,090). As reflected in the relative size of the Gross Margin, the irrigated farming operation also has a much greater capacity to withstand temporary downturns in the agricultural economy.

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Unit Conversion Factors

	SI Units		Imperial Units
Area:	1.0 hectare (ha)	=	2.471 acres
Length:	1.0 millimetre (mm)	=	0.0394 inches
	1.0 metre (m)	=	3.281 feet
	1.0 kilometre (km)	=	0.621 miles
Volume:	1.0 cubic metre (m^3)	=	35.315 cubic feet
	1.0 cubic decametre (dam^3)	=	0.811 acre feet
Rate of Flow:			
	1.0 cubic metre per second (m^3/s)	=	35.315 cubic feet per second
Yield:			
	1.0 kilogram per hectare (kg/ha)	=	0.893 pounds per acre
	1.0 tonne per hectare (t/ha)	=	0.446 tons per acre