Chapter V.

Simulation Modelling

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A. INTRODUCTION

Computer simulation modelling of water demand and supply is an essential analytical technique for assessing water management options and optimizing the performance of complex water management systems. In the Irrigation Water Management Study, computer models were used to simulate various scenarios of development, management options and operational policies. Model output included water demands, water deliveries required to meet demands, stream flows, canal flows, losses, reservoir levels, irrigation deficits, and impacts of deficits on farm financial viability. The model output assists government and the irrigation districts to make informed decisions related to long-term planning.

Modelling was conducted for stream flow and climatic conditions in the South Saskatchewan River Basin for the historical period, 1928 to 1995. The output represents what probably would have occurred had the level of irrigation development and the management scenario been in place during the period simulated.

To facilitate modelling, the districts were divided into blocks of irrigated land primarily on the basis of infrastructure configuration and discrete inflow and outflow points. The characteristics of each block were determined based on inventories of variables such as crop types, irrigation methods, soil types, and water delivery systems. The number and sizes of the blocks within the districts are summarized in Table 20. There are 25 blocks within the districts supplied by diversions from the Bow River, and 26 blocks within the districts served by the Oldman River system. The blocks range in size from 756 hectares to 32,407 hectares. Some blocks are more susceptible to water supply shortages than others, depending to a large extent on the existence of supporting storage reservoirs. Irrigation water users in some blocks can also be impacted by irrigation deficits to a higher degree than those in other blocks, depending on factors such as crops grown and agro-climatic conditions.

Table 20. Irrigation blocks established for simulation modelling.

District	No. of Blocks	Block Size (hectares)[1]		
		Smallest Block	Largest Block	Mean
Bow River	8	1,182	27,097	10,014
Eastern	12	915	18,849	9,309
Western	5	1,905	12,625	5,941
All Bow Basin Districts	25	915	27,097	8,861
Aetna	1	756	756	756
Leavitt	1	1,871	1,871	1,871
Lethbridge Northern	4	5,832	32,407	14,835
Magrath	1	6,045	6,045	6,045
Mountain View	1	1,420	1,420	1,420
Raymond	1	16,741	16,741	16,741
St. Mary River	12	1,301	26,354	12,002
Taber	3	7,793	12,486	10,487
United	2	1,171	5,868	3,522
All Oldman Basin Districts	26	756	32,407	10,341

[1] Based on 1999 irrigation areas.

B. MODELLING ASSUMPTIONS AND CALIBRATION

Each of the three simulation models required certain assumptions and operating principles that are common for all scenarios analyzed. An understanding of these assumptions and principles is essential to the interpretation of model output. Each model was calibrated against monitored data to ensure the model was representative of actual field conditions. Assumptions and calibrations for each model are discussed below.

1. Irrigation District Model (IDM)

a) IDM Assumptions

i) Soil-Plant-Water Relationships

- Weather conditions (rainfall, temperature, etc.) for all fields modelled were taken from the nearest grid point in the agro-climatic database.
- Soil types, textures and water holding capacities were considered to be homogeneous for each field and throughout the root zone depth.
- Crop seeding dates were randomized across all fields within normal periods for seeding for each specific crop.
- Fall irrigation was assumed to take place each year on a randomized selection of 50% of the fields where soil moisture levels were at or below the irrigation threshold level. Fall irrigation was ruled out on certain fields that would not normally be irrigated in the fall, such as late harvest sugar beets.

ii) On-Farm Irrigation System Operations

- System coverage rates (hectares/day) were based on typical coverage rates for a quarter-section system.
- Irrigation system application efficiencies were set for each system type, at industry-accepted standard values for local conditions.
- Irrigation applications were controlled for daily soil moisture conditions and crop growth stage for individual fields. Specific to each system type, irrigations were curtailed when precipitation events exceeded specified levels.

iii) Conveyance Works Operations

- Seepage and evaporation losses were based on the assumption that all canals were "checked" to run full for the entire irrigation season.
- Seepage from canals was determined based on capacity and soil texture specific to the location of each canal. Seepage from rehabilitated earth canals was considered to be significantly less than that from unrehabilitated earth canals. Seepage from pipelines and canals lined with materials other than clay was assumed to be zero.
- Canal start-up and shut-down dates are district specific and were assumed to be the same each year, regardless of weather variations.
- Operational spills due to unscheduled on-farm system down-times were assumed to be unavailable for downstream re-use. Therefore, the spills contributed to return flow. In reality, some of this water could be recaptured and re-used, thus slightly increasing the efficiency of water use beyond that computed from model output.
- Conveyance works capacities were assumed to be non-restrictive to meeting downstream demands for all scenarios.

b) IDM Calibration and Validation

The IDM and its modules were first calibrated to ensure output results matched well with observed or recorded water demand or moisture supply situations in the field. Calibrations were derived for parameters such as:

- Total seasonal consumptive use for each crop type;
- Timing of crop water use, harvesting dates and "water on and off" dates;
- Carry-over and net residual soil moisture conditions through fall, winter and into early spring of each year;
- On-farm irrigation efficiencies and irrigation system water management as monitored in the intensive block studies;
- On-farm irrigation management by crop-type and method, as monitored in the field for several years;
- Return flow volumes scaled to match monitored flows in 1999; and
- Canal seepage rates based on soil texture categories and data from ponding tests.

The validation process then compared modelling results against actual recorded water demand and consumption data. Model output comparisons were made for:

- Water diversions through the conveyance systems;
- Return flow quantities;
- Seasonal profiles of daily water demands; and
- Reservoir levels throughout the irrigation season.

The validation exercise involved examining the three-year period, 1987 through 1989, within the SMRID, TID, RID and MID. In general, modelling results were within 1% to 2% of the actual recorded data. Additionally, the IDM was calibrated and validated for special applications within the EID. Model results compared well with the results of extensive multi-year water audits the EID conducted through the late 1990s.

2. Water Resources Management Model (WRMM)

The WRMM (and its sub-models) determined the relationship between water supply and demand for the entire SSRB. Model runs included all major storage reservoirs, diversions, water uses, and apportionment commitments.

a) WRMM Assumptions

- The rights and priorities of existing licences and licence-holders were recognized and adhered to. Licence priorities were modelled for major water allocations, such as the irrigation districts. Private projects were lumped together by river reach and modelled as one demand, with a priority that reflected the average priority of the individual projects.
- Alberta’s interprovincial apportionment commitments were respected.
- An allowance was made for future municipal and industrial water demands.
- All established instream flow objectives were considered.

- Private irrigation demands included the existing licensed area and reservations for new irrigation blocks, as defined in the 1991 *South Saskatchewan Basin Water Allocation Regulation*.
- No new provincial flow regulation works were considered beyond the existing and committed works.
- For the Base Case Scenario, existing capacities were used for headworks infrastructure owned and operated by the province. For future scenarios, planned capacities of headworks infrastructure were used as limits for water deliveries.

b) WRMM Calibration

Integration and joint use of the IDM and WRMM were tested in calibration runs simulating the St. Mary Project for 1988 and the EID for 1994 to 1999. Adjustments were made to variable parameter settings until modelled gross diversions and return flows for the districts matched recorded data reasonably accurately. Insufficient historical data from other irrigation blocks precluded calibration in other districts.

3. Farm Financial Impact and Risk Model (FFIRM)

The FFIRM was used to determine the impacts of irrigation deficits in four selected scenarios on typical farm enterprises in various regions within the irrigation areas. Two additional scenarios were analysed using the FFIRM to verify certain conclusions drawn from model output.

a) FFIRM Approach

The climate of southern Alberta tends to influence the size of irrigation farms and the types of crops grown. In cooler regions with higher natural precipitation, irrigation farms are generally smaller and producers tend to irrigate primarily forage and cereal crops. In warmer, more arid regions, crop mixes are more diverse and include specialty crops such as corn, sugar beets and potatoes.

Six climate and crop regions were identified for analysis using FFIRM (Figure 31). Within each region, two to four typical types of farm enterprises, represented by crop and irrigation methods mixes, were considered in the analysis. The typical crop mixes were developed from crop statistics for 1999. The typical on-farm methods and crop mixes for each region used in the FFIRM analysis are provided in Figures 32 to 37 and in Table A-2 in the appendix.

FFIRM consists of two main components – a water application optimization component, and a farm financial simulation component. In the optimization component, the water demand and supply conditions for each year, derived from the IDM and WRMM, were reviewed to determine the optimal allocation of water among the two to four fields on the representative farms. In years when a water shortage occurred, the optimization routine allocated water on a priority basis to the crops that maximized financial returns to the farm.

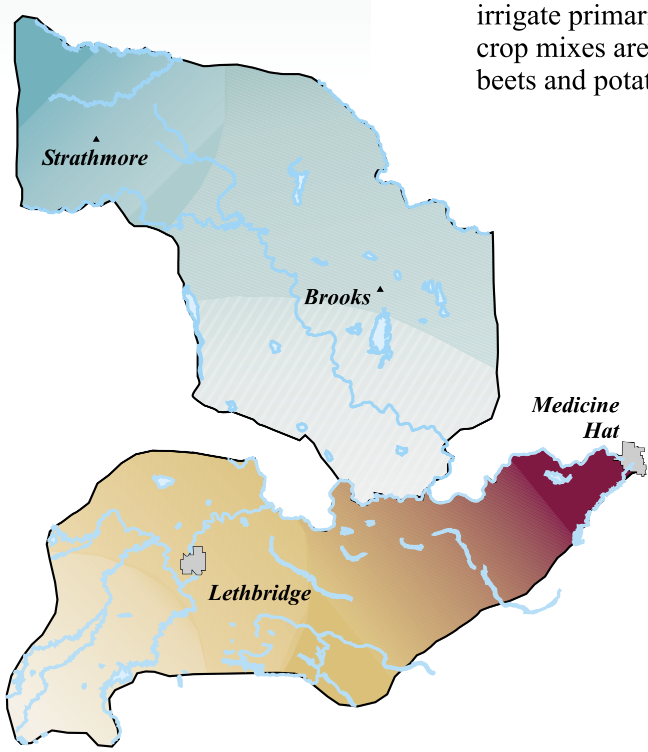


Figure 31. Climate and crop regions applied in FFIRM analyses.

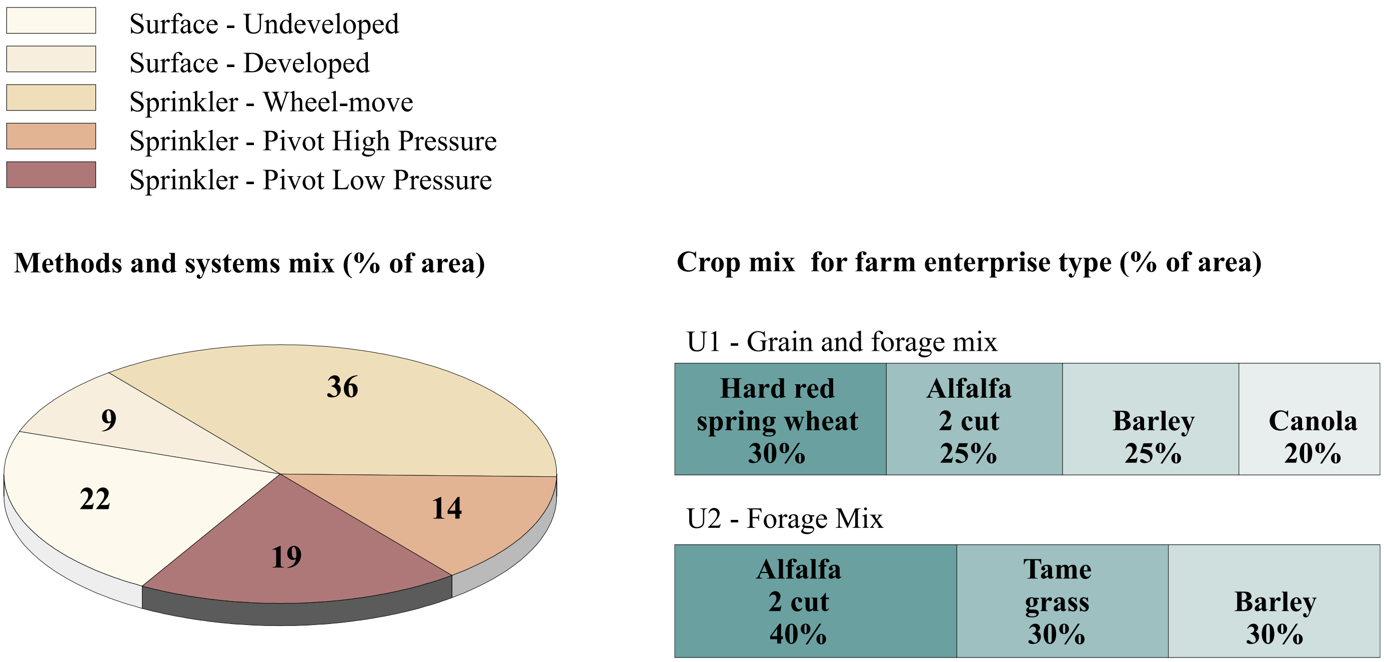


Figure 32. Mix of on-farm irrigation systems and crops for two farm enterprise types in the UID - MID area.

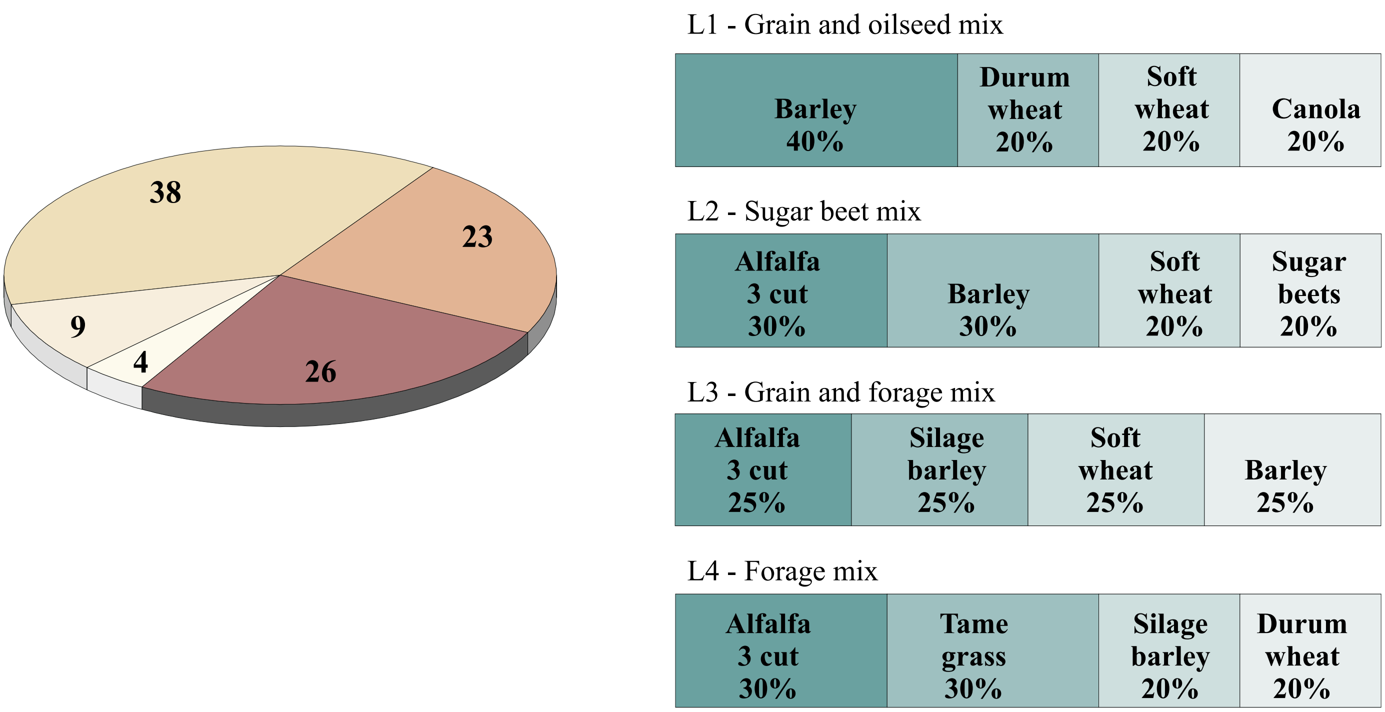


Figure 33. Mix of on-farm irrigation systems and crops for four farm enterprise types in the LNID, RID, and SMRID-W (Lethbridge area).

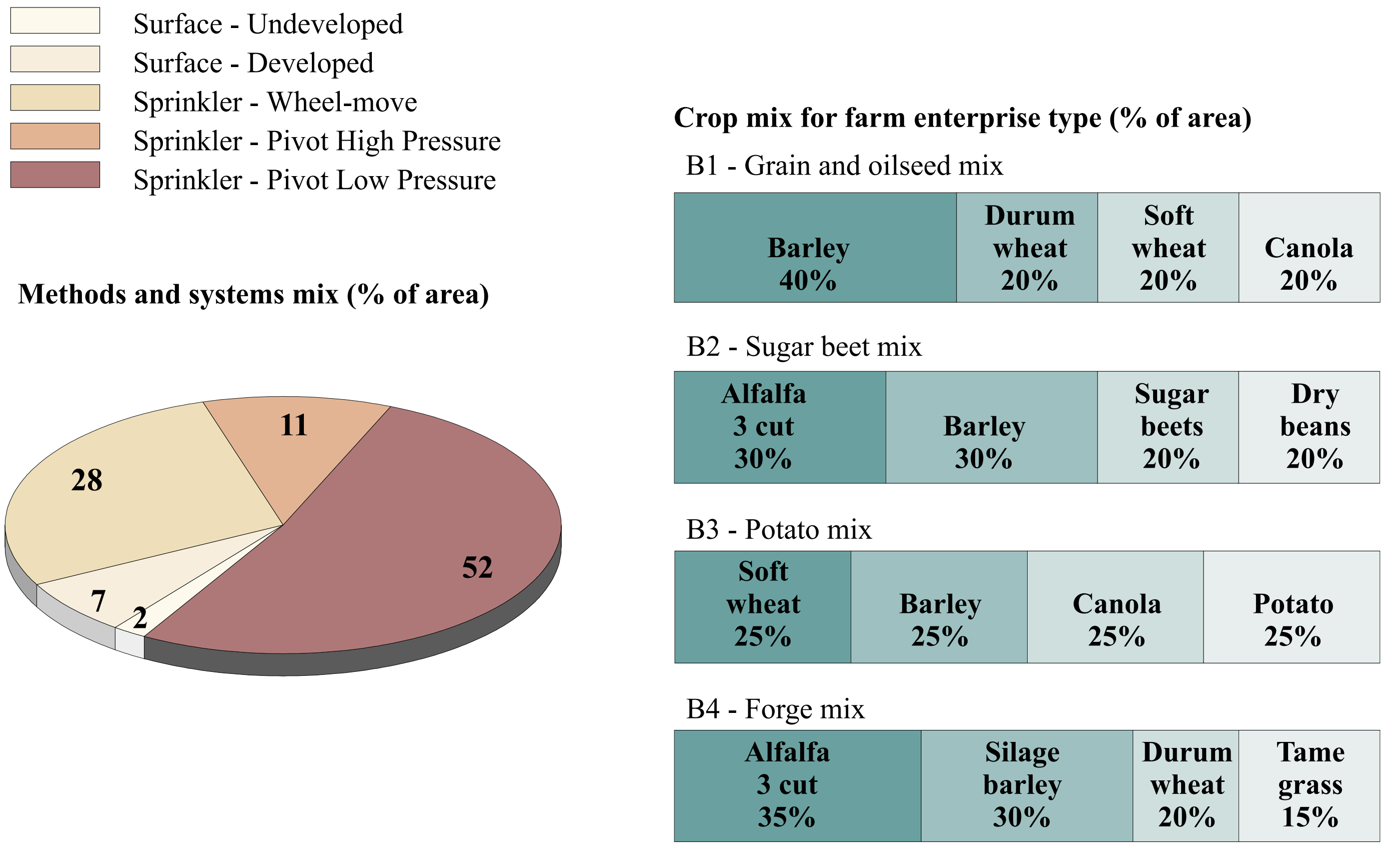


Figure 34. Mix of on-farm irrigation systems and crops for four farm enterprise types in the TID and SMRID-E (Burdett area).

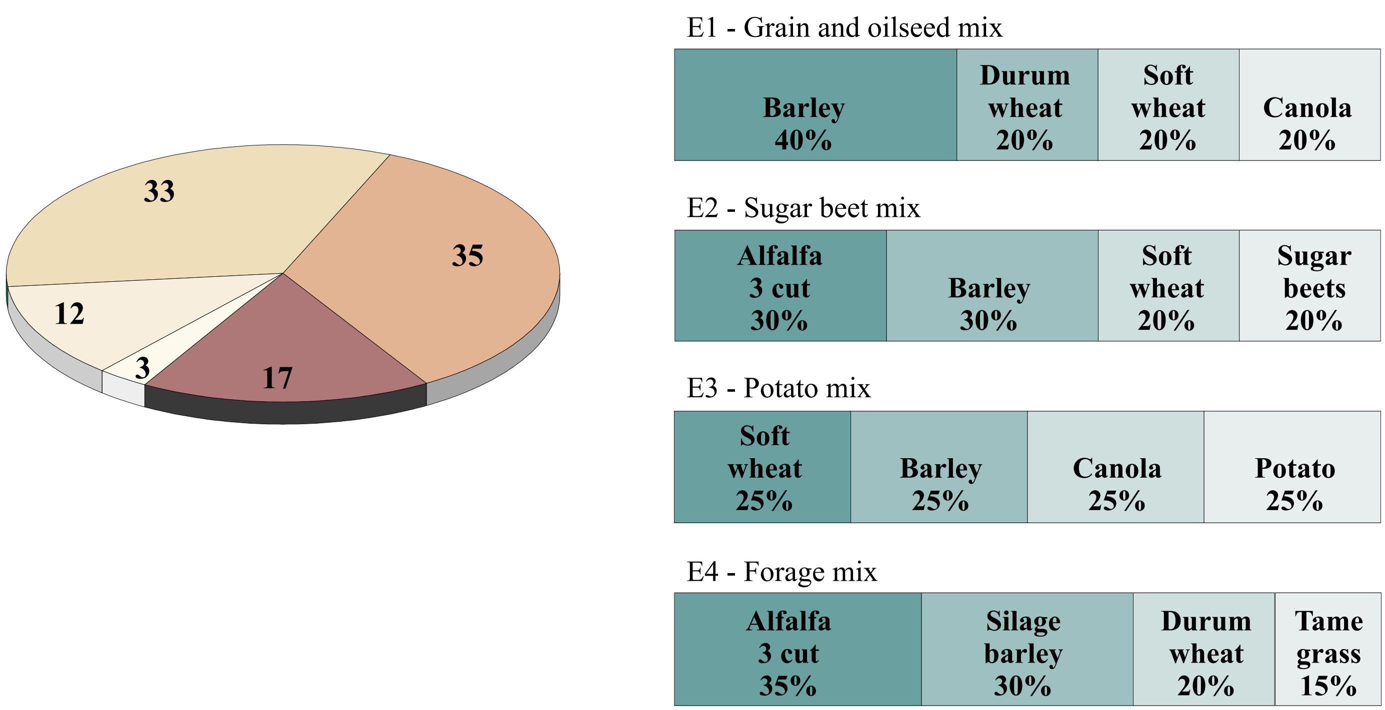
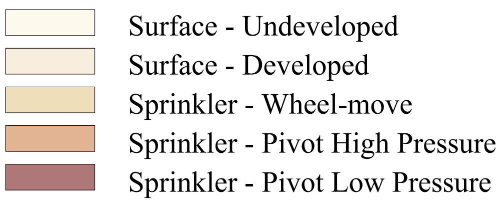
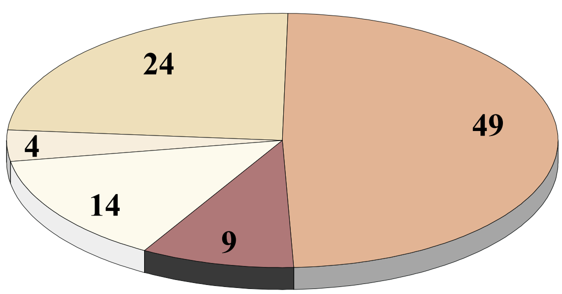


Figure 35. Mix of on-farm irrigation systems and crops for four farm enterprise types in the EID-S and BRID (Enchant area).



Methods and systems mix (% of area)



Crop mix for farm enterprise type (% of area)

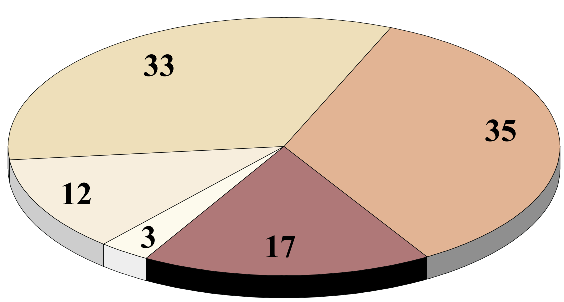
S1- Grain and forage mix

Hard red spring wheat 30%	Alfalfa 2 cut 25%	Barley 25%	Canola 20%

S2 - Forage mix

Alfalfa 2 cut 40%	Tame grass 30%	Barley 30%

Figure 36. Mix of on-farm irrigation systems and crops for two farm enterprise types in the WID-W (Strathmore area).



R1- Grain and oilseed mix

Barley 40%	Durum wheat 20%	Soft wheat 20%	Canola 20%

R2 - Grain and forage mix

Alfalfa 3 cut 25%	Silage barley 25%	Soft wheat 25%	Barley 25%

R3 - Forage mix

Alfalfa 3 cut 30%	Tame grass 30%	Silage barley 20%	Durum wheat 20%

Figure 37. Mix of on-farm irrigation systems and crops for three farm enterprise types in the WID-E and EID-N (Rosemary area).

The second component simulated the farm financial characteristics during the entire 68-year period, 1928 to 1995. The financial component tracked the costs and returns related to each individual field, as well as all farm financial accounts relating to depreciation, capital purchases and farm loans.

Three key performance indicators – net farm income (NFI), debt and equity levels – for the 68-year period are illustrated in Figure 38 for a grains and oilseed farm. The annual NFI was more often negative than positive. Consequently, the net worth of the farm generally declined and the debt increased. As the debt increased, interest costs increased, putting further downward pressure on NFI. Figure 39 shows the same information for a farm that includes a specialty crop within the mix. Annual NFI was highly variable, but usually positive. As a result, debt was eliminated with time, and the net worth of the farm continually increased.

b) FFIRM Assumptions

- **Irrigation Methods Mix** – Field inventory data for 1999 indicated the mix of on-farm application methods varied within the six regions. The methods affected on-farm efficiencies, capital and operating costs, and annual depreciation costs.

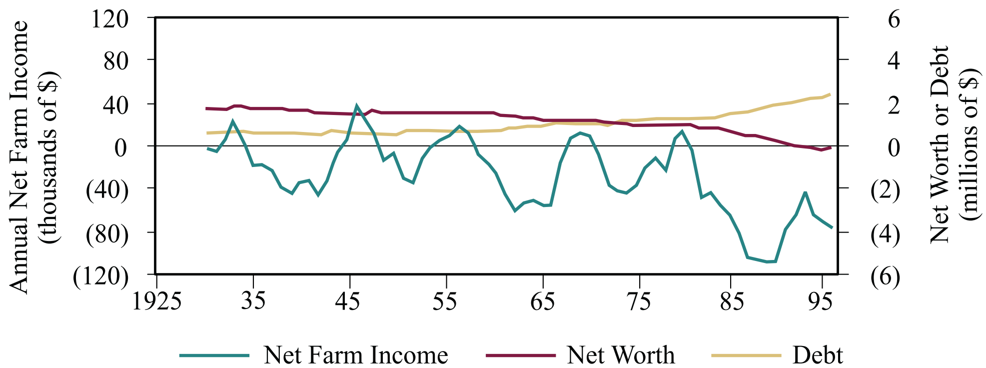


Figure 38. Financial performance of a grains and oilseeds farm.

Figure 39. Financial performance of a sugar beet farm.

- **Farm Debt Levels** – Three different opening debt levels were assessed for each representative farm. Debt level is an important factor in determining the risk of financial insolvency as a result of water supply shortages. Producers with higher debt levels are less able to withstand irrigation deficits. The opening debt to asset ratio for the Base Case was set at 15%. The medium and high opening debt to asset ratios were set at 35% and 50%, respectively.
- **Crop Prices** – Crop prices used in the financial simulations were based on the average prices experienced for the 10-year period from 1990 to 1999, expressed in 1999 dollars. These prices represent average price expectations for the future. Superimposed on these average prices were the actual variability of crop prices demonstrated during the 25-year period from 1975 to 1999.
- **Cost of Production** – Variable non-irrigation costs were based primarily on cost-of-production analyses conducted by AAFRD for irrigation farms in 1999 and 2000, as well as cost-of-production budget projections for 2001. Production costs included management and labour.
- **Set Crop Mixes** – The producer was assumed to have established the crop mix and crop inputs for the representative farm at the first of the year, before water shortage information becomes available. An indication of the impact of changing crop mixes in anticipation of water shortages can be assessed in a general sense by comparing financial returns across representative farm types.
- **Farm Revenue** – The model estimated only the revenue accruing from crop production. It did not provide any revenue from sources such as crop insurance or government farm income assistance programs.

c) FFIRM Calibration and Validation

The financial analysis results are a product of a wide range of input variables, including farm machinery complements, yield formulas, historical price data and cost-of-production profiles. Farm simulation runs were conducted to assess the performance of the FFIRM. Based on this preliminary assessment, various adjustments were made to the input variables, particularly with respect to some yield formulas and cost-of-production profiles.

d) FFIRM Evaluation Criteria

The FFIRM results can be used to compare the benefits and costs, at the farm level, of the Base Case Scenario (S1) to the other scenarios. The model generated a wide variety of farm financial measures. For details on the financial simulation model and measures of financial viability, refer to the technical reports in Volume 5. In this Summary Report, three financial measures are presented.

- **Risk of Insolvency** - The model estimates the likelihood representative farms would experience financial difficulties to the extent of facing insolvency. For the purposes of this analysis, the debt to asset ratio and the current ratio were used in tandem to evaluate the solvency/insolvency condition. The model farm was considered to be insolvent when the debt to asset ratio exceeded 0.6 (more than $0.60 of total debt per dollar of total assets) and the current ratio fell below 1.0 (less than $1 in current assets per dollar of current liabilities) at the same time.

Assessing the Risk of Insolvency –

Two criteria are used to assess the risk of insolvency:

- *Debt to asset ratio is the ratio of total farm debt to total farm assets. Total farm debt is the amount owing on all farm loans, plus additional interest owed on overdue payments. Total farm assets is cash on hand plus depreciated value of all buildings and equipment, plus value of farmland.*
- *Current ratio is the ratio of current assets to current liabilities, where assets is cash on hand, and liabilities is the year's required payments on all farm loans.*

Irrigation Area -
For the purposes of this study, irrigation area refers to the area developed or equipped to be irrigated. It is the area modelled in the IDM as having the potential to generate an irrigation demand for a given scenario.

- **Net Farm Income** - NFI is total revenue minus farm cash costs (excluding capital replacement costs) and minus depreciation. It is an indicator of the average profitability of the representative farms under different scenarios.

- **Probability of Negative Net Farm Income** - A higher risk of negative annual NFI increases the likelihood of farm financial difficulties, primarily through increased borrowing needs, and the risk of reduced credit ratings and higher loan rates. A new water supply scenario may indicate an increase in average NFI during the 68-year period. However, it is also possible there is an associated increase in income variability.

C. THE SCENARIOS

Simulation modelling was conducted to determine the impacts of various on-farm and district water management demand variables on the performance of the irrigation system, as well as the ability of the river basins to meet the demand. Modelling scenarios were formulated considering 1999 conditions, projected future conditions and various future management options. Variables considered in the scenarios included:

- Irrigation expansion;
- Shifts in crop mixes;
- Shifts in the mix on-farm irrigation methods;
- Increased irrigation applications to near optimum crop water requirements;
- On-farm system operating and application efficiency improvements; and
- Improved district water supply operations and reduced return flows.

System performance was evaluated based on:

- Crop irrigation requirements;
- On-farm losses;
- Irrigation district system losses;
- Return flows;
- Water supply deficits; and
- Economic impacts on farm enterprises.

Each planning scenario consisted of a set of assumptions, based on crop mix, on-farm equipment mix, on-farm management capability, distribution system efficiency, and irrigation area within the districts. Output identified the frequency and magnitude of deficits in delivery of the ideal requirements.

Ten scenarios, representing a variety of irrigation areas, crop mixes and levels of water management, both on-farm and within the districts, were formulated and modelled (Table 21). The variables considered were as follows.

Column (1): Irrigation Area – The area actually equipped to be irrigated in the districts in 1999 was used to represent the irrigation area in Scenario S1. In Scenarios S2 and S3, the 1991 *Regulation* limits of irrigation expansion were used for all districts except the EID. The EID negotiated an adjustment to their expansion limit from 111,293 hectares to 115,740 hectares. This adjustment was approved by Irrigation Council and is the irrigation area used in Scenarios S2 and S3, to give a total irrigation area for all districts, except Ross Creek, of 535,400 hectares. Scenarios S4, S5, S6, 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 21. Summary description of the various scenarios developed and analysed.[1]

Scenario Number	(1) Irrigation Area	(2) Crop Mix	(3) On-farm System Mix	(4) On-farm System Mgmt.	(5) Crop Water Mgmt.	(6) District Return Flow Mgmt.	Primary Purpose
S1.	1999[2]	1999	1999	1999	80% of optimum	1999	Determine water demand, supply deficits and risks to producers under 1999 irrigation conditions (**Base Case**).
S2.	1991 limit	1999	1999	1999	80% of optimum	1999	Determine impacts on demands and deficits with expansion to the 1991 *Regulation* limits, under 1999 irrigation demand and management conditions.
S3.	1991 limit	1999	1999	Improved	90% of optimum	Improved	Determine risks to producers of expansion to the 1991 *Regulation* limits, with projected improvements in on-farm and district management and near optimum crop water management.
S4.	1991 limit plus 10%	1999	1999	Improving	80% of optimum	1999	Determine water demand and supply deficits with 10% expansion beyond the 1991 *Regulation* limits, with projected improvements in on-farm management conditions.
S5.	1991 limit plus 10%	Future	1999	Improving	80% of optimum	1999	Determine water demand and supply deficits with 10% expansion beyond the 1991 *Regulation* limits, with a projected shift in crop mix.
S6.	1991 limit plus 10%	1999	Future	Improving	80% of optimum	1999	Determine water demand and supply deficits with 10% expansion beyond the 1991 *Regulation* limits, with a projected shift in on-farm irrigation system mix.
S7.	1991 limit plus 20%	1999	1999	Improving	80% of optimum	1999	Determine water demand and supply deficits with 20% expansion beyond the 1991 *Regulation* limits, with projected improvements in on-farm management conditions.
S8.	1991 limit plus 10%	1999	1999	Improved	90% of optimum	Improved	Determine impacts and risks to producers with 10% expansion beyond the 1991 *Regulation* limits, with improved on-farm and district management and near optimum crop water management.
S9.	1991 limit plus 10%	Future	Future	Improved	90% of optimum	Improved	Determine water demand and supply deficits with 10% expansion beyond the 1991 *Regulation* limits, with shifts in on-farm system and crop mixes, and near optimum crop water management.
S10.	1991 limit plus 20%	Future	Future	Improved	90% of optimum	Improved	Determine water demand and supply deficits with 20% expansion beyond the 1991 *Regulation* limits, with shifts in on-farm system and crop mixes, and near optimum crop water management.

[1]All scenarios were analysed using output from the IDM and WRMM. Highlighted scenarios are the primary focus of extensive analysis.
[2]'1999' = the weighted average in 1999.

The model runs assume the entire area in each scenario is irrigated every year. In practice, a portion of the land on the district assessment rolls is not irrigated. The percentage of unirrigated land varies from district to district and from year to year, depending on agro-climatic conditions, crop rotations, market conditions, and other factors.

Column (2): Crop Mix – The crop mix used for Scenarios S1 to S4, S6 and S8 is based on a crop mix distribution as grown in 1999 (Table 22). The future crop mix for Scenarios S5, 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.

Column (3): On-farm System Mix – The on-farm system mix includes irrigation systems (surface irrigation vs sprinkler irrigation) as well as types of on-farm equipment, all of which have a bearing on application efficiency. The Base Case system mix used in Scenarios S1 to S5, S7 and S8 was taken from the methods and systems used in 1999 (Table 22). The future system mix considered a shift from surface irrigation to sprinkler irrigation, and a shift toward low pressure centre pivot systems.

Column (4): On-farm System Management – The 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. Each system type has a range of efficiencies in delivering water to the soil root zone. The place where any individual water user's system falls within the range is a function of system design, soil, topographic and climatic characteristics, as well as management style and skill. A detailed 1999 inventory of on-farm systems throughout the irrigation districts indicated a potential weighted-average on-farm application efficiency of approximately 71% (Table 23). However, for modelling Scenarios S1 and S2, the on-farm system management level setting for 1999 conditions placed respective system application efficiencies at slightly less than their respective averages (*i.e.*, a weighted-average of approximately 68%). In Scenarios S4, S5 and S7, system management levels were assumed to be **improving,** with system application efficiencies modelled at an overall weighted-average efficiency of nearly 70%. For Scenario S6, the system management level was once again modelled as **improving**, but as a result of the projected shift in system mix to future conditions, the weighted-average system application efficiency applied was nearly 77%. For Scenarios S3 and S8, system management was projected to be **improved**, resulting in a weighted-average application efficiency of 71% for all districts. Scenarios S9 and S10 also reflect **improved** system management for all districts, but when combined with a projected shift in system mix, they provide results based on a weighted-average application efficiency of nearly 78%.

Column (5): Crop Water Management – Monitoring from 1996 to 2000 indicated that irrigated crops receive, on average, about 84% of the total moisture required for optimal yields. (Total crop moisture includes soil moisture, growing season precipitation and irrigation applications.) This level of irrigation management has increased during the past 10 years, and is projected to increase to as high as 90% of optimum, on average. An overall average application of 80% of optimum was used to represent 1999 crop water management in Scenarios S1, S2 and S4 to S7. Scenarios S3, S8, S9 and S10, used an application of 90% of optimum.

Table 22. Base Case (1999) and projected crop mixes.

Crop Type	Base Case Crop Mix	Future Crop Mix	
		Adjustment Factor	Mix
Cereals	33.4%	balance*	21.8%
Forages - Pasture	8.7%	0.80	7.0%
- Other Forages	29.9%	1.20	35.8%
Oil Seeds	9.5%	1.10	10.5%
Specialty Crops - Potatoes	2.4%	2.00	4.9%
- Sugar beets	3.2%	1.25	4.0%
- Fresh Vegetables	0.8%	3.00	2.4%
- Pulse	4.4%	1.35	5.9%
- Other Specialty Crops	7.7%	1.00	7.7%

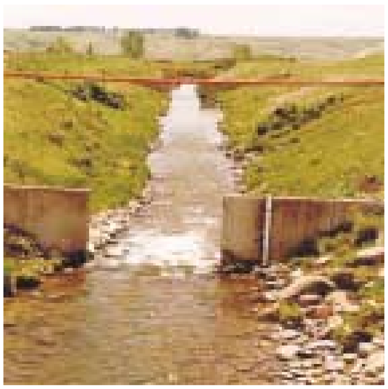
* Balance refers to the percentage of irrigation area converted from cereals to other crops.

Table 23. On-farm irrigation methods/system mixes and application efficiencies.

Method or System	On-farm Methods and Systems (%)			On-farm Application Efficiency (%)		
	1999 Mix	Future Mix		Efficiency Range	1999 Efficiency	Future Efficiency
		Adjustment	Mix			
Surface - Undeveloped	5.6	0.25	1.4	20 - 45	30	30
- Developed Uncontrolled	7.8	0.50	3.6	50 - 75	60	63
- Developed Controlled	3.0	1.50	4.4	70 - 85	75	80
Sprinkler - Hand Move and Solid Set	0.8	0.50	0.4	55 - 85	65	70
Sprinkler - 2 Lateral Wheel	21.7	0.30	6.5	65 - 80	67	70
Sprinkler - 4 Lateral Wheel	8.2	1.20	9.8	65 - 80	70	72
Sprinkler - HP Pivot, Linear[1]	18.1	0.25	4.5	70 - 85	74	76
Sprinkler - LP Pivot, Linear[1]	34.6	balance[2]	69.3	75 - 90	80	82
Volume Gun, Traveller, etc.	0.2	0.50	0.1	55 - 75	63	66
Micro-spray or Drip	0.01	1.50	0.01	70 - 95	82	87
Weighted-Average					71	78

[1] HP = high pressure; LP = low pressure.

[2] Balance refers to the percentage of irrigation area converted from other systems to low pressure (LP) pivot or linear systems.



Column (6): District Return Flow Management – The district return flow management variable is a function of several factors, including 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.

As district water management improves, return flow generally decreases, although there may be circumstances that make significant reductions in return flow more difficult to achieve in some districts than in others.

Return flow is comprised of operational spills, on-farm system downtime losses, drainage from irrigated fields, and base flow. Down-time losses and runoff from irrigated fields are primarily a function of on-farm irrigation methods and on-farm management. These two components of return flow were computed directly in the IDM based on the method mix and the level of on-farm water management assumed. The base flow component is the amount of flow required in canals and open pipelines (as opposed to pressure pipelines or closed systems) to keep the conveyance system hydraulically primed and to ensure the last user on the system has an adequate and accessible water supply. The amount of base flow in the districts is largely a function of district infrastructure and operations management. The 1999 base flow was determined in the model through a calibration process, by adjusting the base flow component until modelled return flow matched well with recorded return flow.

Future return flows were estimated based on the expected mix of methods, systems and reduced base flows that reflect an improved level of district return flow management. The degree of adjustment in base flow was based on an understanding of unique circumstances within each district, the levels of return flow reduction already accomplished in some districts, and expert judgement.

Modelling of each scenario involved three steps. The IDM was used to determine daily crop water requirements, farm gate delivery requirements, losses within the district works, return flow and total diversion requirements for the 51 irrigation blocks. The WRMM was used to determine the extent to which the total diversion requirements could be met, considering the natural flow regime of the South Saskatchewan River system, the capability of the water management infrastructure in the basin to regulate flows, and all other consumptive and instream water needs in the basin, according to their respective licensed priorities. Output from the WRMM runs was used to determine deficits in meeting total diversion requirements for each block and for each time step in the modelling period. FFIRM was used to determine the impacts of irrigation deficits from four selected scenarios on typical farm enterprises in various regions within the irrigation areas.

Results of the simulation modelling are presented and discussed in the following chapter.

D. CONCLUSIONS

The following key conclusions have been derived from irrigation water demand and financial impact modelling.

The simulation models developed in this study are excellent tools for evaluating the effects of changing water management variables on water demand and supply within the irrigation districts.

Irrigation systems are complex and variable. In order to effectively and accurately project the effect that any one change or combination of changes in variables may have on water demand and supply, extensive computations are required. The computer models developed in this study were proven to mathematically represent the demand and supply of water for various climatic and irrigation conditions in southern Alberta.

The models replicate actual water demand and supply conditions in southern Alberta to within approximately 1% of recorded data.

In order to verify that the irrigation demand and water supply models were capable of adequately representing actual conditions, the models were run for a series of years with well documented and extensive irrigation demands within the RID, SMRID and TID. Results showed that modelled irrigation diversions and reservoir storage changes were within approximately 1% of actual recorded data. Similar results were achieved using multi-year water auditing data from the EID.

A detailed 1999 crop and irrigation inventory identified the crop varieties and irrigation systems for all irrigation fields in each irrigation district. This database is essential for irrigation districts to assess water demands and to plan future irrigation development.

The inventory quantified the location and areal extent of 56 different crops grown and 18 different types of irrigation systems being used within the irrigation districts. This comprehensive database enhanced the accuracy of the irrigation water demand assessments. Inventory data also allowed the delineation of six climate and crop regions to support the characterization and financial modelling of various farm enterprise types within those regions. This database provides an excellent basis for further modelling and analysis by the irrigation districts.