Chapter VI

Potential for Irrigation Expansion

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This chapter discusses the water supply and demand relationship for each of the two major source basins, the Bow River Basin and the Oldman River Basin. The Bow River Basin includes three irrigation districts (BRID, EID and WID); the Oldman River Basin includes nine districts (AID, LID, LNID, MID, MVID, RID, SMRID, TID and UID). All districts in the Oldman River Basin, except the LNID, rely on the Waterton-Belly-St. Mary River system for their water supplies. The Oldman River is the source stream for the LNID. Ross Creek Irrigation District, which is part of the South Saskatchewan River Sub-basin, was not included in this analysis.

The water supply and demand relationship is unique for each individual district. It is dependent on numerous factors, including the hydrology of the source stream, capacities and locations of headworks and district storage, climate, on-farm and district efficiencies, and return flow. A detailed assessment of each individual district is essential for making district-specific decisions, but such an assessment is beyond the scope of this report.

In this chapter, the irrigation blocks are combined into districts, and districts into those supplied from the Bow River and those supplied from the Oldman River systems. Data averages presented for each basin are weighted by the irrigated area within each block. Irrigation deficits are presented in terms of the weighted frequency for various magnitudes of deficits. More detailed data, at the block and district level, are available to address specific issues and enquiries. Ten scenarios and three modelling components provided an extensive amount of data that could be analysed.

The results of each of the three modelling components, Irrigation District Model (IDM), Water Resources Management Model (WRMM), and Farm Financial Impact and Risk Model (FFIRM), will be examined separately, followed by a discussion of the integrated findings of all three modelling components for four selected scenarios.

A. ANALYSIS OF IDM IRRIGATION DEMAND DATA

The IDM determined the character of water demands for each scenario. Output from the IDM runs provides a breakdown of the water demand components.

- **Crop irrigation requirement** – the portion of the diverted irrigation water that is required for crop use.
- **On-farm losses** – the irrigation water lost in the on-farm application process due to evaporation, run-off and deep percolation.
- **District infrastructure losses** – irrigation water lost through district canal seepage and evaporation, reservoir evaporation, and tail-water flows that are not returned to a river system as return flow.
- **Return flow** – the portion of diverted water that passes through the irrigation district, due to on-farm system downtime, re-captured field run-off, and conveyance works base flow, and is then returned to a creek or river system.
- **Gross diversion demand** – the total water demand for the irrigation system at a primary river or reservoir diversion location. It is the sum of the above four components.

The crop irrigation requirement, on-farm losses and district infrastructure losses are components of the consumptive use of the irrigation system. The return flow component is part of the overall gross diversion requirement, but is returned to a river system and is available for downstream consumptive or instream use.

1. Comparisons with 1991 *Regulation* Licence Volumes

Figure 40 provides a comparison of the irrigation district licensing volumes determined for administering the 1991 *Regulation* with current and future irrigation water demands. The demands shown are the 90th percentile weighted-mean values for all 12 districts, consistent with the quantification process used in developing the licensing volumes in 1991 (see Table 4 and associated text). The comparison is based on the following six conditions.

- **1990** refers to 90th percentile irrigation district water uses as they were understood to be in 1990. These water uses served as a basis for developing the 1991 *Regulation* licence volumes.
- **Reg.** (*Regulation*) **Limit** shows the 90th percentile irrigation demand determined for administering the 1991 *Regulation*. The volumes were determined by adjusting the 1990 uses to reflect improvements in efficiencies and management.
- **S1** refers to the modelled demand for the 1999 actually-irrigated area (or area equipped to be irrigated) using current crop mixes, irrigation efficiencies and management practices.
- **S2** refers to the modelled demand for the 1991 *Regulation* irrigation area limits, with current (1999) crop mixes, on-farm and district efficiencies, and crop water application levels at 80% of optimum.
- **S9** refers to the modelled demand for the 10% expansion beyond the *Regulation* limits, with future crop mixes, improved irrigation efficiencies, and water application levels at 90% of optimum.
- **S10** refers to the modelled demand for the 20% expansion beyond the *Regulation* limits, with future crop mixes, improved irrigation efficiencies, and water application levels at 90% of optimum.

The graphics and discussion of water demands and deficits are expressed as depths of water per unit area of irrigation, using mm/ha, or mm.

Millimetres per hectare can be converted to a volume unit, cubic decametres (dam^3), by multiplying mm/ha by the irrigated area in ha, divided by 100 (dam^3=mm/ha x ha/100).

Base Case (S1) and future (S2, S9, S10) gross diversion demands, expressed in millimetres per irrigated unit area (Figure 40a), are considerably less than those used in determining the licence volumes for administering the 1991 *Regulation*. This is a result of significantly decreased crop water applications, reduced seepage losses and increased on-farm efficiencies. For the Reg. Limit Scenario, it was assumed 100% of the optimum crop water requirement would be applied. Current applications (S1 and S2) average about 80% of optimum. Future applications (S9 and S10) are expected to increase to 90% of optimum. Reduced

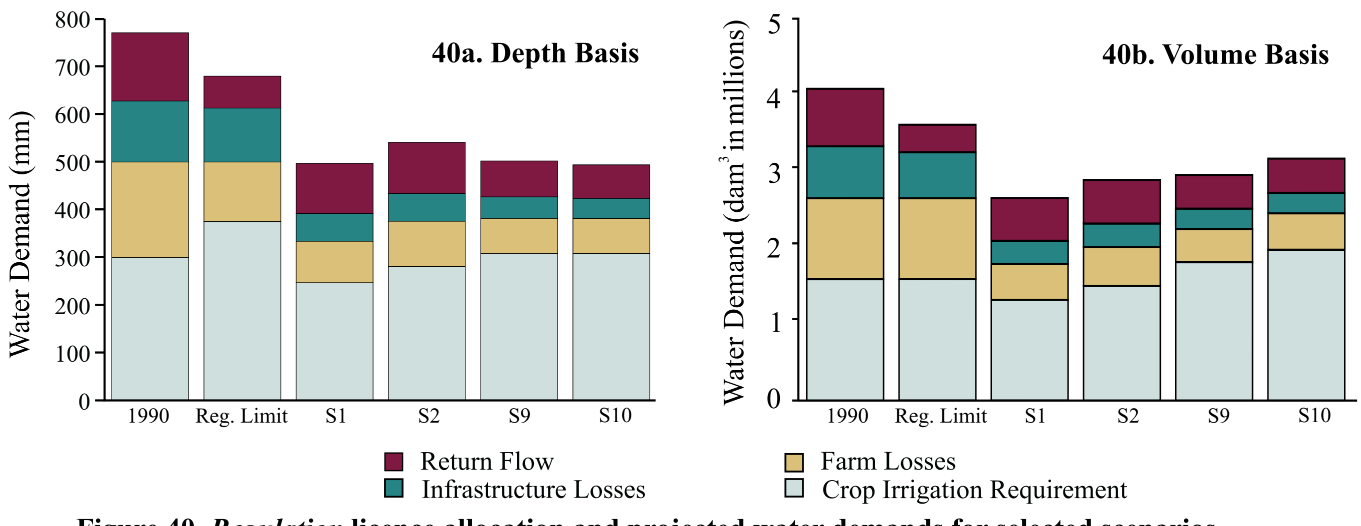

Figure 40. *Regulation* licence allocation and projected water demands for selected scenarios. (All values represent 90th percentile weighted-means for all districts.)

current and future seepage losses are due to canal rehabilitation, extensive replacement of canals by pipelines, and over-estimation of seepage losses due to a lack of reliable data in 1991. Increased on-farm efficiencies are due to continual upgrading of irrigation methods and systems, and improved on-farm management. Current and future return flows are as high or higher than those assumed for the 1991 *Regulation*.

IDM output shows that, with improved efficiencies and crop water application at 90% (Scenario S10), an irrigation area 20% larger than the 1991 *Regulation* limits could be irrigated with less water than proposed for administering the 1991 *Regulation* (Figure 40b). This conclusion does not apply equally to all districts. Nor does it consider any aspects of water supply and the needs and priorities of other water users. All districts in the Oldman Basin have licence water allocations equal to the *Regulation* licence volumes developed in 1991. In the Bow Basin, the WID and BRID do not have licenced allocations for those volumes, though both districts have applied for additional allocations. The EID has a licence volume greater than the volume determined in 1991. However, a portion of their allocation is for diversions during the non-irrigation season. The EID has applied for an amendment to their licence to better reflect irrigation needs.

2. Basin Specific Variations

Figure 41 shows individual scenario **weighted-mean demand**, in depth of water per hectare, for the Bow and Oldman basins. On average, the irrigation districts served from the Oldman Basin require 25% to 30% less water per unit of irrigation area than the districts served by the Bow River. In both basins, the crop irrigation requirement and on-farm losses are approximately equal. However, infrastructure losses and return flows are substantially higher in the Bow Basin. Evaporation losses from district reservoirs in the Bow Basin are almost double those of the Oldman Basin, due to almost double the surface area. Return flow in the Bow Basin is 200% to 250% greater than in the Oldman Basin districts. The reasons for increased return flow in the Bow Basin are district-specific and include lower-density districts (as measured in the ratio of irrigated area to length of conveyance works), the greater percentage of surface irrigation, and the lack of strategically located storage reservoirs to capture unused irrigation water deliveries.

The IDM water demand output for all scenarios is summarized in Table A-3 in the appendix.

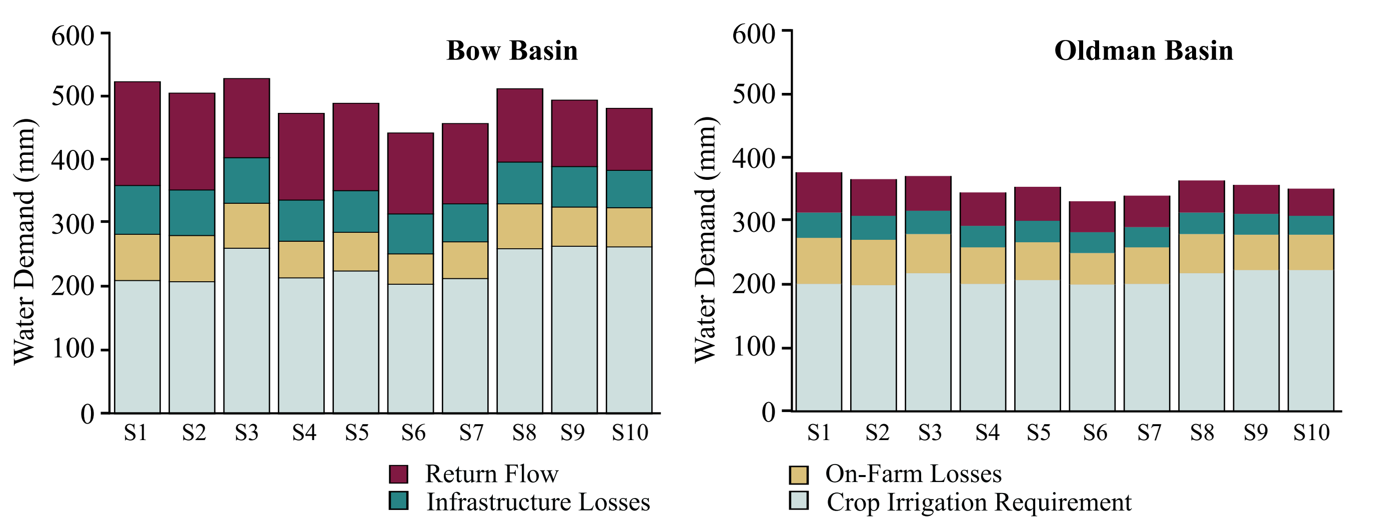

Figure 41. Modelled weighted-mean irrigation water demands for 10 water management scenarios.

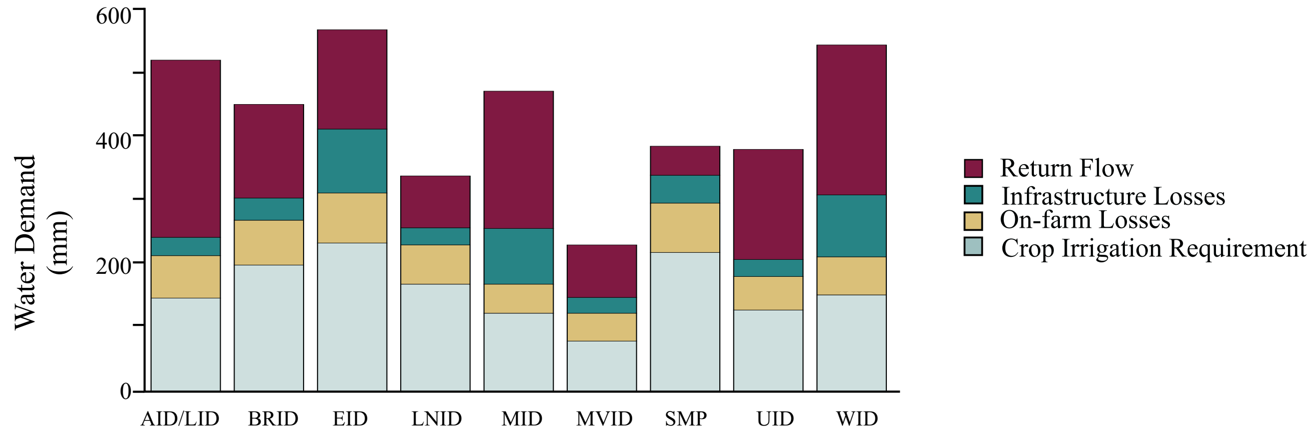

Figure 42. Modelled irrigation district mean annual gross diversion demand for Scenario S1.

3. District Specific Variations

Water demand for Scenario S1, representing current (1999) conditions for each district or for district groups, is presented in Figure 42. The mean gross diversion demand, in depth of water per irrigated unit area, varies widely among the districts. It ranges from a low of about 230 mm in the MVID to highs of about 570 mm and 550 mm in the EID and WID, respectively. There is also a wide range in the contribution of each water demand component to the gross diversion. For instance, return flow ranges from a low of about 12% of the gross diversion in the St. Mary Project (combined return flows from the St. Mary, Raymond and Taber Irrigation Districts), to a high of 53% in the AID and LID. Infrastructure losses range from a low of about 5% of the gross diversion for the AID and LID, to highs of about 18% for the MID, WID and EID.

Table A-4 (Appendix) summarizes the gross diversion and component demands for each of the nine districts or district groups for Scenario S1.

4. Variation in Water Use Efficiencies

Figure 43 shows mean annual irrigation demand as a percentage of the gross diversion demand for each scenario. The crop irrigation requirement for districts in the Oldman Basin ranges from 53% to 63% of the gross diversion demand. For districts in the Bow Basin, the crop irrigation requirement ranges from 41% to 52% of the gross diversion, reflecting higher losses and return flow.

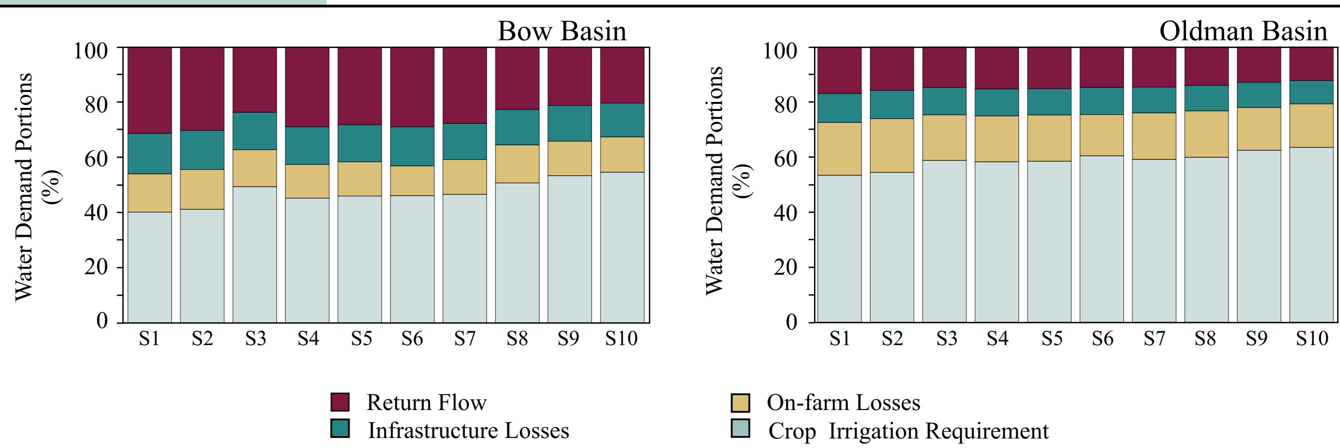

Figure 43. Modelled weighted-mean irrigation water demand as a percentage of gross diversion.

The crop irrigation requirement is generally a progressively increasing portion of the total diversion demand for Scenarios S1 to S10 for several reasons.

- Increases in on-farm and district efficiencies, and reduced return flow, primarily as a result of improved on-farm and district management, more efficient irrigation equipment and methods, and rehabilitation of district works, including more pipelines and automation of structures.
- Increases in water application rates from 80% of optimum crop requirements in Scenarios S1, S2, and S4 through S8, to 90% of optimum in Scenarios S3, S9 and S10.
- Irrigation expansion, primarily by in-fill within the existing serviced area and minimal new district infrastructure. This results in more compact districts and lower infrastructure losses and return flow when expressed in terms of depth of water per unit of irrigated area.
- Changes in crop mixes in Scenarios S5, S9 and S10 that increase the overall crop irrigation requirements.

Most efficiency improvements reflected in the scenarios are extensions of current trends that are expected to continue.

5. Impacts of Water Management on Gross Diversion Demand

Table 24 summarizes the effects on the total diversion demand of individual, one-at-a-time changes in irrigation management measures. Changes in irrigation areas and impacts of management measures are referenced to the Base Case (S1).

An estimate of the gross diversion demand, generally within plus or minus 1.0%, can be made by adjusting the Scenario S1 gross diversion demand by the percent change impact of a single management measure or a combination of several management measures. For example, the expansion to 10% more than the 1991 *Regulation* limits (a 20.1% expansion beyond the 1999 irrigation area) would increase the gross diversion demand by 13.4% compared to 1999 conditions. If that expansion were accompanied by a continuing shift to more efficient on-farm systems, improved on-farm management, as well as reductions in district return flow, the gross diversion demand would be reduced to just 1.4% more than the 1999 requirements (13.4 - 5.7 - 3.0 - 3.3 = 1.4).

Table 24. Impacts of management decisions on gross diversion demand.

Management Variable	Irrigation Area (ha)	Expansion from Base Case (S1) (%)	Gross Diversion Demand (dam^3)	Change in Gross Diversion (%)
Base Case - 1999 conditions	**490,385**		**2,187,018**	
Expansion to 1991 *Regulation* limit	**535,400**	**9.2**	**2,305,681**	**5.4**
Expansion to 1991 *Regulation* plus 10%	**588,939**	**20.1**	**2,479,483**[1]	**13.4**[1]
Expansion to 1991 *Regulation* plus 20 %	**642,479**	**31.0**	**2,623,666**[1]	**20.0**[1]
Crop Mix Shift[2] (increasing proportion of forage and specialty crops)				**3.1**
System Mix Shift[2] (increasing proportion of higher efficiency sprinkler systems)				**-5.7**
On-farm System Management Efficiency Improvements[2]				**-3.0**
Increase toward On-farm Crop Water Optimization[2]				**9.5**
Improvements in District Return Flow Management[2]				**-3.3**

[1] Values represent changes resulting exclusively from the expansion variable. Actual expansion scenario modelling reflects minor on-farm system management improvements (Table 23).

[2] Variables that can be applied in combination with any of the other management variables. The percentage change in gross diversion is referenced to the Base Case.

A crop mix shift and increasing on-farm water applications would, in turn, increase the gross diversion demand to 14.0% more than 1999 requirements (1.4 + 3.1 + 9.5 = 14.0).

Table 24 can be used to indicate the projected impact of various management measures as a weighted average for all districts. For individual districts, the impact of such measures may be substantially different than shown in the table.

B. ANALYSIS OF WRMM WATER DEFICIT DATA

The WRMM and IDM were used in tandem to determine the magnitude, frequency and duration of water supply deficits in the 10 scenarios. To compare the performance of the scenarios, a “deficit index" was computed for each scenario and for each basin (Appendix Tables A-5 and A-6). The deficit indices are expressions of the percentage of years that deficits within certain magnitudes would be experienced if all districts within each basin, and all irrigation blocks within each district, had an equal chance of experiencing those deficits. However, due to differences in water licence priorities, and the location and size of headworks and district storage reservoirs, not all districts and all blocks within districts have the same deficit probability. Hence, the deficit indices should be used only to compare the relative performance of the scenarios, rather than as an absolute measure of the magnitude and frequency of deficits.

The deficit indices within each magnitude class were ranked from lowest to highest. Generally, deficit rankings across all magnitude classes are consistent within a given scenario. Therefore, the deficit indices for any one magnitude class provide a quick overview comparison of scenario performance. Figure 44 summarizes scenario performance using the deficit indices for deficits greater than 100 millimetres. The figure shows:

- Deficits are substantially higher in the Oldman Basin than in the Bow Basin for most scenarios; and
- In both basins, deficits are the lowest in Scenario S1, representing 1999 conditions. In the Bow Basin, deficits are highest in Scenario S8, with 10% expansion from the 1991 *Regulation* limits*,* using 1999 on-farm and district efficiencies, but irrigating to meet 90% of crop water requirements. Scenario S10, with 20% expansion, but with improved efficiencies, has slightly lower deficits than S8. In the Oldman Basin, deficits are highest in Scenario S10, with 20% expansion beyond the 1991 *Regulation* limits.

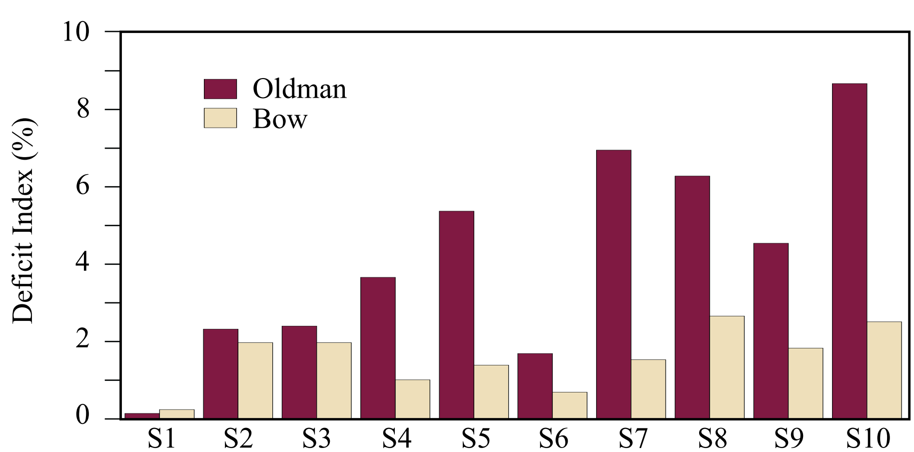

Figure 44. Scenario performance for deficits greater than 100 mm.

The impact of water supply deficits is a function of the degree to which crop yields are affected, and is thus highly dependent on crop type. Figure 45 illustrates the diminishing yields for various crop types under a variety of deficit levels. For instance, a 125-mm deficit would have a relatively small effect on yields of alfalfa or canola, but a drastic impact on dry beans, tame hay or barley. Determining the impacts of deficits on farm enterprises would bring into play a number of other farm-specific factors. FFIRM runs are required to assess the impacts of deficits on farm enterprises under a variety of circumstances.

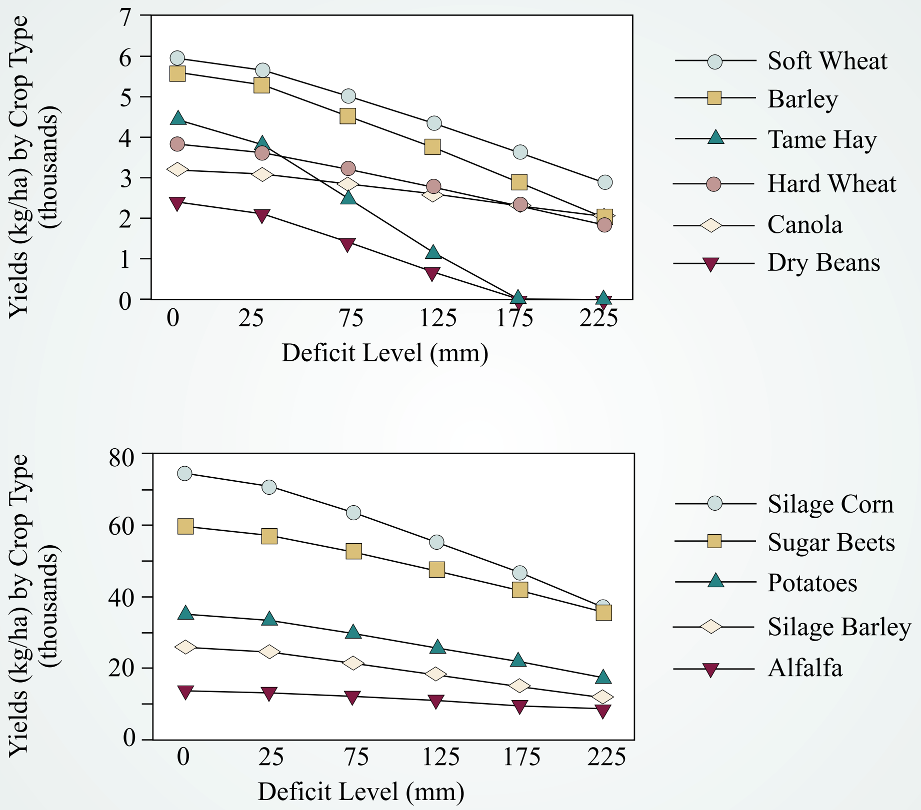

Figure 45. Yield response to irrigation deficits for various crop types.

C. ANALYSIS OF FFIRM OUTPUT ON IMPACTS OF IRRIGATION DEFICITS

FFIRM runs were conducted for six climate and crop regions, two to four typical types of farm enterprises within each region (as determined by crop mix), and three different starting debt levels. In total, 57 different farm enterprises were assessed for seven scenarios – S1, S3, S4, S7, S8, S9 and S10. FFIRM tracks the farm financial characteristics during the entire 68-year period, 1928 to 1995.

Key performance indicators are net farm income, debt and equity levels, and the likelihood of financial insolvency of the farm enterprise. Analyses of the output from the FFIRM runs led to the following key findings.

Crop Mix – Farms that rely only on cereals and oilseeds were significantly less profitable than farms that also produced specialty crops or forages (Figures 38 and 39). Including a higher value crop provided the opportunity to optimize returns in deficit years by shifting water applications from low value crops to higher value crops.

Farm Debt Level – Farms with high starting debt levels had considerably reduced net farm incomes over time. These farm types, particularly cereals and oilseed farms, generally had low net farm income (NFI). High starting debt levels considerably increased their risk of financial insolvency. High starting debt levels also reduced NFI of farms that included a specialty crop in their mix, but these farms were better able to deal with higher interest costs due to higher crop revenues.

Irrigation Water Application Levels – For scenarios that maintained the current level of crop water application (80%), such as S4 and S7, most farm enterprises experienced a significant decrease in average NFI from 1999 (S1) conditions (Figure 46). This is due to more frequent water deficit years as a result of irrigation expansion, and lower incomes in those years. The risk of insolvency either remained the same or increased slightly (Figure 47).

Most farm types would experience a higher average NFI with time under water management Scenarios S3, S9 and S10. Higher average incomes are due to the higher on-farm water application level (90%), in combination with improved on-farm and district water management efficiencies (Figure 48). Because of higher revenues in the non-deficit years, producers would be in a better position to withstand lower revenues in the deficit years. The risk of insolvency remained the same or decreased marginally (Figure 49). For scenarios S9 and S10 to be favourable from a farm financial perspective, all water management related improvements would have to be fulfilled, particularly the increased water applications.

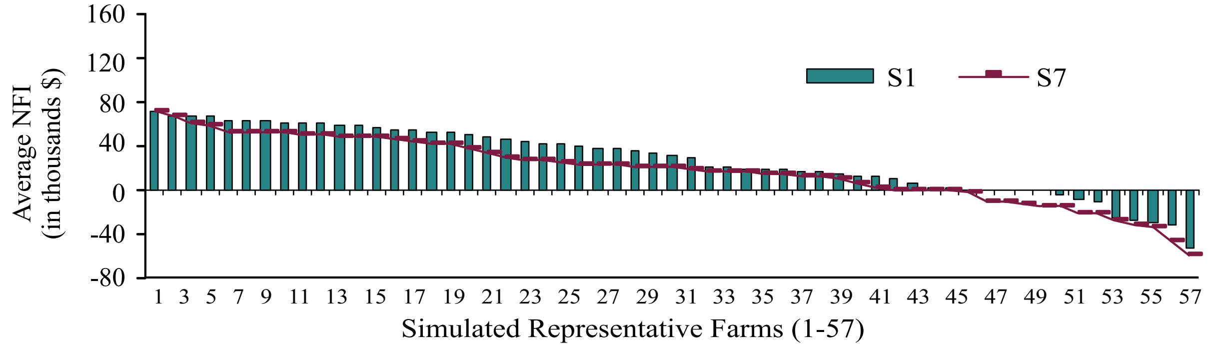

Figure 46. Average net farm incomes for Scenarios S1 and S7.

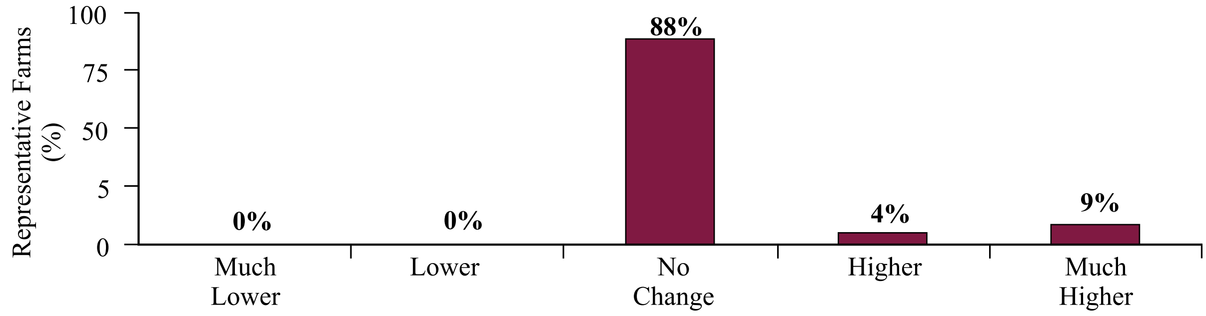

Figure 47. Risk of insolvency for Scenario S7 compared to S1.

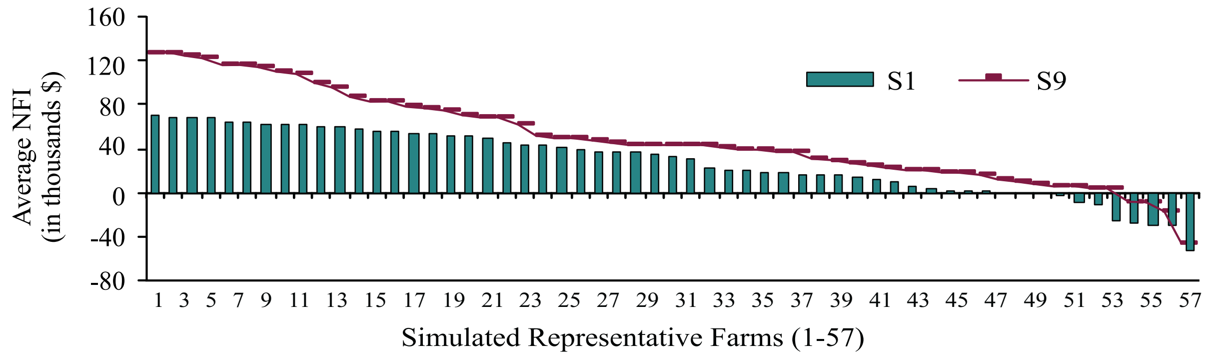

Figure 48. Average net farm incomes for Scenarios S1 and S9.

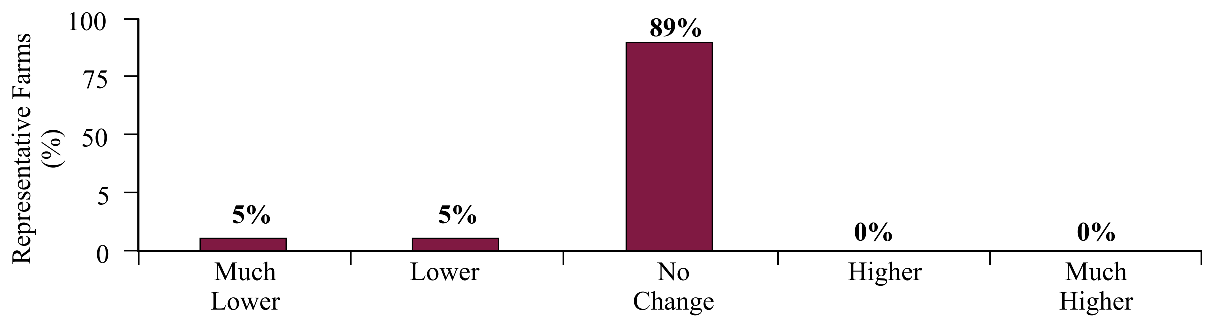

Figure 49. Risk of insolvency for Scenario S9 compared to S1.

D. DETAILED ASSESSMENT OF SELECTED EXPANSION SCENARIOS

Scenarios S1, S3, S9 and S10 were examined in detail with respect to water demand and supply, and the impact of water deficits on farm financial sustainability. Scenarios S3, S9 and S10 represent future conditions, with:

- increasing levels of irrigation expansion;
- improved on-farm and district efficiencies;
- changing crop mixes; and
- increased levels of crop water application.

Scenario S1 represents 1999 conditions and is presented as a basis for comparison.

Profiles of modelling output for irrigation districts in the Bow and Oldman basins are provided for each scenario in Figures 50 to 54. Each figure has four parts. Parts a) and c) deal with the Bow Basin districts; parts b) and d) with the Oldman Basin districts. The profiles include 68-year histograms showing the irrigation water demands and deficits in the river basins (parts a and b); and a bar graph showing the probability of deficits of various magnitudes, a line graph showing the areal extent of the deficits, a line graph showing the average net farm incomes for each representative farm modelled in the Bow and Oldman basins, and a line graph showing the probability of negative net farm incomes in any one year (parts c and d).

The teal-colored bars in each histogram show the variation in the annual weighted-average irrigation demand, as determined using the IDM. The weighted-average demand for the entire 68-year period is shown as black horizontal dashed lines.

There is considerable variation in total demand from one year to another, due in large part to the annual variation in weather conditions. Growing season precipitation on the irrigated lands has the greatest influence on irrigation demand. Evapotranspiration is also a factor, but usually of lesser significance. Deficits usually correspond to low runoff years caused by below average mountain snow pack and rainfall. Depleted soil moisture and reservoir storage from previous years can also have a significant effect on deficits.

The extent of any shortfall in water supply, as determined by the WRMM, is shown as red bars, superimposed over the teal demand bars. The red horizontal dashed lines show the weighted-average *Regulation* licence water allocation for all the irrigation districts supported by the basin. The licence volumes were determined in 1991 when the irrigation expansion guidelines were established. It provides a reference to indicate the extent to which the annual demand for each scenario approaches or exceeds the proposed allocations. All districts in the Oldman Basin are licensed up to the 1991 licence allocations. Not all districts in the Bow Basin are licensed to that extent, although applications have been made and are under review.

The deficit frequency graphs show the probability of one or more irrigation blocks in the basin experiencing deficits of various magnitudes. For instance, there would be a 6.5% probability that irrigation blocks in the Bow Basin would experience a deficit between 1 mm and 50 mm (Figure 50c). There would be an 8.5% probability that a similar deficit would occur in the Oldman Basin (Figure 50d). The deficit frequency graphs provide a little more insight into the frequency and magnitude of deficits that do not show up in the histograms. The bar graphs are based on the same deficit data as the histograms, without the diminishing effect of averaged deficits for all blocks in the basin.

The areal extent of deficits graphs show how wide spread deficits of various frequencies and magnitudes would be within a basin. For instance, Figure 50c shows that in 30 years out of 68, a deficit of between 1 millimetre and 50 millimetres would occur on less than 20% of the irrigated land in the Bow Basin. A deficit of between 51 and 100 millimetres would occur in three out of 68 years on less than 20% of the irrigated land.

Graphs also show the average NFI during the 68-year period for each of the representative farms that were simulated using the FFIRM. In the Bow Basin, a total of 27 farms were simulated; in the Oldman Basin, 30 farms were simulated. Each farm differed on the basis of agro-climatic region, crop mix and/or the starting farm debt and asset level. Average NFI for all the representative farms has been sorted from lowest to highest. This permits an easy assessment of the overall financial outcome for each basin and scenario. The figures also show the results for Scenario S1 to provide a direct comparison with Scenarios S3, S9 and S10. Because of the sorting, the results for specific farms are not necessarily plotted in the same order for each scenario.

Graphs also show the probability of negative NFI in any one year for the representative farms. 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. The graphs for Scenarios S3, S9 and S10 show the results for Scenario S1 for comparison purposes. A scenario line lower than the S1 line indicates the scenario would have less risk of negative NFI than currently experienced.

Each set of graphs includes a discussion of the significant findings and comparisons for each scenario and basin. The discussion is continuous throughout the four pages for each scenario. The detailed discussion of the four scenarios in this chapter capture the full range of option combinations related to irrigation expansion and water management. Six additional scenarios were simulated to provide a more complete understanding of the impacts of individual management measures. Histograms showing annual demands and deficits, and graphs showing the deficit frequencies and areal extent for the six additional scenarios modelled (S2, S4, S5, S6, S7, and S8) are included in the Appendix as figures A-1 through A-12.

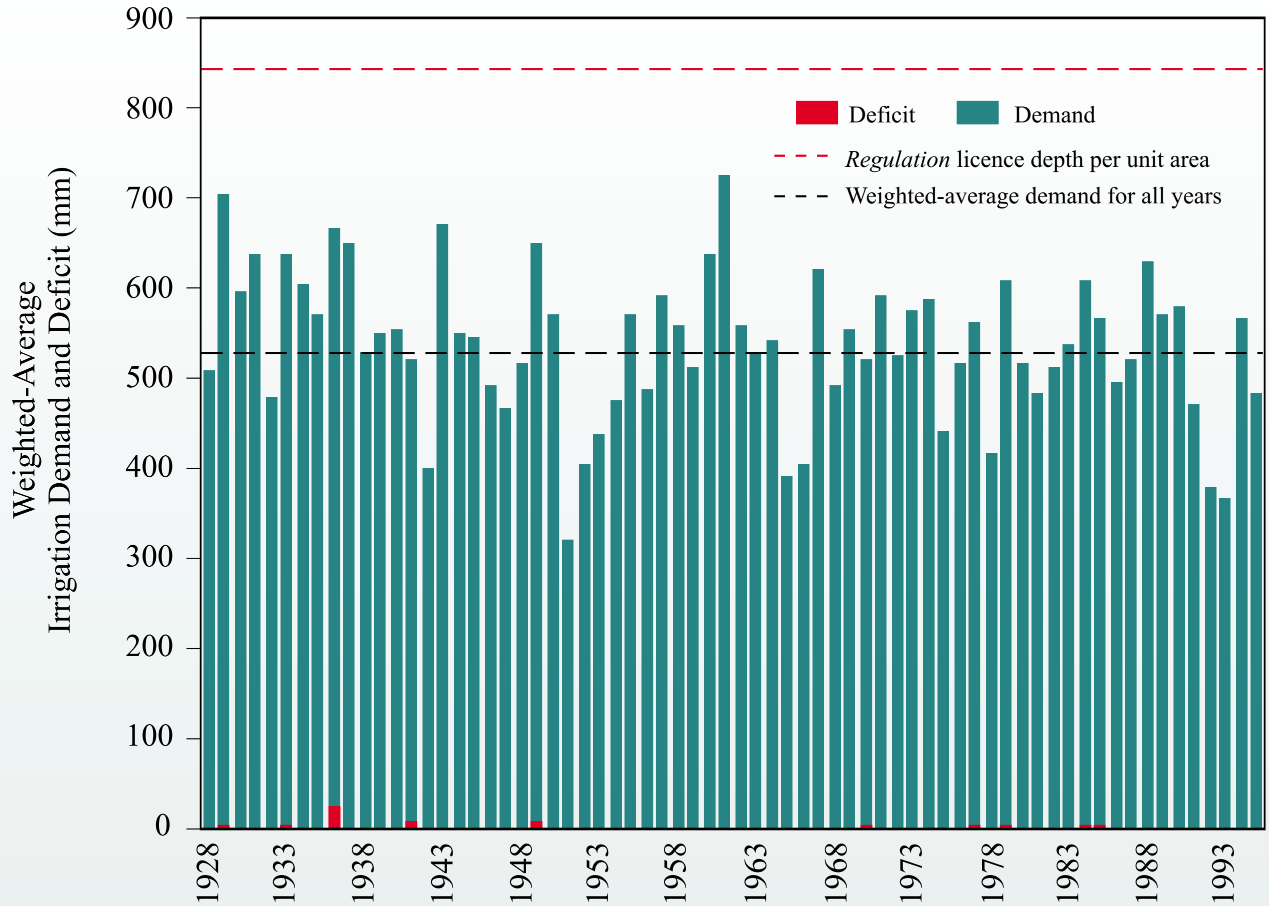

Figure 50a. Scenario S1 total demands and deficits - Bow Basin districts.

Scenario S1 - Base Case (1999) Conditions	
Irrigation area:	
Bow Basin	221,526 hectares
Oldman Basin	268,859 hectares
Crop mix	1999
On-farm system mix	1999
On-farm management	1999
Crop water management	1999
Return flow management	1999
1991 *Regulation* licence volume:	
Bow Basin	1,881,088 cubic decametres
Oldman Basin	1,738,003 cubic decametres
Scenario weighted-average demand:	
Bow Basin	1,165,466 cubic decametres
Oldman Basin	1,021,552 cubic decametres

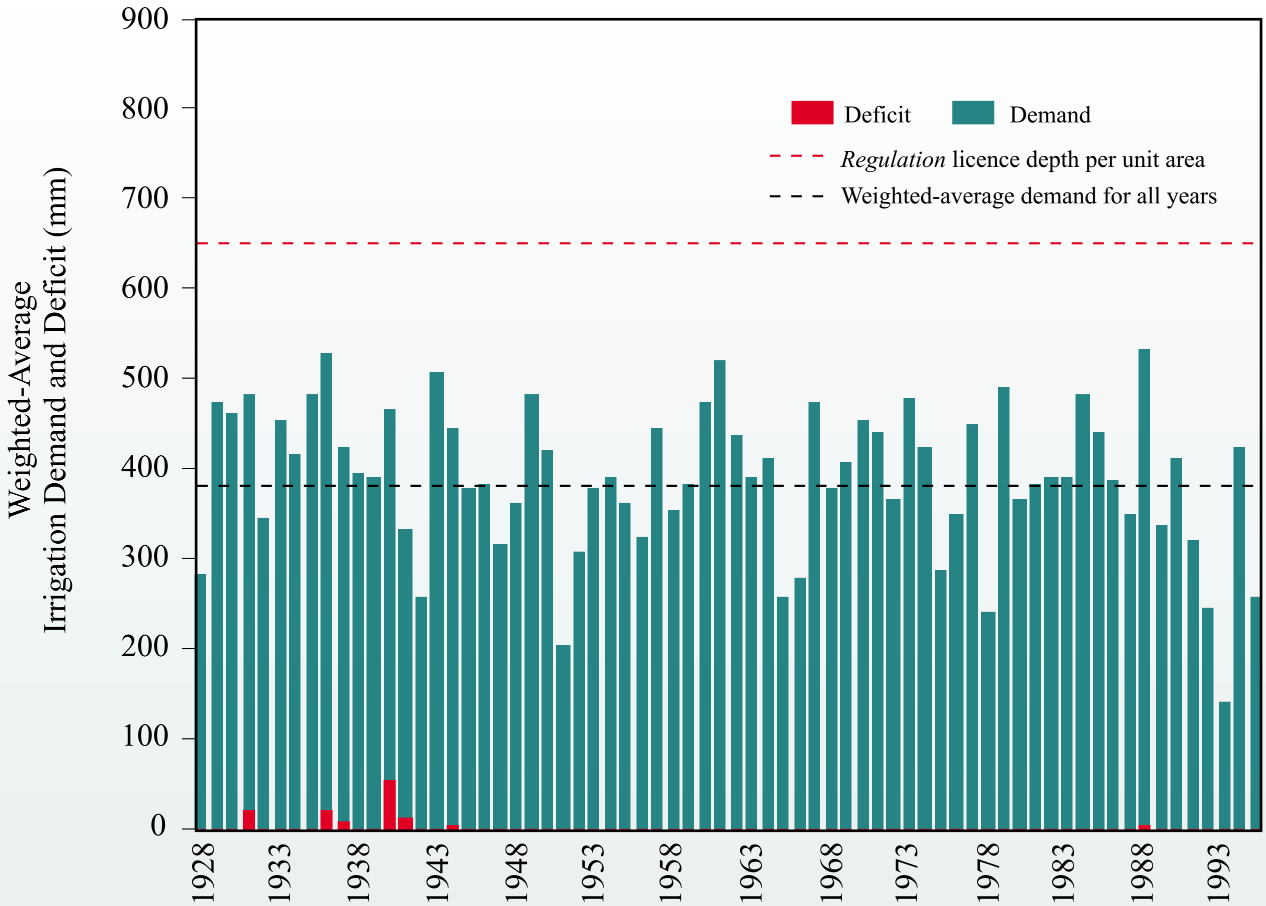

Figure 50b. Scenario S1 total demands and deficits - Oldman Basin districts.

Discussion of Results

The weighted-average unit demand for the 68-year period is 526 mm in the Bow Basin and 380 mm in the Oldman Basin. The higher total unit demands in the Bow Basin are primarily due to higher evaporation losses from reservoirs and much higher return flows than for the Oldman Basin districts. The variability in demand in the two basins is about the same. The 1991 licence allocation is well above the demands in all years, in both basins.

The modelling shows occasional deficits would be experienced in the Bow Basin, but their frequency and magnitudes would be low and their impacts insignificant. Deficits would be slightly higher in both magnitude and frequency in the Oldman Basin, but still insignificant. It is generally considered that deficits up to 50 mm are of little consequence in terms of overall irrigation production. Deficits greater than 100 mm are significant.

In this and other scenarios, deficits within some districts and some irrigation blocks would be higher than the weighted averages. The deficit-frequency graphs show deficits would be small and infrequent in both basins. Deficits greater than 100 mm would be rare.

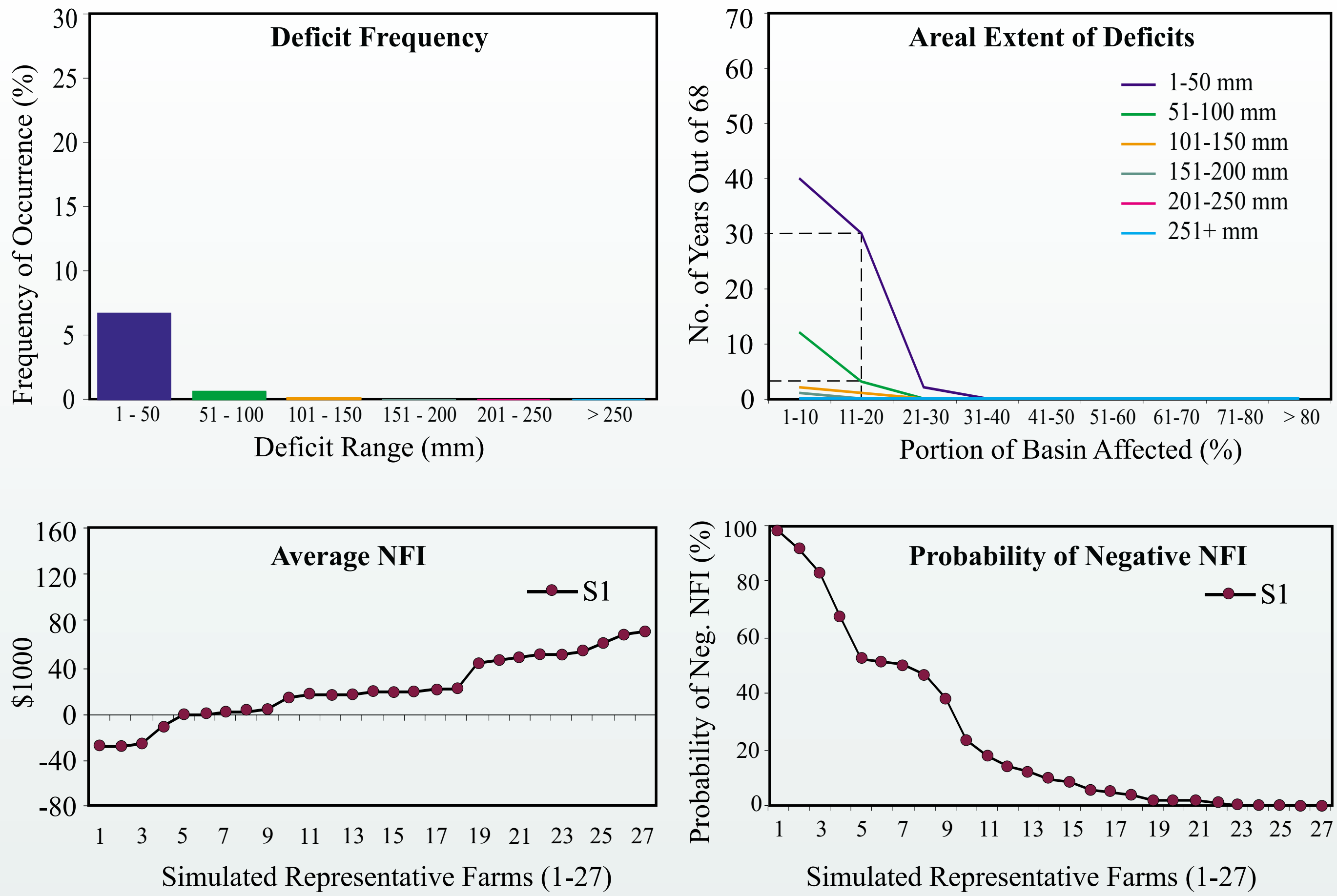

Figure 50c. Scenario S1 irrigation deficits and farm incomes - Bow Basin districts.

Discussion cont'd...

The deficit-areal extent graphs indicate that in the Bow Basin, deficits between 100 and 200 mm may affect between 11 and 20% of the irrigated land in one year out of 68. In the Oldman Basin, minor deficits (less than 50 mm) affecting up to 10% of the irrigated area would be common. Occasionally these deficits could affect up to 70% of the irrigated area. Significant deficits (more than 100 mm) are rare.

The average NFI for the simulated representative farms in the Bow Basin ranged between –$29,000 and +$71,000. Six of the 27 representative farms in the basin had a negative average NFI. In general, the lower NFI was associated with farm types that emphasize grains and oilseeds. 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 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.

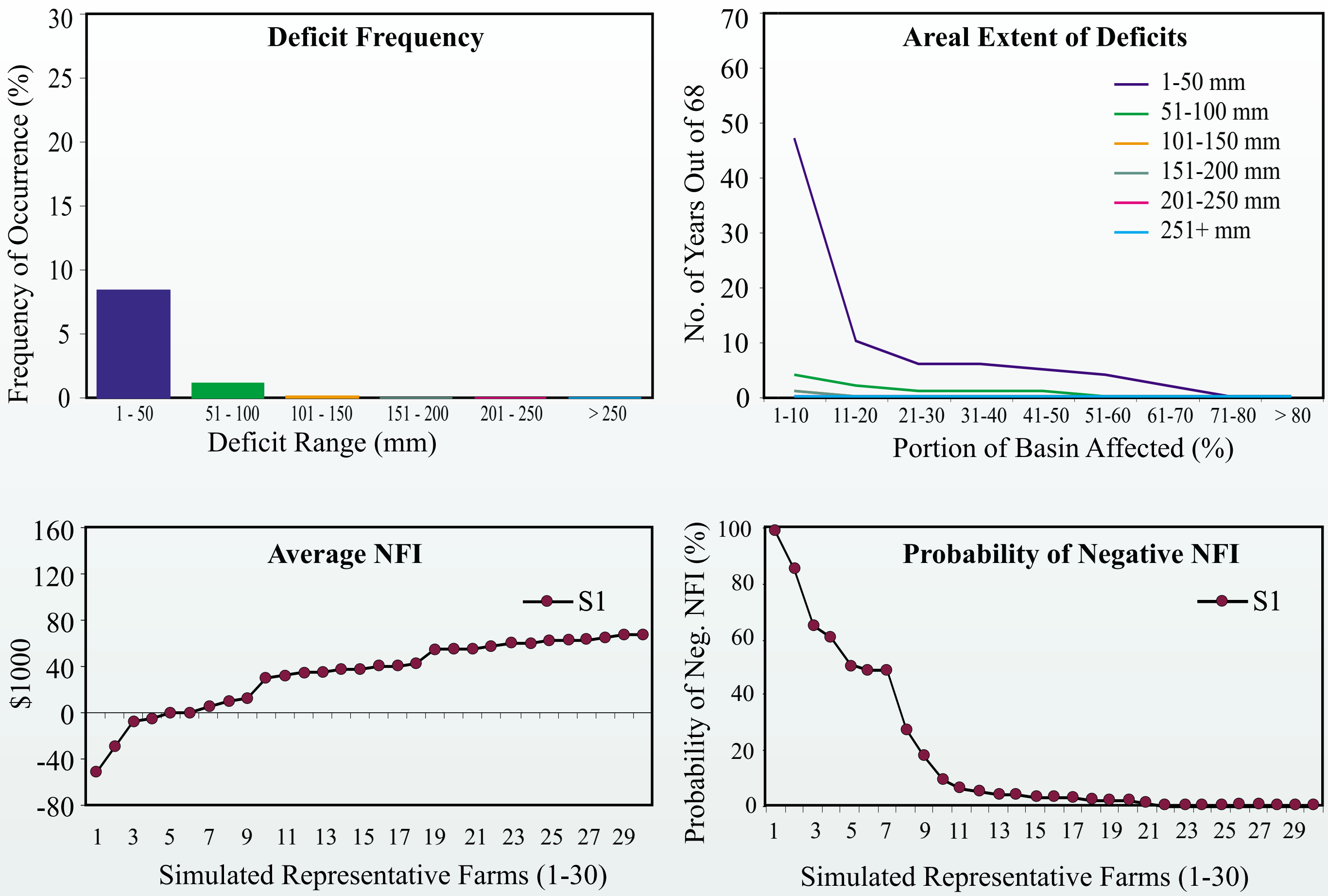

Figure 50d. Scenario S1 irrigation deficits and farm incomes - Oldman Basin districts.

Ten of the representative farms (37%) in the Bow Basin and eight (27%) in the Oldman Basin have a probability of a negative NFI in greater than 20% of the years (one year in five, on average). About 30% of the representative farms in each basin have little or no risk of a negative NFI.

KEY FINDINGS

- **At the current level of irrigation development, and with current on-farm and district management practices, the potential for significant irrigation deficits is low.**
- **Even with the low frequency and magnitude of deficits, farm enterprises based on lower value crops, such as grains and oilseeds, may be at financial risk in both basins. This likely reflects the reality that irrigation in much of southern Alberta cannot be sustained with conventional crop production, due to the high input costs and low crop prices.**

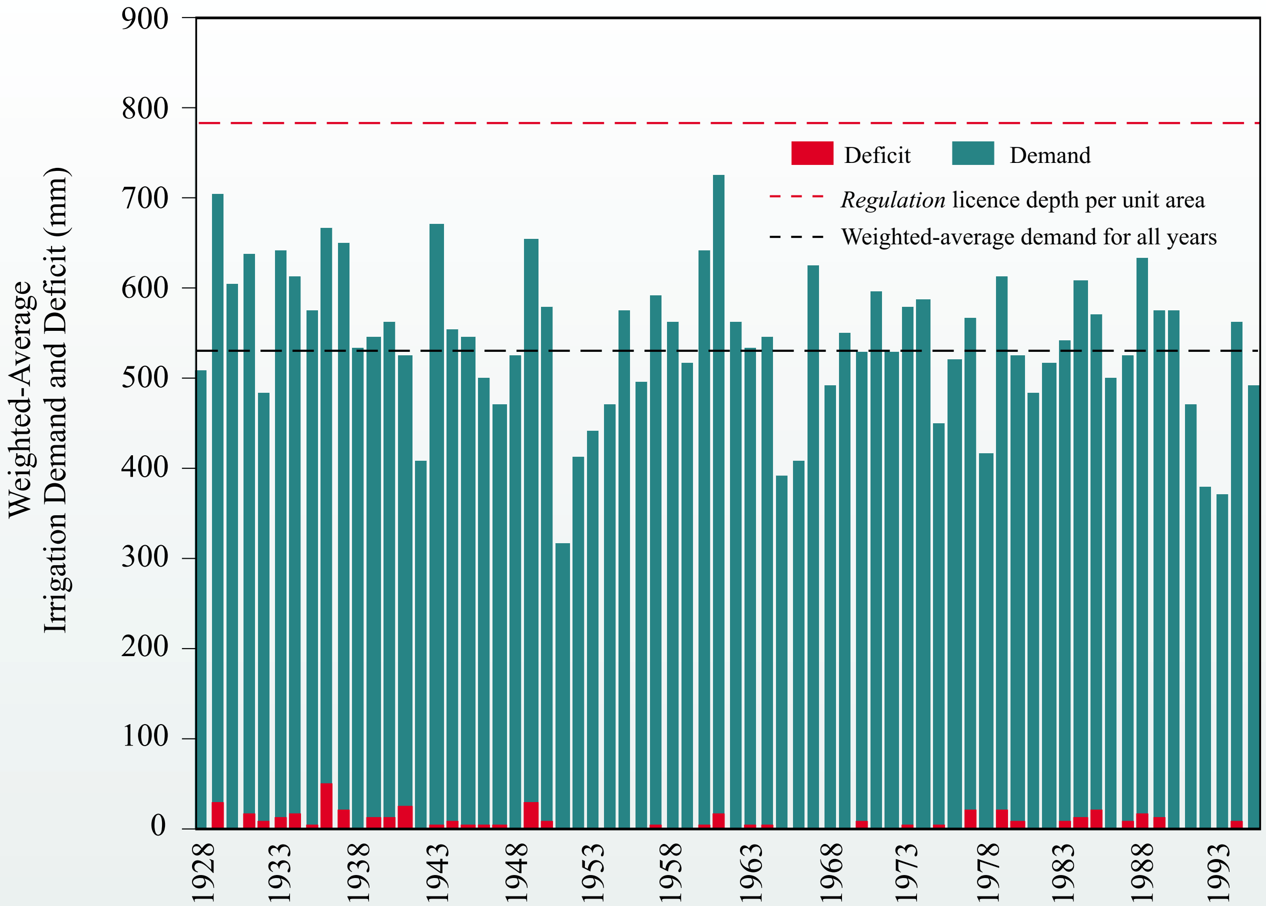

Figure 51a. Scenario S3 total demands and deficits - Bow Basin districts.

Scenario S3 - Expansion to 1991 *Regulation* Limits	
Irrigation area:	
Bow Basin	239,170 hectares
Oldman Basin	296,230 hectares
Crop mix	1999
On-farm system mix	1999
On-farm management	Improved
Crop water management	Near optimum (90%)
Return flow management	Improved
1991 *Regulation* licence volume:	
Bow Basin	1,881,088 cubic decametres
Oldman Basin	1,738,003 cubic decametres
Scenario weighted-average demand:	
Bow Basin	1,267,601 cubic decametres
Oldman Basin	1,107,900 cubic decametres

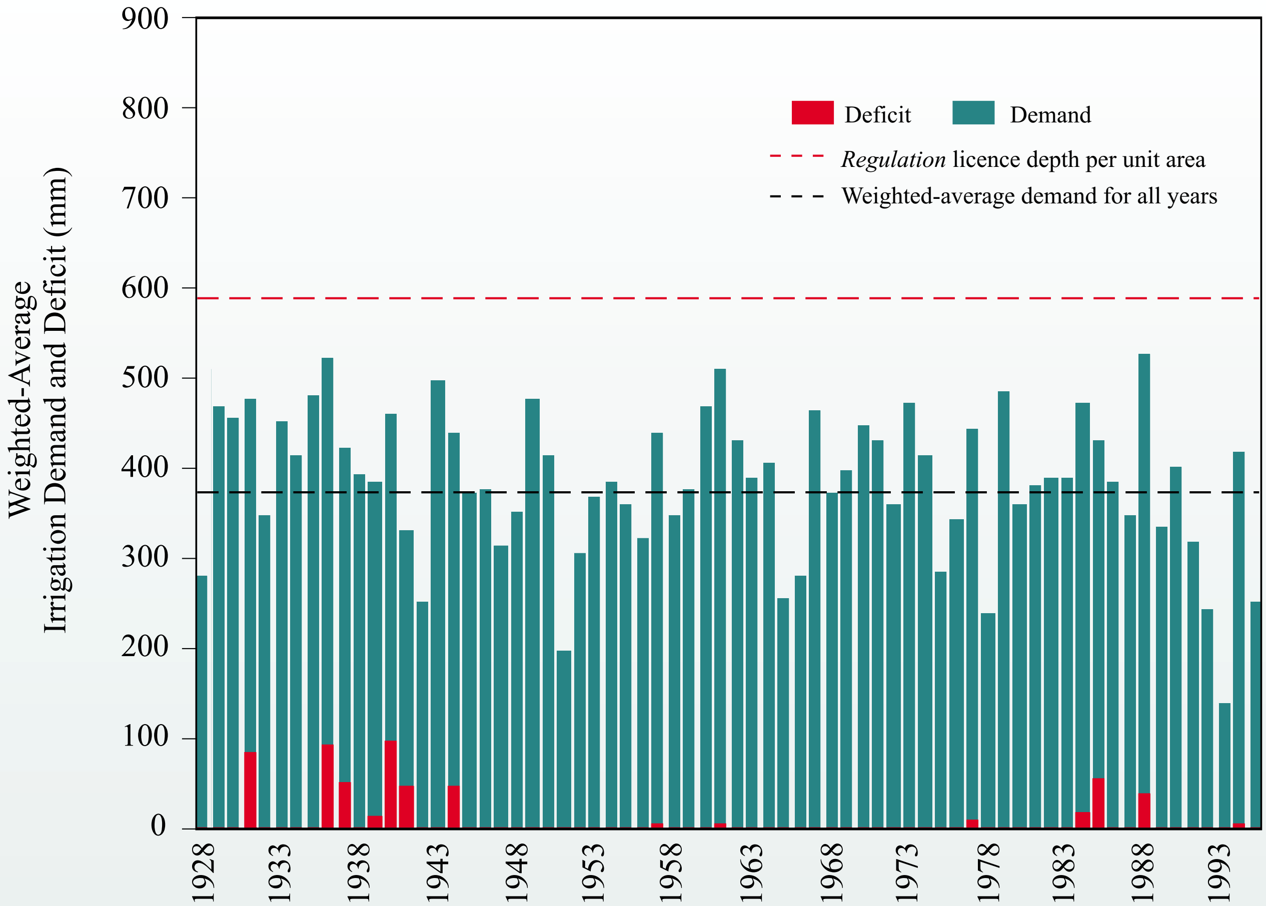

Figure 51b. Scenario S3 total demands and deficits - Oldman Basin districts.

Discussion of Results

In the Bow River Basin, the weighted-average unit demand for the 68-year period increased only slightly from 526 mm in Scenario S1 to 530 mm in S3, in spite of a 24% increase in crop irrigation requirement. The crop irrigation requirement was almost entirely offset by efficiency improvements and reduced return flow. In the Oldman Basin, the crop irrigation requirement increased by 8%, and the unit demand decreased by about 2%, again reflecting the increase in efficiencies. For all districts, the average annual volume of water required to support the 9.2% expansion and increased irrigation applications was about 8.6% higher than in Scenario S1. The 1991 *Regulation* licence allocation remains well above the highest demand years in both basins.

The frequency of water supply deficits in the Bow Basin is much more noticeable for Scenario S3 than for Scenario S1, although the magnitudes remain low. Deficits would be higher in the Oldman Basin. Should back-to-back deficits occur in the Oldman Basin, similar to those of the 1930s and early 1940s, they would be cause for concern.

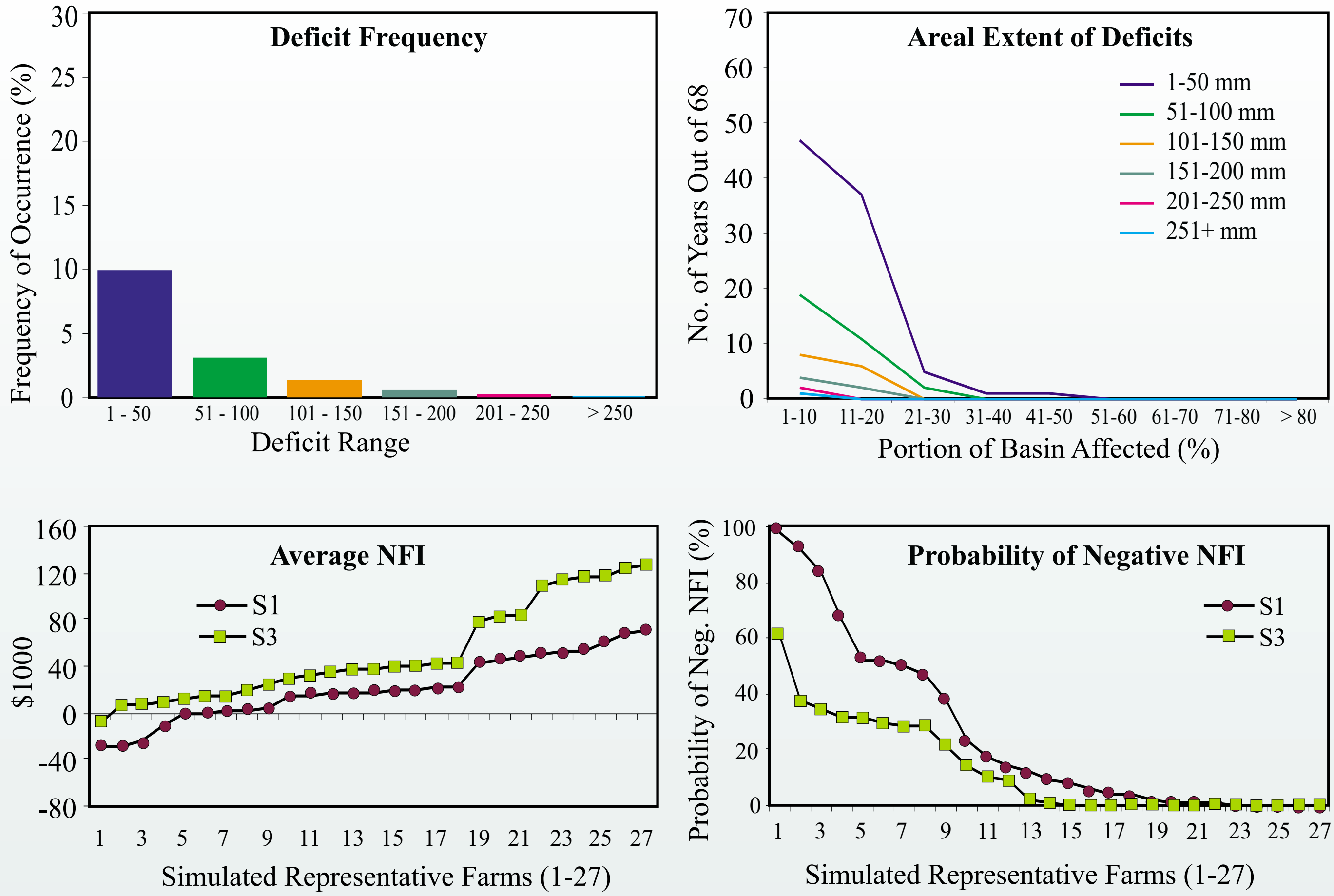

Figure 51c. Scenario S3 irrigation deficits and farm incomes - Bow Basin districts.

Discussion cont'd...

A deficit greater than 100 mm would be experienced in about 2% of years in the Bow Basin. Deficits of that magnitude would not affect more than 20% of the irrigated land in the basin. A deficit greater than 100 mm would be experienced in about 2.5% of years in the Oldman Basin. Deficits of that magnitude could affect up to 50% of the irrigated area in a small percentage of years.

In Scenario S3, the average NFI for the 68-year period would increase from that of 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 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 farms in the Bow Basin had a negative average NFI, compared with six in Scenario S1. All of the farms in the Oldman Basin show an increase in NFI compared to Scenario S1. The farms growing higher value crops showed a significant increase. Two of the 30 representative farms in the Oldman Basin had a negative average NFI, compared with five in Scenario S1.

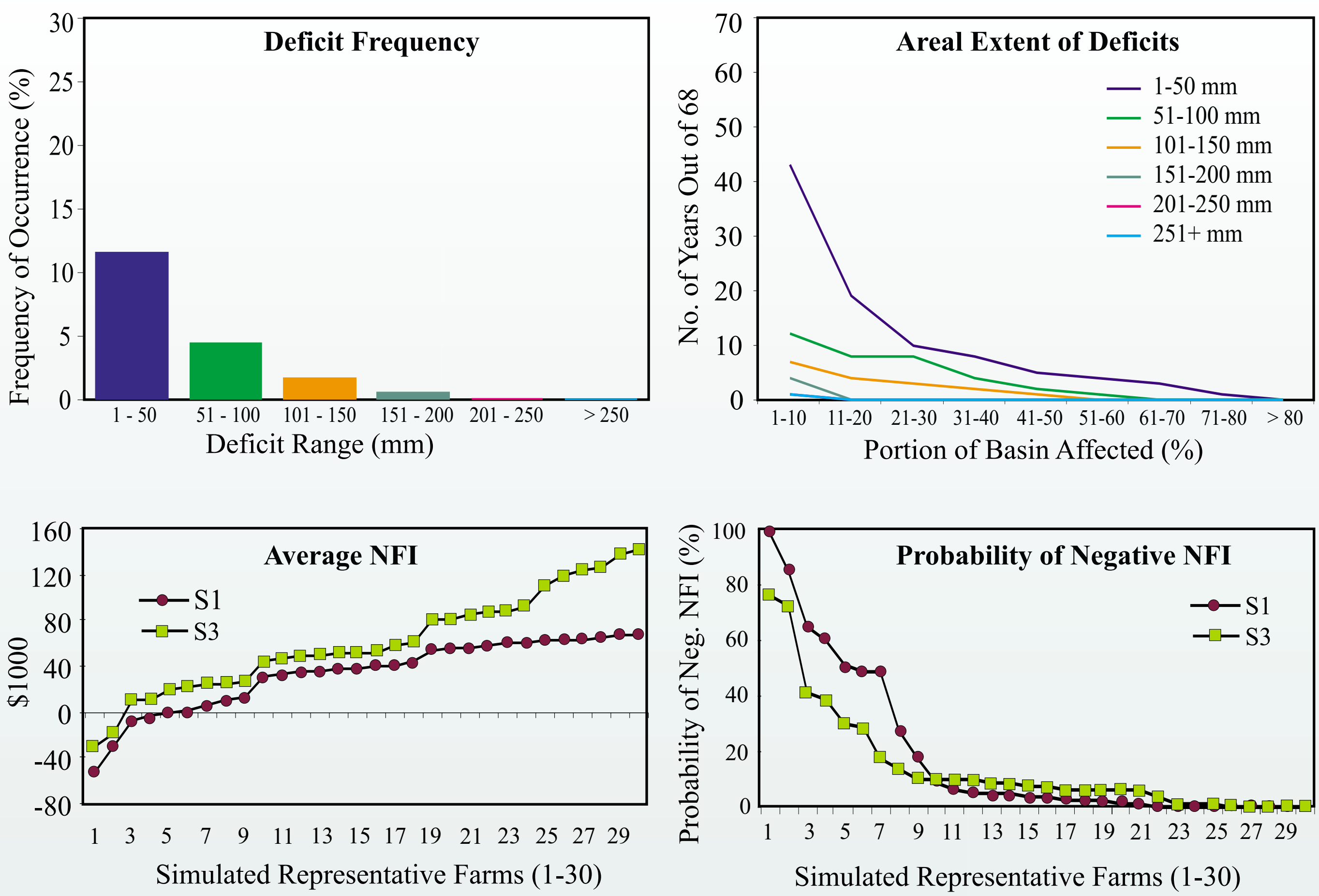

Figure 51d. Scenario S3 irrigation deficits and farm incomes - Oldman Basin districts.

In the Bow Basin, the probability of negative NFI declined for most farms, despite the increase in water deficits. Deficits would be small, and water applications in most deficit years would be greater than under Scenario S1, with crop water application at 80% of optimum. In the Oldman Basin, the probability of negative NFI declined for 9 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.

KEY FINDINGS

- **Improvements in irrigation efficiencies and reduced return flow are essential to minimize water supply deficits caused by increased crop irrigation applications and expansion of the irrigated areas.**
- **Despite more frequent and higher deficits in Scenario S3, all farms experienced higher average NFI because of increased on-farm water application levels (90%) and higher yields during non-deficit years.**
- **Producers would be in a better position to withstand lower revenues in deficit years because of higher revenues in non-deficit years.**

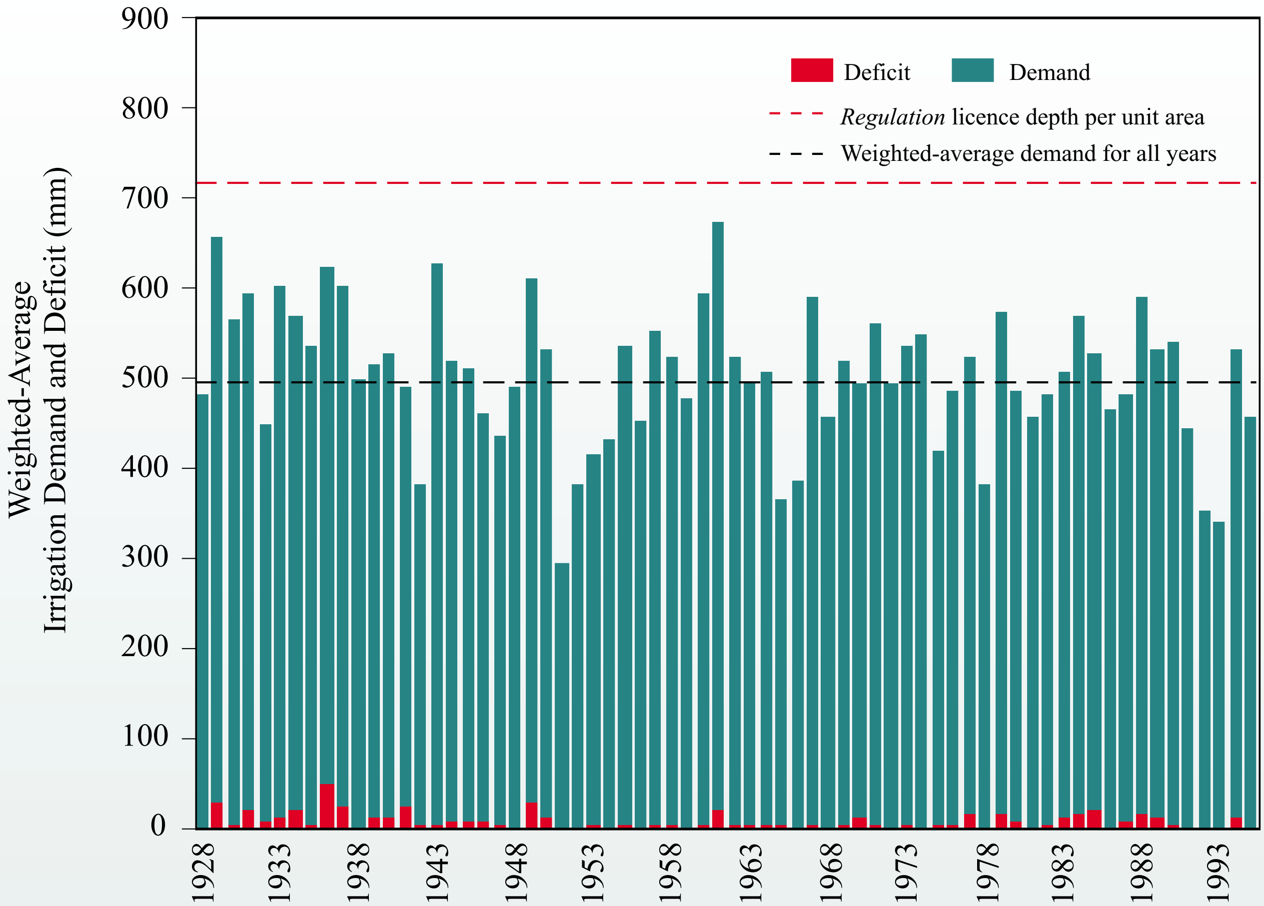

Figure 52a. Scenario S9 total demands and deficits - Bow Basin districts.

Scenario S9 - Expansion to 10% Beyond 1991 *Regulation* Limits	
Irrigation area:	
Bow Basin	263,086 hectares
Oldman Basin	325,853 hectares
Crop mix	Future
On-farm system mix	Future
On-farm management	Improved
Crop water management	Near optimum (90%)
Return flow management	Improved
1991 *Regulation* licence volume:	
Bow Basin	1,881,088 cubic decametres
Oldman Basin	1,738,003 cubic decametres
Scenario weighted-average demand:	
Bow Basin	1,304,907 cubic decametres
Oldman Basin	1,173,071 cubic decametres

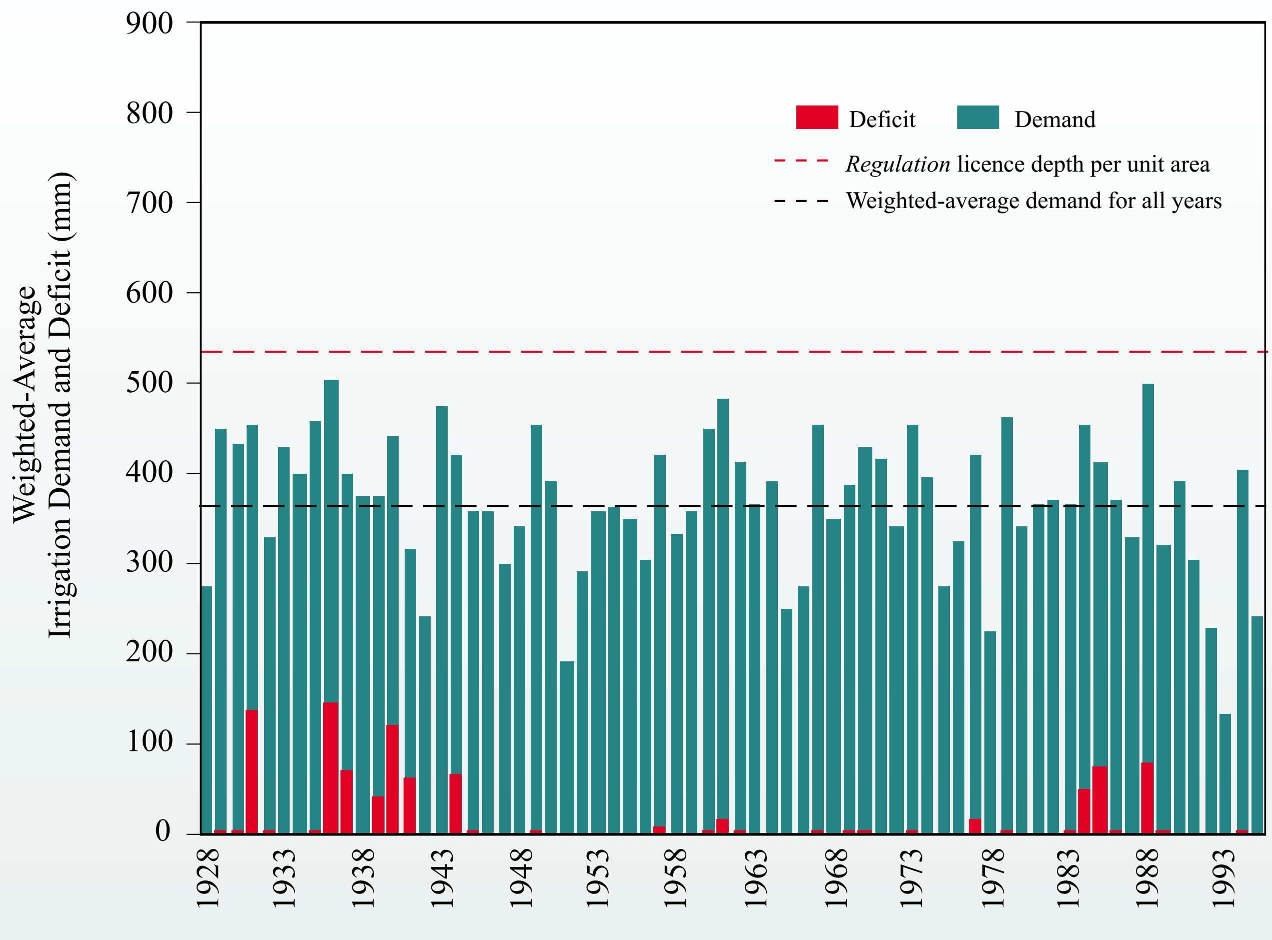

Figure 52b. Scenario S9 total demands and deficits - Oldman Basin districts.

Discussion of Results

In the Bow River Basin, the weighted-average unit demand decreased from 526 mm in Scenario S1 to 496 mm in Scenario S9, in spite of a 26% increase in crop irrigation requirement. In the Oldman Basin, the unit crop irrigation requirement increased by 11%, and the unit demand decreased from 380 mm in Scenario S1 to 360 mm in S9, reflecting the increase in efficiencies. The highest demand years for the Bow Basin districts were still well below the 1991 *Regulation* licence allocation for that basin. In the Oldman Basin, the highest demand years remained somewhat below the 1991 *Regulation.*

The frequency and magnitude of water supply deficits in the Bow Basin were greater than S1 deficits, but not much different than S3. Deficits in the Oldman Basin would be significantly higher than in S3. Should a clustering of deficits similar to those of the 1930s and 1980s reoccur, it would be a concern to producers. On the positive side, there was a period of about 40 consecutive years with no significant deficits.

In the Bow Basin, deficits greater than 100 mm would still be experienced in only about 2% of years, and would impact up to 20% of the irrigated area in the basin. In the Oldman Basin, deficits greater than

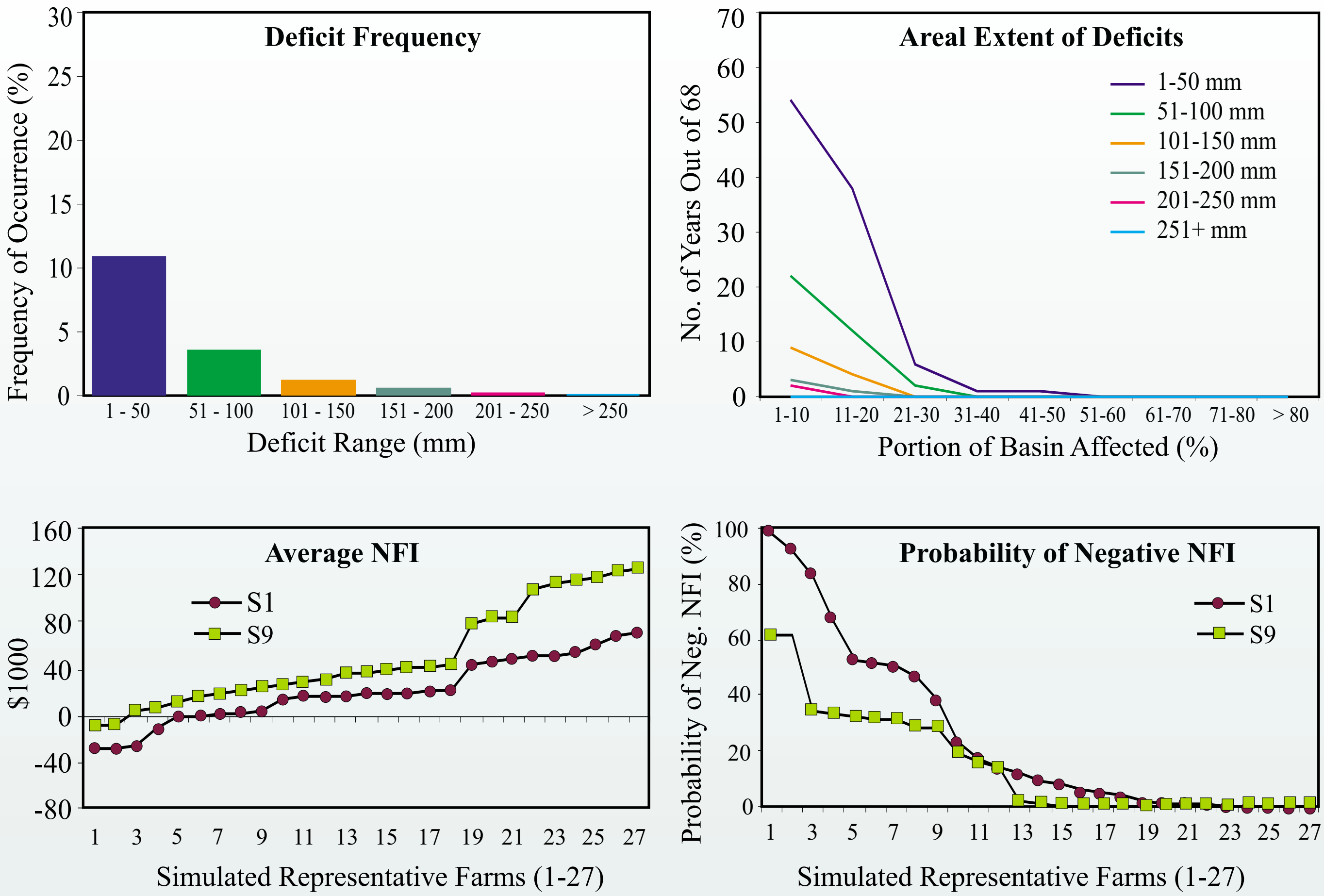

Figure 52c. Scenario S9 irrigation deficits and farm incomes - Bow Basin districts.

Discussion cont'd...

100 mm would be experienced in about 4.5% of the years. Deficits of this magnitude could impact up to 60% of the irrigated area in the basin.

The financial impact on Bow Basin district farms would be improved compared to the Base Case Scenario, and would be similar to Scenario S3. Two of the 27 representative farms showed a negative average NFI. The financial gains in the Oldman Basin districts would be less than those for the Bow districts. Gains in NFI from the current situation would be minor for most of the 30 farms, but more significant for farms with an emphasis on specialty crops. Financial performance of farms in the Oldman Basin declined from Scenario S3.

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

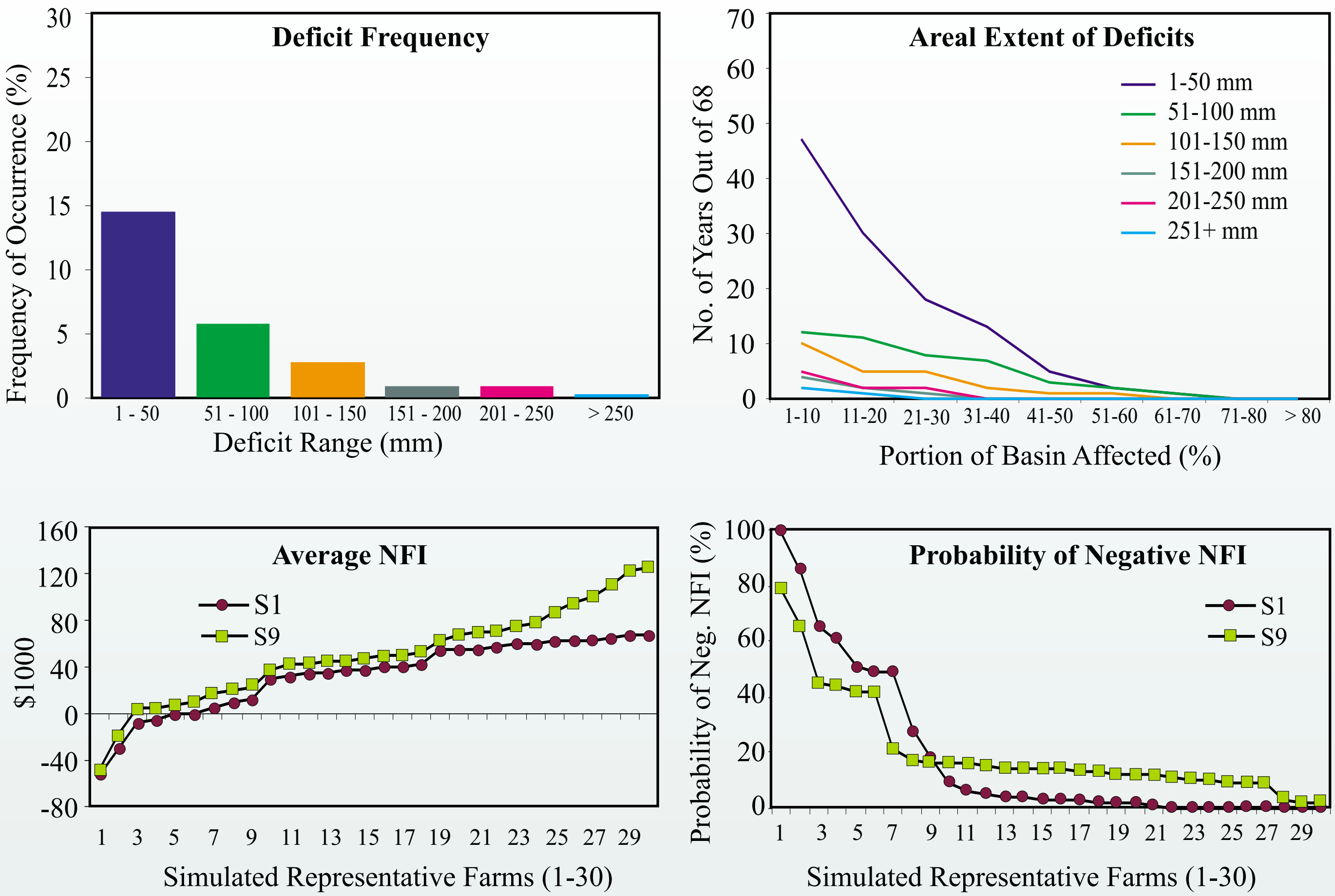

Figure 52d. Scenario S9 irrigation deficits and farm incomes - Oldman Basin districts.

KEY FINDINGS

- With 10% expansion beyond the *Regulation* limit (20% expansion beyond the 1999 irrigation area) in the Bow Basin, the probability of deficits greater than 100 mm remained low.
- All farms in the Bow Basin would experience higher average NFI and lower risks of negative NFI than in Scenario S1.
- With 10% expansion beyond the *Regulation* limit (20% expansion beyond the 1999 irrigation area) in the Oldman Basin, the probability of deficits greater than 100 mm almost doubled compared to Scenario S3.
- NFI in the Oldman Basin decreased from Scenario S3. NFI increased marginally from the Base Case on 80% of farms, but more significantly on the other 20%. However, the risk of negative NFI increased on 60% of the farms, indicating higher variability in NFI.
- The farms with increased risk of negative NFI are still at a relatively low risk, with probabilities of negative NFI at less than 20% (one year in five).

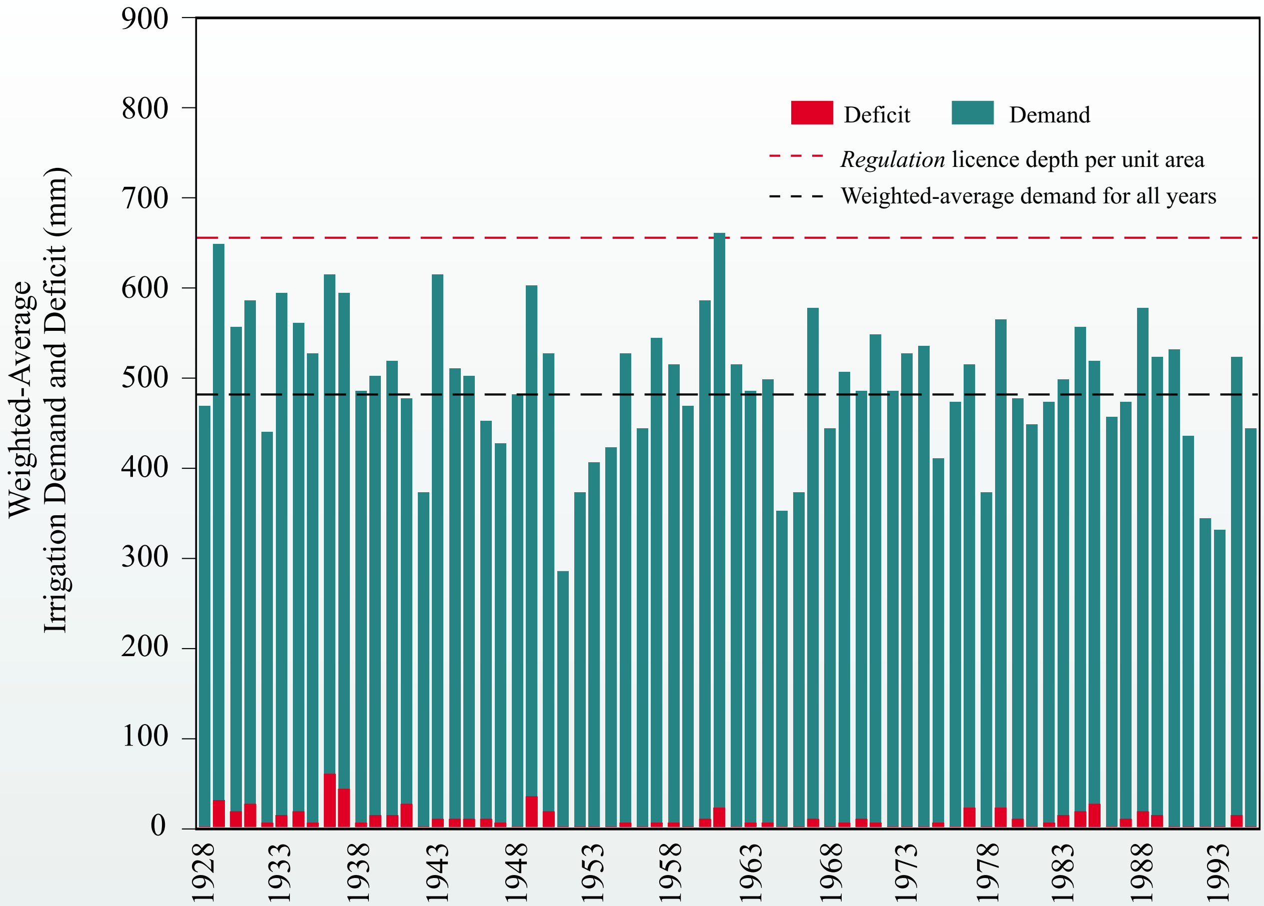

Figure 53a. Scenario S10 total demands and deficits - Bow Basin districts.

Scenario S10 - Expansion to 20% Beyond 1991 *Regulation* Limits	
Irrigation area:	
Bow Basin	287,003 hectares
Oldman Basin	355,476 hectares
Crop mix	Future
On-farm system mix	Future
On-farm management	Improved
Crop water management	Near optimum (90%)
Return flow management	Improved
1991 *Regulation* licence volume:	
Bow Basin	1,881,088 cubic decametres
Oldman Basin	1,738,003 cubic decametres
Scenario weighted-average demand:	
Bow Basin	1,386,224 cubic decametres
Oldman Basin	1,258,385 cubic decametres

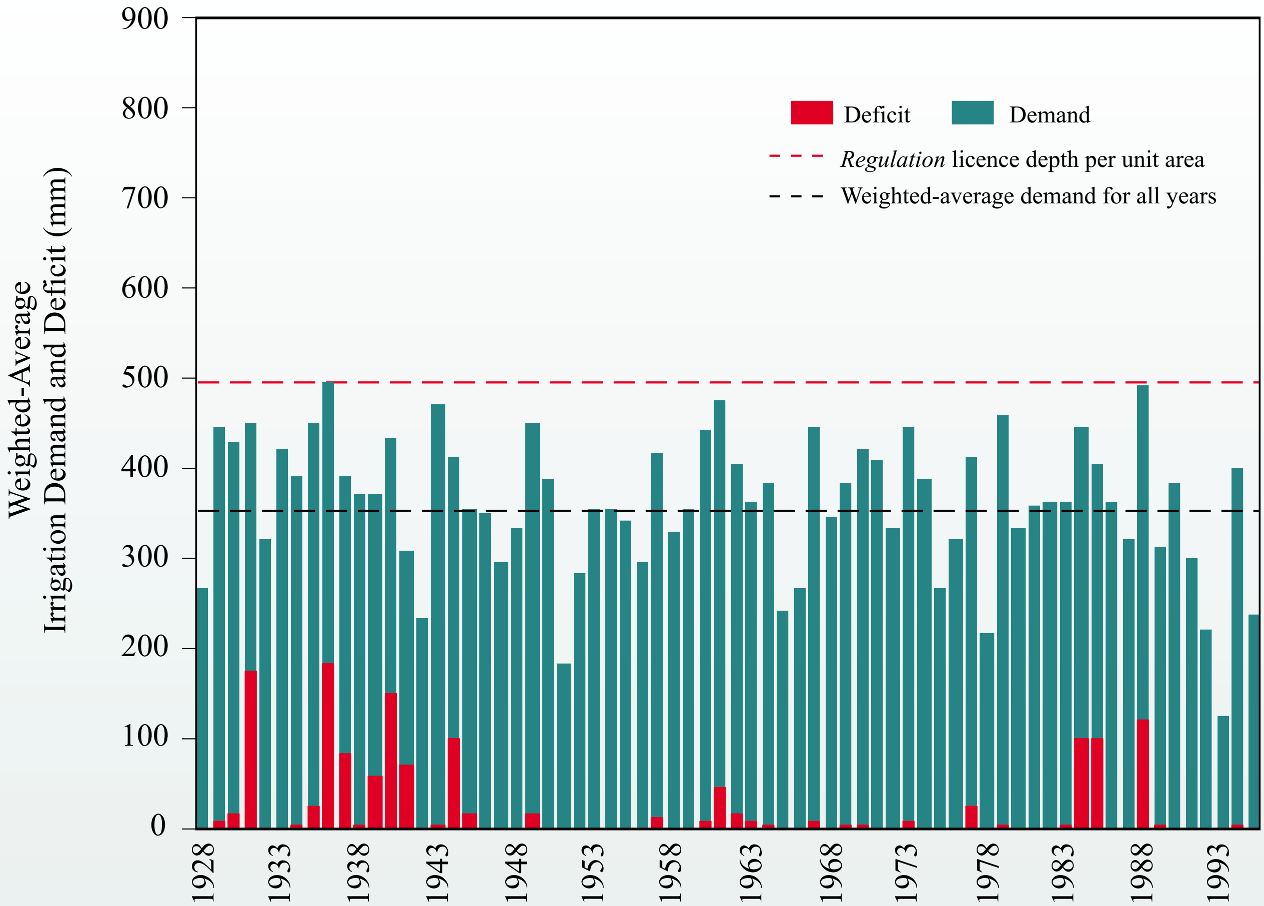

Figure 53b. Scenario S10 total demands and deficits - Oldman Basin districts.

Discussion of Results

In the Bow Basin, the weighted-average unit demand for Scenario S10 decreased to 483 mm from 496 mm in Scenario S9. The decrease was a result of further expansion by in-fill using existing infrastructure, making the districts more compact and therefore more efficient. In the Oldman Basin, the unit demand decreased to 354 mm from 360 mm in Scenario S9. These unit demands were about 8% lower than current (S1) demand, in spite of increased irrigation applications and crops that use more water. For all districts, the average annual volume of water required to support the 31% expansion (from S1), change in crop types, and increased irrigation applications in the two basins would be 21% higher than in Scenario S1. The irrigation demands for the Bow Basin districts in 1929 and 1961 would be close to the 1991 licence allocation for that basin. In the Oldman Basin, the demands for 1936 and 1988 would be up to the 1991 licence allocation. These were both deficit years, so actual diversions would be well below the licence allocation.

Deficits in the Bow Basin would be frequent but relatively low in magnitude. In the Oldman Basin, there would be a marked increase in the

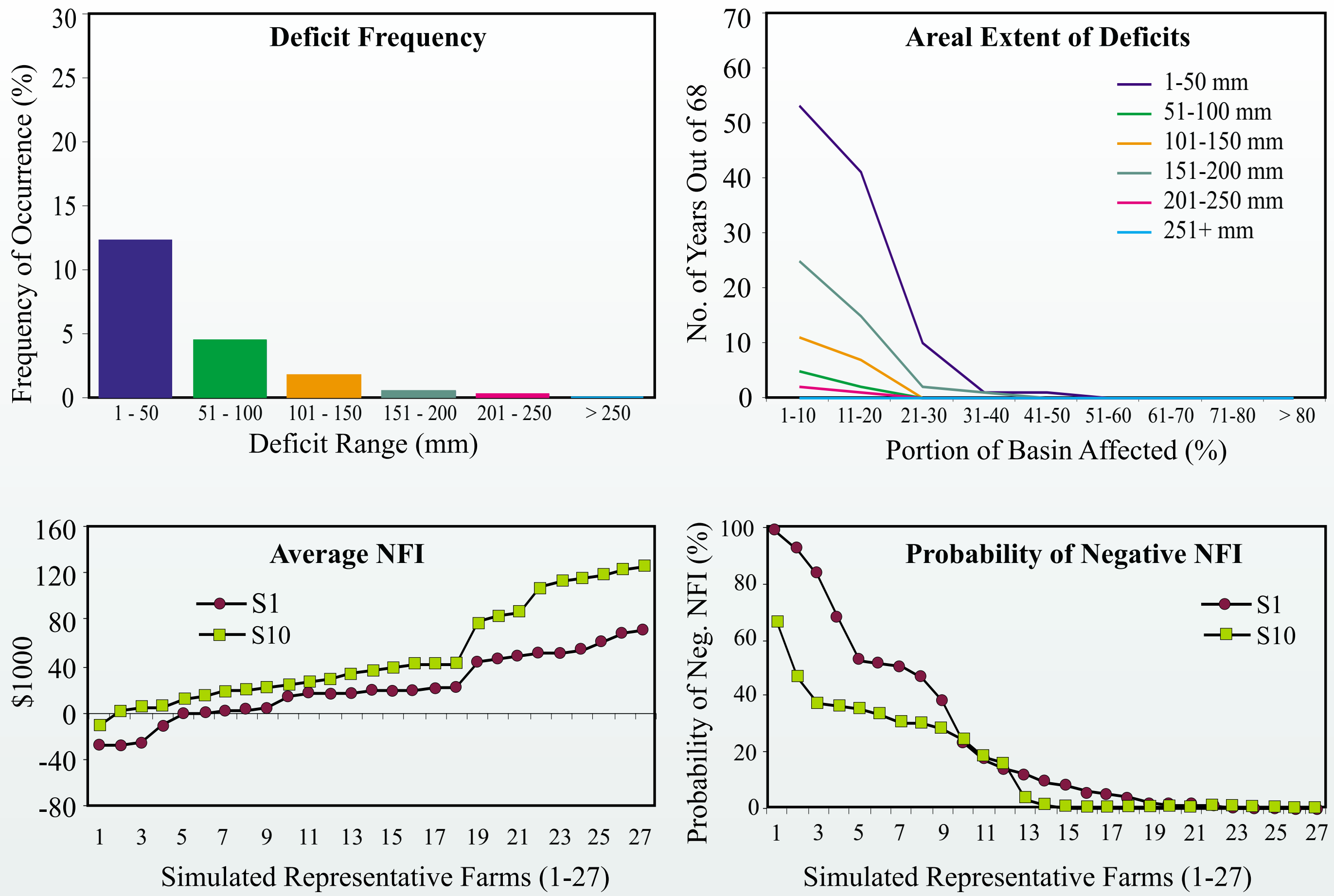

Figure 53c. Scenario S10 irrigation deficits and farm incomes - Bow Basin districts.

Discussion cont'd...

magnitude of deficits from Scenario S9. Deficits similar to those prevalent in the 1930s and 1980s, with several periods of consecutive deficit years, would be of concern.

In the Bow Basin, deficits greater than 100 mm would be experienced in about 2.5% of years, about the same as deficits in the Oldman Basin for S3. Deficits of this magnitude could affect up to 20% of the irrigated area in the Bow Basin. For Scenario S10, deficits greater than 100 mm would be expected in the Oldman Basin about 8.7% of years, and could affect up to 60% of the irrigated area. The current (S1) probability of deficits greater than 100 mm in the Oldman Basin was less than 1%.

Average NFI for Bow Basin farms would be similar to Scenario S9, continuing to show improvements from Scenario S1. In the Oldman Basin, average NFI would decline slightly from Scenario S9. No farms would experience any appreciable decline in average NFI from Scenario S1, but a few would experience an appreciable gain. The risk of negative NFI would be significantly lower than Base Case for about 35% of the farms in the Bow Basin, and about the same for the remaining 65%.

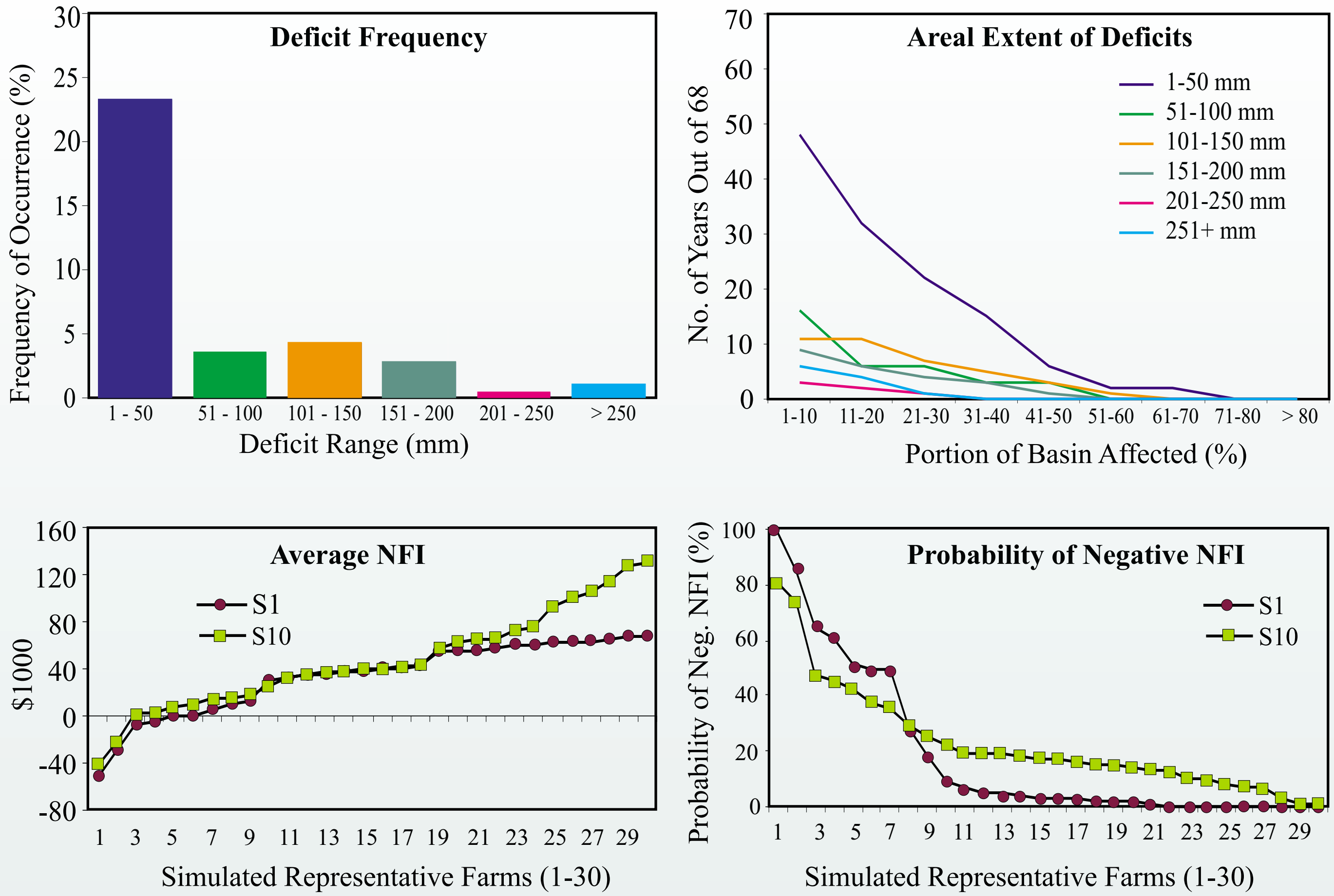

Figure 53d. Scenario S10 irrigation deficits and farm incomes - Oldman Basin districts.

In the Oldman Basin, about 25% of the farms would have a decreased probability of negative NFI, but most others would have an increased risk, albeit still not greater than 20%.

KEY FINDINGS

- **With increased on-farm and district efficiencies, and increased irrigation water applications to 90% of crop water requirements, an expansion of 20% beyond the *Regulation* limit (30% beyond the 1999 irrigation area) in the Bow Basin could be sustained without serious water supply risks or negative farm financial risks.**
- **Expansion by 20% beyond the *Regulation* limit (30% beyond the 1999 irrigation area) in the Oldman Basin could result in significant deficits in a sizable portion of the irrigated area in the basin, even with efficiency improvements. Only a few farm types would experience higher average NFI compared to current income.**

E. CONCLUSIONS

Based on simulation modelling conducted for the Irrigation Water Management Study, the following key conclusions on potential irrigation expansion have been drawn.

Assuming continued improvements in on-farm and district infrastructure and water management, overall irrigation water management efficiencies could improve in the Oldman Basin districts from the 1999 level of 53% to 64% in the future. Similarly, efficiencies are projected to increase from 40% to 55% for the Bow Basin districts.

The potential for efficiency gains is greater for Bow Basin districts than for Oldman Basin districts, primarily because of infrastructure configuration and the density of irrigation parcels relative to length of conveyance works. Also, a lower percentage of district infrastructure has been rehabilitated and a higher percentage of surface irrigation is still practiced in the Bow Basin.

Based on modelling conducted in this study, a 10% to 20% expansion in the irrigated area beyond the 1991 *Regulation* limits is sustainable in districts supported by the Bow Basin, with improvements in water use efficiency, reduced return flows, and higher crop water applications.

Financial performance indicators for Scenarios S9 and S10 showed improvements compared to Base Case conditions in the Bow Basin, in spite of higher irrigation deficits. This conclusion does not apply equally to all districts nor to all irrigation blocks within the districts. More detailed analyses are required to determine the impacts of expansion on individual districts and blocks.

Modeling output suggests an expansion in the irrigated area of the Oldman Basin of up to 10% beyond the 1991 *Regulation* limits could be considered, with efficiency improvements, reduced return flows, and higher crop water applications.

A cautious approach to irrigation expansion in the Oldman Basin is recommended. Most financial performance indicators show improvements compared to the 1999 situation. However, some irrigation blocks and some districts should probably not expand beyond the 1991 *Regulation* limits. More detailed analyses of individual district modelling output are required for decision making.

Financial modelling indicates irrigation farm financial performance can be improved compared to Base Case conditions, even with irrigation expansion and more frequent and higher water supply deficits.

Comparison of model output for expansion scenarios to current conditions indicated that average net farm incomes increased, and the risk of insolvency decreased from current conditions, for most representative farms. The probability of negative net farm income in any one year decreased for all farms in the Bow Basin districts, but increased for some farms in the Oldman Basin, indicating higher variability in annual income in the Oldman Basin.

Prerequisites to improved farm financial performance are on-farm and district water use efficiency improvements, reduced return flows, higher crop water applications, and crop mixes that include at least one high value crop. Improved efficiencies and reduced return flows will minimize the magnitude and frequency of water supply deficits. Higher crop water applications will increase yields and revenues in non-deficit years, so producers are in a better position to withstand lower revenues in deficit years. Farms that irrigate only cereals and oilseeds are considerably less profitable than farms that include higher value specialty crops or forages. Including a higher value crop in the mix provides an opportunity to maximize revenues by shifting water applications from low to high value crops.

Irrigation water supply deficits less than 100 mm per year are not considered to have serious financial consequences for most producers.

At the crop level, the net effect of a specified water supply deficit is only a portion of that deficit. The actual net effect at the crop level is somewhat reduced because a portion of the projected deficit consists of losses incurred through water application inefficiencies that were already accounted for in the irrigation demand. These on-farm losses do not occur if water is not available for diversion to meet the projected irrigation demand. For example, a projected 100 mm deficit in the gross diversion supply may only translate into a 70 mm to 75 mm deficit at the crop level. Irrigators can also redistribute available water to those crops generating higher net revenues. As a result, the impact of smaller projected gross diversion deficits (less than 100 mm) is unlikely to have much financial significance.