SOUTH SASKATCHEWAN RIVER BASIN

WATER MANAGEMENT PLAN
PHASE 2

Scenario Modelling Results
Part 1

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EXECUTIVE SUMMARY

Phase 1 of the South Saskatchewan River Basin (SSRB) Water Management Plan was completed in June 2002, with the issuance of the document: *Phase One, Water Allocation Transfers*. Phase 2 of the Water Management Plan began shortly thereafter, with the primary goal of finding the balance between water consumption and environmental protection in the basin. This phase will recommend Water Conservation Objectives (WCOs) for the major mainstem reaches of the Red Deer, Bow, Oldman, Waterton, Belly, St. Mary and South Saskatchewan rivers.

Because of the complexity and significant consequences that establishing WCOs are expected to have, it was decided to divide modelling of Phase 2 into two parts. Part 1, the subject of this report, is an exploratory and educational exercise that gathers information on the current and "committed to" state of the basin, and the potential consequences of a number of hypothetical water management scenarios.

This report documents results obtained from eight scenario simulations using Alberta Environment's Water Resources Management Model (WRMM). The scenarios were developed with the assistance of the SSRB Basin Advisory Committees (BACs).

The model allocates available water supply to the various demands including instream flow requirements and makes best use of storage structures to mitigate shortages in times of low water supply and high demands.

There are two categories of instream flow requirements utilized in this phase of the modelling. Some scenarios utilize the existing instream objectives (IO) while others utilize the instream flow needs (IFN) of a highly protected aquatic environment.

Existing Instream Objectives are flows that are included in conditions attached to licences currently being issued. Licensees are not permitted to withdraw water when river flows fall below the specified IO. Alberta Environment generally operates the provincial infrastructure to meet the current IO. The existing instream flow needs have varying degrees of benefit for the aquatic environment.

The Technical Instream Needs Group has completed a report entitled: *Instream Flow Needs Determinations for the South Saskatchewan River Basin, Alberta, Canada.* That report details the quantitative estimates of the flows required to protect the aquatic environment (IFN). Four components are used as surrogates for the overall aquatic environment: Water Quality (Temperature, Dissolved Oxygen and Ammonia), Fish Habitat, Riparian Vegetation and Channel Maintenance. For each of the main reaches of the major rivers in the basin, 52 weekly flows for 68 years (1928 to 1995) are recommended to protect the aquatic ecosystem.

To assist dissemination of information from the scenario modelling, the results are displayed on an Internet Web site at:

http://www3.gov.ab.ca/env/water/regions/ssrb/wrmmoutput/index.asp

Detailed flow and reservoir elevation data and results for river reaches, diversion canals, reservoirs, consumptive demands, etc. are provided on the website. This site allows the user to browse either Phase 1 or Phase 2, Part 1 information.

Eight scenario simulations were carried out. These are labeled A1 to A3 and B1 to B5 respectively. In general, Scenarios B1 to B4 are built upon the base case Scenario A1. Similarly, Scenario A3 and B5 are built upon Scenario A2. For presentation purposes, the eight scenario simulations are divided into three groups: **Base Case**, **Potential Development** and **Exploratory**.

Base Case Scenario

Scenario A1 – Current Allocations and Commitments and District Irrigation at SSRB Regulation Acreages (Existing IOs)

This is an update of Scenario A in the Phase 1 modelling, with more detailed breakdown of senior and junior licences. It represents current (July 2002) licences and the existing IO, plus commitments in the SSRB. District irrigation is at SSRB Regulation acreages.

Potential Development Scenarios

These scenarios represent the direction water management is currently taking in the South Saskatchewan River Basin.

Scenario A2 –Non-District Irrigation at SSRB Regulation Acreages on Scenario A1 (Existing IOs)

Scenario A2 is the same as Scenario A1 but with non-district irrigation consumption increased to the acreage limits set by the SSRB Water Allocation Regulation. With this increased consumption, Scenario A2 evaluates the performance under current IOs.

Licence applications by WID and BRID are modelled as required in Scenarios A2, A3 and B5.

Scenario A3 – Irrigation District Expansion beyond SSRB Regulation Limits, and 50-year Projected Non-Irrigation Allocation (Existing IOs)

A3 shows what would happen if, with current IOs, irrigation districts expand to acreages that are 110% (in the Oldman basin) and 120% (in the Bow basin) of the acreage limits set by the SSRB Regulation, and non-irrigation consumption increases in accordance with a 50-year projection.

Exploratory Scenarios

Scenario B1 – IFN Licence Condition on Base Case

This scenario is the same as Scenario A1 but replaces current IOs with IFNs. In this scenario, IFNs are imposed on any new allocations and back-fitted, where legally possible, to existing allocations.

Scenario B2 – IFN Priority on Base Case

This scenario is the same as Scenario B1, but imposes IFNs on <u>all</u> allocations. It shows the consequences of giving IFNs first priority in the SSRB over all licences and storage.

Scenario B3 – Consumptive Use Reduction (IFN Licence Condition)

This scenario is the same as Scenario B1, but shows to what extent the IFNs can be met if water conservation measures reduce consumption in the SSRB by 20%.

Scenario B4 – Apportionment (Existing IOs)

This scenario is the same as Scenario A1, but shows how much extra consumption in the Red Deer basin is possible and the impacts on licences in the Bow, Oldman and South Saskatchewan basins if the Red Deer and South Saskatchewan basins each contribute 50% of their respective natural flow to apportionment to Saskatchewan.

Scenario B5 – IFN Licence Condition on Scenario A2

This scenario is the same as Scenario A2, but replaces current IOs with IFNs on any new allocations and back-fitted, where legally possible, to existing allocations.

Results

The existing Instream Objective flows are relatively low compared to IFN values. In many years of model simulation, the regulated water supply provides flows considerably above existing instream objectives. However, water supply and management in dry years remains the governing factor. The following key findings apply primarily to those dry years.

Base Case Scenario

Scenario A1

- In the Red Deer sub-basin, and Oldman/South Saskatchewan mainstems**,** there are few consumptive use deficits, and existing instream objectives are always met.
- In the Bow sub-basin
  - Junior allocations and commitments have frequent, substantial deficits.
  - The Bow River Irrigation District (BRID) and the Eastern Irrigation District (EID) can achieve their maximum area under the SSRB Regulation with their current licences. The Western Irrigation District (WID) requires an additional licence.
  - Existing instream objectives are frequently not met above Bassano. They are always met below Bassano, but instream flows are frequently at the instream objective value of 11.33 m^3/s (400 ft^3/sec).
- In the Oldman Southern Tributaries**,** junior allocations (there are no commitments) have frequent, substantial deficits. Existing instream objectives are always met.

Potential Development Scenarios

Scenario A2

- In the Red Deer sub-basin, junior allocations and future irrigation would have relatively more infrequent, small deficits as compared to the base case Scenario A1. The Special Areas Water Supply Project would have some deficits.
- In the Bow sub-basin, performance of the WID would be significantly improved with an additional allocation. It should be noted that WID has applied for an additional allocation but the current IO limits the volume that can be diverted.

- In the Oldman/South Saskatchewan mainstem (where most of the Non-District expansion would occur), deficits to junior allocations and commitments increase since the consumptive demand relying on the Oldman Reservoir storage is increased.

- In the Oldman Southern Tributaries (where the expansion is limited to Non-District irrigation applications received), deficits to junior allocations would be similar to the base case Scenario A1.

Scenario A3

- Marginally increases deficits to all districts except WID, which would have a significant deficit increase. BRID, EID and UID would experience no deficit increase.

- Would have a substantial negative impact on junior licences and commitments. The 50-year projected non-irrigation water use has very frequent, large deficits.

Exploratory Scenarios

Scenarios B1, B2, B3 and B4

- Limiting IFNs to "back-fits" in allocations where provision allows and to commitments, plus giving them priority call on government storage, results in increases in instream flows. The IFN flow values are sometimes achieved – frequently not achieved. The performance varies considerably across the entire SSRB, with the most achievable increase in instream flows being in the Red Deer sub-basin and small increases everywhere else. With the exception of the Red Deer sub-basin, any increased instream flows result in frequent and substantial deficits to junior allocations and commitments.

- By assigning IFNs priority over all allocations and storage, they can be generally met in the Bow/Oldman/South Saskatchewan mainstem, Waterton and Belly River sub-basins. However, they cannot be met in:

    - Red Deer River sub-basin - since they are often greater than natural flow and Gleniffer storage cannot be refilled sufficiently to make up the shortfall in instream flows; and

    - St. Mary River sub-basin - since the IFN is based on the entire natural flow of the sub-basin, but there is diversion of the USA share to the Milk River prior to entering Canada.

- A 20% reduction in water consumption provides a modest increase in instream flows - well short of the IFN values. A portion of the "saved" water is actually used to reduce deficits in junior allocations. The WID's senior licence can now supply its maximum area under the SSRB Regulation with only five deficit years (compared with 20 deficit years for the case of no Water Conservation).

- A fixed 50% of natural flow Red Deer River contribution to apportionment would result in 655,000 dam^3 (531,000 acre-feet) on average being available in the Red Deer sub-basin and could be as low as 190,000 dam^3 (154,000 acre-feet) in a dry year. However, this would result in frequent, large deficits to junior allocations and commitments in the Oldman/South Saskatchewan mainstem.

Scenario B5

Results are similar to Scenario A2, except that the SAWSP and additional non-district irrigation demand in the Red Deer basin have frequent and substantial deficits.

Overall Conclusion

In the Red Deer sub-basin, there is potential to increase the instream objective (IO) values above existing levels and provide for additional allocation. However, the opportunities for increasing the IO and issuing additional allocations in the Bow/Oldman sub-basins are limited.

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INTRODUCTION

Phase 1 of the South Saskatchewan River Basin (SSRB) Water Management Plan was completed in June 2002, with the issuance of the document: *Phase One, Water Allocation Transfers*.

Phase 2 of the Water Management Plan began shortly thereafter, with the primary goal of finding the balance between water consumption and environmental protection in the basin. This phase will recommend Water Conservation Objectives (WCOs) for the major mainstem reaches of the Red Deer, Bow, Oldman, Waterton, Belly, St. Mary and South Saskatchewan rivers.

At the same time, the Technical Instream Needs Group[1] produced quantitative estimates of the instream flows required to protect the aquatic environment[2] in the above-listed rivers of the SSRB.[3] These are referred to as Instream Flow Needs (IFNs) in this report.

Because of the complexity and significant consequences that establishing WCOs are expected to have, Phase 2 is divided into two parts. Part 1, the subject of this report, is an exploratory and educational exercise that gathers information on the current and "committed to" state of the basin, and the potential consequences of a number of hypothetical water management scenarios. Part 2 entails the selection of scenarios to explore and recommend water conservation objectives for the major river reaches in the basin.

This report documents results obtained from eight scenario simulations using Alberta Environment's Water Resources Management Model (WRMM). The scenarios were developed with the assistance of the SSRB Basin Advisory Committees (BACs).

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1 A sub-committee of the SSRB Water Management Plan, composed of staff from Alberta Environment and Alberta Sustainable Resource Development.

2 Flows required to ensure Water Quality (assuming current Effluent Treatment Technology), Fish Habitat, Riparian Vegetation and Channel Maintenance.

3 The Technical Instream Needs Group have also produced IFN values for the Highwood River, which is undergoing a separate water planning exercise – the Highwood River Water Management Plan.

WATER MANAGEMENT OVERVIEW AND METHODOLOGY

Description of the WRMM

Alberta Environment began development of the Water Resources Management Model (WRMM) in 1979 for application in the South Saskatchewan River Basin (SSRB) Planning Program (1982-1985). It has subsequently been used in all substantive water management planning and operational studies in the South Saskatchewan and Milk River basins.

The WRMM matches water supplies and demands in a river basin during a long-term time series – for the SSRB the water supplies during the historical period 1928-1995 are matched on a weekly basis with demands. The model incorporates all present and committed infrastructure in the SSRB.

Principal inputs to the model are:

- Historical climatic and river natural flow data (1928 – 1995);
- Canadian share of St. Mary River natural flow;
- Irrigation district and private irrigation consumptive use and return;
- Non-irrigation withdrawals (municipal, industrial, other projects);
- Instream objectives (fish habitat and water quality);
- Reservoir and canal structure capacities and discharge limitations;
- Licence priorities, conditions and volume/rate limits;
- Operating policies for structures;
- 1969 Apportionment Master Agreement.

For each scenario, results are calculated for all demands, and structure storages and flows. The performance of the demand components is determined in terms of deficits; that is the frequency of deficits (failure to meet the component requirement due to insufficient water).

Water Supply

Water supply to the SSRB is primarily from snowmelt in the Rocky Mountain headwaters of the Red Deer, Bow and Oldman basins. Precipitation events throughout the basin contribute additional water. The SSRB water supply is characterized in its natural state in the WRMM as though no human activity had occurred.

Natural flows were computed at a number of points within the basin by adding back to the recorded stream flow any water stored or diverted (and subtracting any water returned), at points above the recording location. Historical natural weekly averaged flows for the period 1928-1995 were obtained from records of stream flow gauges, reservoir storage/releases and consumptive diversions/ return flows.

An exception to the use of natural flow supplies was the St. Mary River which is apportioned between Canada and the United States under Article VI of the 1909 Boundary Waters Treaty.

For the 1928-1995 period, the weekly Canadian entitlement was used in the modelling.

Consumptive Demands

A. Licensed Consumptive Demands

These are all licences that have been issued in the SSRB to date.

The largest demands are from irrigation districts and private irrigation and these vary with climatic conditions for the year. These variable demands and return flows are computed by the Irrigation District Model (IDM) of Alberta Agriculture, Food and Rural Development (AAFRD). Scenarios of these demands for both current conditions and projected future use patterns have been prepared by AAFRD. A report *South Saskatchewan River Basin Irrigation in the 21st Century* was issued by the Alberta Irrigation Projects Association (AIPA), which details these demand sets.

An important parameter governing irrigation demands is the "irrigation practice", which is the response of irrigators to moisture deficit. Currently irrigators apply water at a level corresponding to 80% of moisture deficit. This is referred to as the evapotranspiration (ET) level, i.e. 80%ET is the current application practice. In future, AAFRD predicts that irrigators will apply more water, to a ceiling level of 90% of moisture deficit – the 90%ET level. This level is considered to be the upper limit that irrigators will ever apply.

Non-irrigation demands are generally modelled as non-varying from year to year.

More recent licences have Instream Objectives attached as conditions of withdrawal, and these are modelled. Older licences often have no instream conditions attached.

B. Projects Committed to by the Alberta Government

There are five:

1. Little Bow Storage Project

   The 61,700 dam^3 (50,000 acre-feet) Little Bow River Reservoir, 1.70 m^3/s (60 ft^3/sec) Clear Lake canal and expansion of the Little Bow canal to 8.50 m^3/s (300 ft^3/sec) is in place. Applications for much of the 8,100 ha (20,000 acres) of irrigation associated with this project have been received;

2. Carseland-Bow Headworks Expansion

   This is not yet licensed, however, the following structure expansions will be implemented:

- Main canal, Carseland to McGregor Lake – to 51.0 m^3/sec (1,800 ft^3/sec);
- Canal, McGregor Lake to Travers Reservoir – to 79.3 m^3/sec (2,800 ft^3/sec);
- Travers Reservoir to Little Bow Reservoir – to 87.8 m^3/sec (3,100 ft^3/sec);
- Little Bow Reservoir outlet – to 87.8 m^3/sec (3,100 ft^3/sec)

3. Piikani Indian Reserve Projects 43,200 dam^3 (35,000 acre-feet)
4. Keho-Barons South (incorporated with LNID) 4050 ha (10,000 acres)
5. Siksika Nation Projects 43,200 dam^3 (35,000 acre-feet - assumed volume)

C. Future Irrigation Demands

These are the quantities of water required to irrigate the acreages specified in the Water Allocation Regulation for the SSRB (O.C. 615/91 in September, 1991), that are currently not licensed. They are divided into two categories:

- For Irrigation Districts, they are the volumes and/or rates, additional to those quantities in current licences that are needed to irrigate the acreages specified in the Regulation. The Western and Bow River Irrigation Districts have submitted applications for additional quantities.

- For non-Irrigation Districts, these are the irrigated acres specified in the Regulation that are currently not licensed. In some cases applications have been received, but licences have not yet been issued. For the remainder, no application has been received, e.g. the Special Areas Water Supply Project, which is listed in the Regulation as including 10,100 ha (25,000 acres) of irrigation.

There is no commitment by the Alberta Government to issue licences for these quantities.

D. Future Non-Irrigation Demands

Hydroconsult Ltd has estimated the potential non-irrigation demand growth for the years 2021 and 2046 in the SSRB and these are presented in a separate report: *South Saskatchewan River Basin Non-Irrigation Water Use Forecasts*. Growth estimates for the year 2046 are used in the modelling scenario A3.

Alberta/Saskatchewan Apportionment

Schedule A of the 1969 Master Agreement on Apportionment for the South Saskatchewan River between Alberta and Saskatchewan, specifies that:

- Annually, one half of the natural flow of the SSRB shall be passed to Saskatchewan. However, if natural flow falls below 5.2 million dam^3 (4.2 million acre-feet), Alberta can still keep more than half of the natural flow to a maximum quantity of 2.6 million dam^3

(2.1 million acre-feet), provided that the instantaneous flow does not fall below 42.5 m^3/s (1,500 ft^3/sec) (see clause below);

- Instantaneously, the combined flow of the South Saskatchewan and Red Deer rivers into Saskatchewan shall be not less than 42.5 m^3/s (1,500 ft^3 /sec) or half of the instantaneous natural flow, whichever is less.

These conditions were included in the model.

Instream Flow Requirements

There are two categories of instream flow requirements utilized in this phase of the modelling. Some scenarios utilize the existing instream objectives (IO) while others utilize the aquatic environment protection flows (IFN). The two categories are described in more detail below.

A. Existing Instream Objectives

Existing Instream Objectives are flows that are included in conditions attached to licences currently being issued. They are generally known as Instream Objectives (IO). Licensees are not permitted to withdraw water when river flows fall below the specified IO. Alberta Environment generally operates the provincial infrastructure to meet the current IO.

Red Deer River basin

On the mainstem reaches from Dickson Dam to the Saskatchewan border, the following IOs have been applied:

- 8.50 m^3/s (300 ft^3/sec) for irrigation licences;
- 4.25 m^3/s (150 ft^3/sec) for non-irrigation licences.

The effect of these IOs on protection of the aquatic environment is not known.

Bow River basin

There are five mainstem reaches from Ghost Reservoir to Bassano Dam. These are:

1. Ghost Reservoir outlet to Bearspaw Reservoir outlet;
2. Bearspaw Reservoir outlet to Elbow river confluence;
3. Elbow river confluence to Highwood River confluence;
4. Highwood River confluence to Carseland weir;
5. Carseland weir to Bassano dam.

Each reach has an IO, which is based on a relationship known as the 80% habitat fish rule curve (80FRC). The IO in these reaches is based on habitat only and does not include water quality (temperature and dissolved oxygen) protection parameters.

The reach below Bassano to the mouth has three IO values:

1. 39.6 m^3/s (1,400 ft^3/sec) for all licences except the Eastern Irrigation District (EID);
2. 2.83 m^3/s (100 ft^3/sec) for EID's 1963 licence (1903 priority);
3. 11.3 m^3/s (400 ft^3/sec) for EID's 1998 licence.

The effect of these IOs on protection of the aquatic environment is not known.

The Highwood River has:

- no IO for private withdrawals;
- 1994 Operating Guidelines IO applied to the Women's Coulee and existing Little Bow diversions of 1.70 m^3/s and 2.83 m^3/s (60 and 100 ft^3/sec), respectively;
- a future IO which provides protection for fish, water quality and flushing flows, applied to the Little Bow 5.66 m^3/s (200 ft^3/sec) canal expansion.

Oldman River basin

There are six mainstem reaches from the Oldman Reservoir to the mouth. They are:

1. Oldman Reservoir outlet to Pincher Creek confluence;
2. Pincher Creek confluence to the Lethbridge Northern Irrigation District (LNID) weir;
3. LNID weir to Willow Creek confluence;
4. Willow Creek confluence to Belly River confluence;
5. Belly River confluence to St Mary River confluence;
6. St Mary River confluence to Mouth.

Each reach has an IO that is the greater of the 80% habitat fish rule curve (80FRC) and the water quality (temperature and oxygen) protection IO flows.

The three Southern Tributaries to the Oldman River each have minimum flows specified in the SSRB Regulation. They are:

- 2.27 m^3/s (80 ft^3/sec) for the Waterton River at the mouth;
- 0.93 m^3/s (33 ft^3/sec) for the Belly River below the Belly River Diversion,
- 2.75 m^3/s (97 ft^3/sec) for the St. Mary River at the mouth.

The effect of these IOs on protection of the aquatic environment is not known.

South Saskatchewan River sub-basin

From the confluence of the Bow and Oldman rivers to the Saskatchewan border, an IO of 42.5 m^3/s (1,500 ft^3/sec) is attached to licences.

The effect of this IO on protection of the aquatic environment is not known.

B. Aquatic Environment Protection Flows

The Technical Instream Needs Group has completed a report entitled: *Instream Flow Needs Determinations for the South Saskatchewan River Basin, Alberta, Canada*

That report details the quantitative estimates of the flows required to protect the aquatic environment in the following stream reaches:

Red Deer River

Dickson Dam to Medicine River confluence

Medicine River confluence to Blindman River confluence

Blindman River confluence to Special Areas Water Supply Project diversion site

Special Areas Water Supply Project diversion site to Drumheller

Drumheller to Dinosaur Provincial Park

Dinosaur Provincial Park to Bindloss

Bindloss to Saskatchewan border

Bow River

WID weir to Highwood River confluence

Highwood River confluence to Carseland weir

Carseland Weir to Bassano Dam

Bassano Dam to Mouth

Oldman River

Oldman Reservoir outlet to Pincher Creek confluence

Pincher Creek confluence to LNID Weir

LNID Weir to Willow Creek confluence

Willow Creek confluence to Belly River confluence

Belly River confluence to St Mary River confluence

St Mary River confluence to Little Bow River confluence

Little Bow River confluence to Mouth

South Saskatchewan River

Oldman River/Bow River confluence to Medicine Hat

Medicine Hat to Saskatchewan border

Waterton River

Waterton Reservoir to Mouth (2 reaches)

Belly River

Belly River Weir to Waterton River confluence (2 reaches)

Waterton River confluence to Mouth

St Mary River

St Mary Reservoir outlet to Mouth (2 reaches)

Four components are used as surrogates for the overall aquatic environment: Water Quality (Temperature, Dissolved Oxygen and Ammonia), Fish Habitat, Riparian Vegetation and Channel Maintenance. For each of the reaches listed above, 52 weekly flows for 68 years (1928 to 1995) are recommended to protect the aquatic ecosystem. The fundamental basis for these flows is the "natural flow paradigm".

The weekly flow sets for each reach were input into the WRMM as time series data. The values were applied as required in selected scenarios to replace the existing IO on licences where provision exists to modify the condition (i.e. "back-fitted") and on future allocations.

In this report, these potential flow requirements are described by the acronym "IFN" to be distinguished from the existing instream flow requirements "IO".

Water Storage and Operations Management

The IFN flows described above are substantially higher than current IO flows. When they are imposed as the IO on licences that can be back-fitted and future allocations, the question arises as to the degree to which on-stream Alberta Government storage should be operated to satisfy the new IO.

It is possible that the Alberta Government storages (Gleniffer Lake, Oldman, Waterton and St Mary Reservoirs could be operated as much as possible to meet the higher flows. This would require significant draining of these reservoirs and result in extended periods of low levels (or empty) for long periods. A hypothetical scenario (B2), is modelled as an extreme example to assess the impact of assigning highest priority to the IFN.

However for the remaining scenarios (B1, B3, B5), where the IFN is used as the new IO, some restrictions are applied:

- The storage is not allowed to fall below the top of the invert for diversions, so that licences requiring diversion from natural flow (but via the storage invert) can always draw to the maximum of their diversion capacity although limited by natural flow;
- Sufficient storage is protected in the Oldman Reservoir in the model so that 42.5 m^3/s (1500 ft^3/sec) is always maintained in the South Saskatchewan River (the IO condition on senior licences);
- Gleniffer summer recreation levels are always protected.

Any remaining water can, at the discretion of the Alberta Government, be released to supply junior licences, which cannot be completely satisfied from natural flow. However, reservoir operating rules must be followed in order to ensure enough water in the reservoir to meet priorities of recreation, IO and apportionment. Therefore, there are times when the additional water needed to supplement junior licences is not available for release. The junior licences experience severe deficits under these conditions.

An identical situation occurs in the Oldman mainstem with junior licences (those issued after 1988 when the Oldman Reservoir was licensed).

Modelling of Licences and Priorities

The model allocates the available water supply to the various demands in order of licence priority and makes best use of storage structures to mitigate shortages in times of low water supply and high demands.

All major licences are represented according to their priorities and with their restrictions, e.g. stage/flow and IOs, where applicable. It is not possible or practical to model all licences individually in the SSRB – there are so many. Thus, the smaller licences are lumped together by river reach into two categories; senior and junior. Categorization as senior or junior is based on licence date relative to introduction of the IO and construction of Alberta Government on-stream storage.

In the Red Deer River, licences earlier than 1977 (when Gleniffer Reservoir was licensed) are senior, since they must be satisfied before Gleniffer Reservoir can store water. Licences after 1977 are junior, since they receive supply after Gleniffer, which can fill as often as needed in order to maintain a recreation level and also to release water for IOs and apportionment.

An identical situation occurs in the Oldman mainstem where junior licences are those after 1988 when the Oldman Reservoir was licensed.

In the Bow sub-basin, junior licences are defined as those licences that are subject to the 80%FRC, which has been applied since 1992.

SSRB Sub Basin Models

There are some technical limitations and practical considerations related to the simulation of an extremely complex river system such as the SSRB. Therefore, the WRMM computer simulation model for the SSRB consists of several component models. The inputs and outputs for the various models are utilized in a manner such that the water balance results would be very similar to what would happen if there were a single model.

In the Bow mainstem the only on-stream storage is licensed to TransAlta Utilities (TAU). A separate WRMM model of the upper Bow basin (above Bearspaw reservoir) was run to simulate TAU operations during the 1928-1995 period and to obtain a file of flow releases from Bearspaw reservoir. The water availability analysis reflects current TAU operations. Junior licences are defined as those licences that are subject to the 80% FRC applied since 1992.

The Southern Tributaries to the Oldman River (Waterton, Belly and St Mary Rivers) are modelled separately. The output from the Southern Tributaries model is input into the SSRB model.

The Highwood, Little Bow and Mosquito Creek basins are modelled separately. These basins are the subject of the Highwood Management Plan, which is currently proceeding. The interim diversion plan is used as the base input to the SSRB model.

The Special Areas Water Supply Project (SAWSP) is represented in a separate WRMM simulation. It is proposed to withdraw water from the Red Deer River near Nevis and to supply this to Sounding and Berry Creeks for irrigation and wildfowl (Ducks Unlimited) projects. The model was run for the 1928-1995 period and the demand flow requirements for the various projects were added to produce a single demand value at the Nevis diversion point on the Red Deer river. This single demand was input at the Nevis location point in the SSRB simulation. Thus the results presented are for the overall SAWSP demand, rather than for individual irrigation or wildfowl projects within SAWSP.

DESCRIPTION OF SCENARIOS

Eight scenario simulations were carried out and are described in this section. The scenarios are labeled A1 to A3 and B1 to B5 respectively. In order to understand results from the scenarios it is important to understand the basic assumptions for each scenario and their differences.

Tables 1 and 2 summarize the scenarios. Apart from scenarios A1 and A2, which Alberta Environment considers essential, the numbers in parentheses below the scenario abbreviation indicate the priority set by the BAC for modelling. For example, the BAC's rated Scenario B3 as higher priority than Scenario B4. Scenario B2 was added by the Steering Committee.

In general, Scenarios B1 to B4 are built upon the base case Scenario A1. Similarly, Scenario A3 and B5 are built upon Scenario A2. For presentation purposes, the eight scenario simulations are divided into three groups: **Base Case**, **Potential Development** and **Exploratory**.

Base Case Scenario

Scenario A1 is an update of Scenario A in the Phase 1 modelling, with more detailed breakdown on senior and junior licences. It represents current (July 2002) licences and the existing IO, plus commitments in the SSRB. District irrigation is at SSRB Regulation acreages. Additions to the Phase 1 Scenario A are:

- The 1998 priority EID licence, with a new IO below Bassano of 11.3 m^3/s (400 ft^3/sec).

- An additional 4,050 ha (10,000 acres) in the Lethbridge Northern Irrigation District (LNID), representing the Keho-Barons South project, named in the SSRB Water Management Regulation. LNID has taken over Keho-Barons South's application and will treat the project as an integral part of the District.

Potential Development Scenarios

These scenarios represent the direction water management is currently taking in the South Saskatchewan River Basin.

Scenario A2 is the same as Scenario A1, but with non-district irrigation consumption increased to the acreage limits set by the SSRB Water Allocation Regulation. These scenarios assume that new allocations will be issued for the Special Areas Water Supply Project, the Oldman River Reservoir Area, the Western Oldman Area, and the Willow Creek projects and private irrigation (principally in the Red Deer sub-basin). With this increased consumption, they evaluate the performance under current IOs.

Scenario A3 shows what would happen if, with current IOs:

- Irrigation Districts expand to acreages that are 110% (in the Oldman basin) and 120% (in the Bow basin) of the acreage limits set by the SSRB Regulation, and;

- non-irrigation consumption increases in accordance with a 50-year projection.

Applications by WID and BRID were modelled as required in Scenarios A2, A3 and B5.

Table 1 – Description of Base Case and Potential Development Scenarios

Scenario	Description	Comments
	Base Case Scenario	
A1	**Current Allocations and Commitments (Existing IOs)** • Commitments: Little Bow Storage Project, Carseland Headworks expansion, Piikani and Siksika Projects; Keho-Barons South Project[4]. • Existing Instream Objectives (IO); • Irrigation Districts at SSRB Regulation limit areas and future irrigation practice (90% ET); • Non-District irrigation at current areas; • Non-Irrigation at current levels; Provincial Storage used to support IO, Apportionment and Licenses.	Evaluates performance of currently licensed plus committed consumption and instream flows, assuming perpetuation of existing IO.
	Potential Development Scenarios	
A2	**SSRB Regulation Acreages (Existing IOs)** *As Scenario A1, except:* • Non-District irrigation at SSRB Regulation limit areas; • WID, BRID licence applications included only if needed.	Evaluates performance of currently licensed, committed consumption, non-committed consumption[5] (up to SSRB Regulation limits) and instream flows, assuming perpetuation of existing IO.
A3 (2)	**Maximum Expansion/Growth (Existing IOs)** *As Scenario A2, except:* • 10 % (Oldman), 20% (Bow) Irrigation District expansion beyond SSRB Regulation limit areas (but within existing licensed volumes); • 50 year projection (medium forecast) for Non-Irrigation consumption (except for Southern Tributaries, where only applications are modelled).	Evaluates performance of Irrigation Districts expanding beyond SSRB Regulation limit areas and future projections[6] of non-irrigation consumption, assuming perpetuation of existing IO.

Exploratory Scenarios

Scenario B1 is the same as the base case Scenario A1, but replaces current IOs with IFNs. In this scenario, IFNs are imposed on any new allocations and back-fitted, where legally possible, to existing allocations.

Scenario B2 is the same as Scenario B1, but imposes IFNs on all allocations. It shows the consequences of giving IFNs first priority in the SSRB over all licences and storage.

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4 Keho-Barons South Project is modeled as part of LNID

5 Non-commited consumption includes: Special Areas Water Supply, Oldman River Reservoir Area, Western Oldman Area and Willow Creek Projects. BRID and WID applications are also included.

6 This is the only scenario to model future projections of non-irrigation consumption.

Scenario B3 is the same as Scenario B1, but shows to what extent the IFNs can be met if water conservation measures reduce consumption in the SSRB by 20%.

Scenario B4 is the same as Scenario A1, but shows how much extra consumption in the Red Deer basin is possible and the impacts on licences in the Bow, Oldman and South Saskatchewan basins if the Red Deer and South Saskatchewan basins each contribute 50% of their respective natural flow to apportionment to Saskatchewan.

Scenarios B5 is the same as Scenario A2, but replaces current IOs with IFNs . IFNs are imposed on any new allocations and back-fitted, where legally possible, to existing allocations

Table 2 – Description of Exploratory Scenarios

Scenario	Description	Comments
	Exploratory Scenarios	
B1 (3)	**IFN Licence Condition on Base Case** *As Scenario A1, except:* • IFNs for all streams applied to: - Licences with an IO condition that can be revised; - Commitments (e.g. Carseland Headworks expansion, Piikani and Siksika Projects; Keho-Barons South Project).	Evaluates performance of currently licensed plus committed consumption and instream flows, when the IFN replaces the existing IO.
B2	**IFN Priority on Base Case** *As Scenario B1, except:* • IFN have precedence over all licences, commitments and storage.	Evaluates full effects on licences, commitments and storage that could result from imposing IFN as IO.
B3 (1)	**Consumptive Use Reduction (IFN Licence Condition)** *As Scenario B1, except:* • 20% Reduction in all (licensed and committed) consumptive uses.	Evaluates improvements in instream flows that can be obtained from water conservation measures.
B4 (5)	**Apportionment (Existing IOs)** *As Scenario A1, except:* • Apportionment contributions fixed at 50/50 (Red Deer/South Saskatchewan sub basins).	Evaluates: - how much expansion and development of new demands in the Red Deer basin is possible when only 50% of the Red Deer basin natural flow is required to be passed to Saskatchewan; - impacts to the Bow, Oldman and South Saskatchewan sub-basins from passing 50% of their natural flow to Saskatchewan.
B5 (4)	**IFN Licence Condition on SSRB Regulation Acreages** *As Scenario A2, except:* • IFNs for all streams are applied to: - Licences with an IO condition that can be revised; - Committed and non-committed consumption	Evaluates performance of currently licensed, committed consumption, non-committed consumption (up to SSRB Regulation limits) and instream flows, when IFNs are used as IO.

SCENARIO RESULTS

The WRMM computer simulation model produces extensive output for all aspects of the components in the model. This section describes evaluation of output from the model for each of the scenarios.

Tables 3 and 4 summarize the results of the scenario modelling. Table 3 contains summaries of results for the Base Case and Potential Development scenarios. Table 4 contains summaries of results for the five Educational/Exploratory scenarios. The tabulated results are presented in the following category order:

- Junior allocations and commitments
- District Irrigation
- Instream flows
- Storage

Appendix 1 shows the result summary tables for the Red Deer, Bow, Oldman, Southern Tributaries and South Saskatchewan sub-basins.

Base Case Scenario

Scenario A1

In the Red Deer sub-basin, there are infrequent consumptive use deficits and existing instream objectives are always met;

In the Bow sub-basin:

- Junior allocations and commitments have frequent, substantial deficits.
- The Western Irrigation District (WID) cannot achieve its maximum area of 38,500 ha (95,000 acres) under the SSRB Regulation with its current licence;
- The Bow River Irrigation District (BRID) can achieve its maximum area of 85,000 ha (210,000 acres) under the SSRB Regulation with its current (two) licences;
- The Eastern Irrigation District (EID) can achieve its maximum area of 115,700 ha (286,000 acres) under the SSRB Regulation with its current (two) licences;
- Existing instream objectives are frequently not met above Bassano;
- Existing IOs are always met below Bassano, but instream flows are frequently at the instream objective value of 11.3 m^3/s (400 ft^3/sec);

In the Oldman/South Saskatchewan mainstems, there are few consumptive use deficits and existing instream objectives are always met.

In the Oldman Southern Tributaries, junior allocations (there are no commitments) have frequent, substantial deficits. Existing instream objectives are always met.

Potential Development Scenarios

Scenario A2

In the Red Deer sub-basin:

- Junior allocations and future irrigation have infrequent, small deficits;
- The Special Areas Water Supply Project has some deficits;
- Existing Instream Objectives are always met.

In the Bow sub-basin:

- Performance is largely similar to Scenario A1, except for the WID where a significant improvement is obtained from an additional allocation;

  It should be noted that WID has applied for 145,000 dam^3 (117,600 acre-ft) but current IOs would limit the volume that can be diverted to 61,700 dam^3 (50,000 acre-ft);
- The two BRID applications are not modelled, since the maximum area under the SSRB Regulation is already achieved in Scenario A1 with its current (two) licences;
- Existing instream flow results are similar to Scenario A1.

In the Oldman/South Saskatchewan mainstem (where most of the Non-District expansion occurs):

- Deficits to junior allocations and commitments increase compared to Scenario A1, since the consumptive demand relying on the Oldman Reservoir storage is increased;
- Existing instream objectives are always met.

In the Oldman Southern Tributaries, where the acreage increase is limited to Non-District irrigation applications received:

- Deficits to junior allocations are similar to those in Scenario A1;
- Existing instream objectives are always met.

Scenario A3

Expanding Irrigation District acreage to 110% (Oldman basin) and 120% (Bow basin) of SSRB Regulation limits marginally increases deficits to all districts, except:

- WID which has a significant deficit increase;
- BRID, EID and UID, which experience no deficit increase; and
- The district expansions reduce the water available for Junior allocations and commitments, so their deficits increase significantly.

The 50-year projected non-irrigation water use has very frequent, large deficits.

Exploratory Scenarios

Scenario B1

Limiting IFNs to "back-fits" in allocations where provision allows and to commitments, plus giving them priority call on government storage results in increases in instream flows. The IFN flow values are sometimes achieved – frequently not achieved. The performance varies considerably across the entire SSRB, with the most achievable increase in instream flows being in the Red Deer sub-basin and small increases everywhere else. With the exception of the Red Deer sub-basin, any increased instream flows result in frequent and substantial deficits to junior allocations and commitments.

Scenario B2

IFNs can be generally met in the Bow/Oldman/South Saskatchewan mainstem, Waterton and Belly River sub-basins. However, they cannot be met in:

- Red Deer River sub-basin - since they are often greater than natural flow and Gleniffer storage cannot be refilled sufficiently to make up the shortfall in instream flows; and
- St. Mary River sub-basin - since the IFN is based on the entire natural flow of the sub-basin, but there is diversion of the USA share to the Milk River prior to entering Canada.

Scenario B3

A 20% reduction in water consumption provides a modest increase in instream flows - well short of the IFN values. A portion of the "saved" water is actually used to reduce deficits in junior allocations. The WID's senior licence can now supply the maximum area under the SSRB Regulation with only five deficit years (compared with 20 deficit years for the case of no Water Conservation in Scenario B1).

Scenario B4

A fixed 50% of natural flow Red Deer River contribution to apportionment would result in 655,000 dam^3 (531,000 acre-feet) on average being available in the Red Deer sub-basin and could be as low as 190,000 dam^3 (154,000 acre-feet) in a dry year. However, this would result in frequent, large deficits to junior allocations and commitments in the Oldman/South Saskatchewan mainstem.

Scenario B5

Results are similar to Scenario B1, except that the SAWSP and additional non-district irrigation demand in the Red Deer basin have frequent and substantial deficits.

Table 3 – Summary of Results - Base Case and Potential Development Scenarios

Scenario	Category	Red Deer Sub-Basin	Bow Sub-Basin	Oldman Mainstem / South Saskatchewan Sub-Basin	Southern Tributaries
A1 Current Allocations and Commitments (Existing IOs)	**Junior allocations and commitments**	Infrequent (1 to 2 years) deficits to consumption.	Frequent deficits (>20 years) in junior consumption and commitments.	The deficit years in junior consumption, and commitments range from 0 to 8 years.	Deficits in junior consumption. No deficits to BTIP
	District Irrigation		WID has 20 deficit years (1903 licence only). No deficits in BRID, EID.	No deficits in LNID/Keho-Barons South.	No deficits in SMP and UID. Frequent minor deficits in MVID, LID and AID due to canal capacity restrictions.
	Instream flows	Existing IO always met.	Frequent deficits (10-34 years) in IO above Bassano. Below Bassano IO 11.3 m^3/s (400 ft^3/sec) always met, but frequently at this value.	Existing IO always met.	Existing IO always met (except for the Belly river above Waterton river confluence in winter, due to low natural flows).
	Storage	Gleniffer recreation always met.	McGregor and Travers storage occasionally at minimum levels	Oldman storage occasionally at low levels.	Waterton and St. Mary storage occasionally at minimum levels
A2 SSRB Regulation Acreages (Existing IOs)	**Junior allocations and commitments**	Infrequent (1-4 years) deficits in junior consumption and future irrigation. Deficits in 8 years in the Special Areas Water Supply Project (SAWSP).	Frequent deficits (> 20 years) in junior consumption, commitments and future irrigation (similar to A1).	The deficit years in junior consumption, commitments and future irrigation range from 2 to 12 years (0 to 8 years in A1). Additional future irrigation shares Oldman Reservoir storage.	Results similar to A1, with addition of irrigation applications, which have deficits almost every year.
	District Irrigation		WID deficit years reduced to 9 (from 20 in A1). WID application of 145,000 dam^3 is modelled, but only 61,000 dam^3 can be diverted. No deficits in BRID and EID (the two BRID applications for additional allocation volumes are not needed, so are not modelled).	No deficits in LNID/Keho-Barons South.	
	Instream flows	Existing IOs always met.	Same deficits in IOs as in A1.	IOs always met.	
	Storage	Gleniffer storage levels slightly lower than in Scenario A1. Recreation levels occasionally not met (due to adherence to existing minimum fill curve).	McGregor and Travers Levels are similar to A1.	Oldman Reservoir storage levels lower than in Scenario A1.	
A3 Maximum Expansion / Growth (Existing IOs)	**Junior allocations and commitments**	22 deficit years in future non-irrigation consumption.	Junior allocations, Commitments and Future consumption have large deficits in many years. The WID, BRID and EID expansion (to 120% of SSRB area limits) reduces the water available for Junior, Commitments and Future consumption.	The number of deficit years in junior consumption, commitments and future consumption increases substantially (33-67 years) from A2. The LNID expansion (to 110% of SSRB area limits) and the future non-irrigation consumption represent extra demands on the Oldman Reservoir storage.	Junior allocations (including BTIP) have a slightly increased number of deficit years compared with A2. Exception is Junior non-district irrigation (no deficit years – similar to Scenario A2). The SMP Districts, UID, MVID, LID and AID expansions (to 110% of SSRB area limits) and the non-irrigation consumption applications represent extra demands on both the natural flow and the Waterton-St Mary headworks storage.
	District Irrigation		WID has 13 deficit years, increased from 9 in A2 (WID application is modelled). No deficits to BRID (as in A2 and B5, additional allocation volumes are not needed, so are not modelled). EID has no deficits.	LNID/Keho Barons-South has 2 deficit years.	Districts have a slightly increased number of deficit years compared with A2. Exception is UID (no deficit years – similar to Scenario A2).
	Instream flows	Adherence to existing minimum fill curve results in one deficit year in existing IOs in the reaches below Dinosaur Provincial Park (no deficit years in A2).	Similar deficits in IOs as in A1 and A2.	IOs are always met.	IOs are always met.
	Storage	The additional consumption draws down Gleniffer storage levels below those in Scenario A2. This increases consumption deficits over A2. Adherence to existing minimum fill curve results in increased frequency of not meeting recreation levels relative to A2.	Greater draw down of McGregor and Travers storage than in A1.	Oldman Reservoir storage levels decrease compared to Scenario A2.	Waterton and St Mary Reservoir storage levels slightly lower than in Scenario A2.

Table 4 – Summary of Results – Exploratory Scenarios

Scenario	Category	Red Deer Sub-Basin	Bow Sub-Basin	Oldman Mainstem/ South Saskatchewan Sub-Basins	Southern Tributaries
B1 IFN Licence Condition on Base Case	**Junior allocations and commitments**	A few deficits in junior consumption not subject to IFN, due to lower levels in Gleniffer. Large deficits every year in junior consumption subject to IFN.	Large deficits every year in junior consumption and commitments.	Large deficits every year in junior consumption and commitments.	Deficits every year in junior consumption and in many years in BTIP.
	District Irrigation		Deficits in 20 years in WID (No change from A1). No deficits in BRID No deficits to EID (Imposition of IFN causes EID to revert to 1903 licence only).	Deficits in 23 years to LNID/Keho-Barons South.	Deficits in many years in SMP. Deficits in 16 years in UID (licence off Waterton subject to IFNs). MVID, LID and AID unchanged from A1 (not subject to IFNs).
	Instream flows	IFN not met in almost all years.	IFN not met in any year.	IFNs not met in almost all years.	IFNs not met in any year.
	Storage	Gleniffer levels only slightly lower than in A1, due to Gleniffer recreation having higher priority than IFN.	Greater draw down of McGregor and Travers storage than in Scenario A1.	Oldman Reservoir levels greatly decreased.	Waterton and St. Mary reservoir levels greatly decreased from A1.
B2 IFN Priority on Base Case	**Junior allocations and commitments**	Frequent and substantial deficits to all allocations.	Frequent and substantial deficits to all allocations.	Frequent and substantial deficits to all allocations.	Frequent and substantial deficits to all allocations
	District Irrigation		Frequent and substantial deficits to all irrigation districts.	Frequent and substantial deficits to LNID/Keho-Barons South.	Frequent and substantial deficits to all irrigation districts.
	Instream flows	IFNs are generally not met, since they are often greater than natural flow. . Also, low storage levels in the Gleniffer Reservoir occasionally do not permit passage of sufficient flow to meet IFNs through the outlet structure.	IFNs are generally met downstream of Calgary using releases from TransAlta storages.	IFNs are sometimes not met in winter, when the water quality instream flow need is greater than natural flow. Also low storage levels in the Oldman Reservoir occasionally do not permit passage of sufficient flow to meet IFNs through the outlet structure.	In the Waterton river, IFNs are always met. In the St. Mary river below St. Mary Reservoir, IFNs are not met, since the prior diversion of the U.S. share of the St. Mary river was not accounted for in the developed of IFNs.
	Storage	Gleniffer storage frequently at low levels.	Greater draw down of McGregor and Travers storage than in Scenario B1.	Oldman Reservoir frequently at low levels.	Waterton and St. Mary reservoirs frequently at low levels
B3 Consumptive Use Reduction (IFN Licence Condition)	**Junior allocations and commitments**	Large deficits every year in junior consumption subject to IFNs.	Large deficits every year in junior consumption and commitments, since they are subject to IFNs.	Large deficits every year in junior consumption and commitments.	Deficits every year in Junior Consumption (No change from B1). Fewer deficit years in BTIP than in B1
	District Irrigation		Deficits in only 5 years in WID, since 1903 licence not subject to IFNs (down from 20 years in B1). No deficits to BRID and EID (No change from B1).	Deficits in 6 years to LNID/Keho-Barons South. (Down from 23 years in B1.)	Fewer deficit years in SMP, UID, MVID, LID, and AID than in B1
	Instream flows	Instream flows increased (IFNs not met in almost all years).	Instream flows increased (IFNs not met in almost all years).	Instream flows increased. (IFNs not met in almost all years.)	Instream flows increased. (IFNs not met in any year)
	Storage	Gleniffer levels similar to B1.	McGregor and Travers storage levels similar to B1.	Oldman Reservoir levels similar to B1.	Waterton and St. Mary reservoir levels similar to B1..
B4 Apportionment (Existing IOs)	**Junior allocations and commitments**	No deficits to consumption.	Little change from Scenario A1, since the additional water required to send 50% of [Bow + Oldman] natural flow to Apportionment is primarily obtained from Oldman River Reservoir storage. (Draw down of the TransAlta reservoirs in the upper Bow sub-basins is not modeled.)	Large deficits most years in junior consumption and commitments.	No change from Scenario A1. (Oldman basin contribution to Apportionment supplied by Oldman mainstem.)
	District Irrigation	In the average year, an additional 655,000 dam^3 is available for consumptive allocation. In the driest year this drops to 190,000 dam^3		Slight increase in deficits in LNID/Keho-Barons South as compared to Scenario A1.	
	Instream flows	Existing IOs always met.		Existing IOs always met.	
	Storage	Gleniffer storage levels similar to those in Scenario A1.		Oldman River Reservoir storage levels significantly lower than in Scenario A1.	
B5 IFN Licence Condition on Scenario A2	**Junior allocations and commitments**	Marginally increased deficits in junior consumption not subject to IFNs compared to A2, due to slightly lower storage levels in Gleniffer. Large deficits in many years in junior consumption, future irrigation and SAWSP that are all subject to IFNs.	Large deficits every year in junior consumption, commitments and future irrigation.	Large deficits every year in junior consumption, commitments and future irrigation. Results similar to B1 with addition of future irrigation, which adds to the deficits.	Results similar to B1, with addition of irrigation applications, which have deficits almost every year.
	District Irrigation		Deficits in 19 years in WID. (Up from 9 in A2; WID application is modeled subject to IFN). No deficits to BRID. (As in A2, additional allocation volumes are not needed, so are not modeled.) No deficits to EID. (Imposition of IFN causes EID to revert to 1903 licence only – as in B1.)	Deficits in 24 years to LNID/Keho-Barons South.	
	Instream flows	IFNs not met in almost all years.	IFNs not met in any year.	IFNs not met in almost all years.	
	Storage	Gleniffer levels only slightly lower than in A2, due to Gleniffer recreation having higher priority than IFNs.	Greater draw down of McGregor and Travers storage than in A2.	Oldman Reservoir levels greatly decreased from A2.	

Apportionment Contribution

For three scenarios (A1, A2, A3) that use existing IOs, tables were generated to illustrate the minimum contribution of the Red Deer sub-basin to the flow required to fulfill the 1969 Apportionment Agreement.

In each case, the annual amount required from the Red Deer River to make up the shortfall in volume contributed by the Bow/Oldman sub-basins was calculated. Appendix 2 contains tables of this required Red Deer contribution and Table 5 summarizes the contributions.

Table 5 – Red Deer River Minimum Apportionment Contribution

Scenario	No of Years required contribution is zero	No of Years required contribution is less than or equal to 50% Natural Flow	No of Years required contribution is greater than 50% Natural Flow
A1	27	30	11
A2	27	28	13
A3	20	25	23

MODEL OUTPUT – WEB SITE

To assist dissemination of information from the scenario modelling, the results are displayed on an Internet Web site at:

http://www3.gov.ab.ca/env/water/regions/ssrb/wrmmoutput/index.asp

Detailed flow and reservoir elevation data and results for river reaches, diversion canals, reservoirs, consumptive demands, etc. are provided on the website. This site allows the user to browse either Phase 1 or Phase 2, Part 1 information. Choosing Phase 1 enables a view of the results from the four scenarios that were modeled, on separate pages for the Red Deer, Bow, Oldman and South Saskatchewan sub-basins. The report that describes and summarizes the findings from the Phase 1 modeling may also be viewed in PDF format.

The Phase 2, Part 1 information is presented in considerably greater detail.

From a map of the SSRB, the user can "mouse-over" any one of the four sub-basins and choose either "Summary Tables" or "Scenarios".

Summary Tables

The results of all eight scenarios can be viewed for individual reaches or as a composite result for the entire sub-basin. Results are presented in terms of numbers of deficit years[7] to specified component groups. The component groups include Irrigation Districts, Non-District Irrigation, Non-Irrigation Consumptive Use and Instream Flows. Non-District Irrigation and Non-Irrigation Consumptive Use are divided into:

- Senior licences that generally are not subject to IOs and, in the Oldman and Red Deer sub-basins, have priorities senior to Lake Gleniffer and the Oldman Reservoir, respectively;
- Junior licences that are subject to IOs[8] and, in the Oldman and Red Deer sub-basins, have priorities junior to Lake Gleniffer and the Oldman Reservoir, respectively;
- Future allocations that are subject to the same conditions as Junior Licences.

In addition to the component groups, the following Existing and Future Projects are listed:

Red Deer sub-basin Special Areas Water Supply Project (SAWSP), Sheerness and Deadfish Projects;

[7] Out of the 68 year modelled period, 1928-1995.

[8] Junior licences are further subdivided based on whether they include a provision to change their IO condition. In the Red Deer basin, where this provision exists, they are described as "subject to WCO". WCO is the potential Water Conservation Objective for the reach, and is set equal to the IFN flow values. Those Junior licences which do not contain provision to change the IO are described as "not subject to WCO". In the Bow, Oldman and South Saskatchewan sub-basins, all Junior licences are subject to WCO.

Bow sub-basin	Siksika Existing and Siksika Project;
Oldman sub-basin	Piikani Project (Irrigation and Non-Irrigation), Keho-Barons South Project (part of LNID) and Blood Tribe Irrigation Project (BTIP)

A "deficit year" is defined for each component group as follows:

- Irrigation: Annual deficit greater than 100 mm;
- Non-Irrigation Consumptive Use: Annual deficit greater than 10%;
- Instream: Flow less than the IO flow for 2 or more weeks

A Non-District Irrigation and a Non-Irrigation consumptive use deficit occurs when the delivery to the component group is less than the lower of the component group's demand or allocation.

The user can "mouse-over" the component groups title rows and the deficit year criteria to obtain a pop-up display of the above definitions.

Appendix 1 shows the result summary tables for the Red Deer, Bow, Oldman, Southern Tributaries and South Saskatchewan sub-basins.

Scenarios

A detailed stream map for the selected sub-basin is displayed, on which the user may highlight any stream reach, storage or diversion point. For the chosen location, the time-dependent performance of any component group and subcategory can be shown, e.g. for the Oldman River Sub-Basin, Scenario A1, St Mary Reservoir to Mouth reach, Non-irrigation, Junior – a bar chart shows the annual % deficits for all 68 years of the period 1928-1995. The 10% deficit line is also shown on the chart, so that the user can understand how the "Number of deficit years" in the Summary table is obtained for the particular component group.

For instream components (e.g. select the Bow sub-basin, Carseland Weir to Bassano Dam reach, Instream), the user is provided with five chart types to view the performance:

Deficit Summary by Year	a bar chart shows, for each year, the number of weeks that the IO is not met;
Deficit Summary by Week	a bar chart shows, for each week, the number of years that the IO is not met;
Annual Hydrograph	a line chart shows, for each week, the maximum and, minimum flows plus the 25th, 50th and 75th percentile flows;

Exceedances by Week	52 line charts (one for each week); each chart shows the Scenario, Natural, Current IO and IFN flows in exceedance format;
Results by Year	68 line charts (one for each of the years 1928-1995); each chart shows the Scenario and IO flows for each week. Optionally the Natural and IFN flows can also be displayed.

Use of the Website to View Instream Flow Performance

The comments in Tables 3 and 4 relating to the ability to meet IFNs are necessarily brief. The following tours demonstrate how the user can obtain information on instream flow performance.

Results By Year – Scenario A1

1. On the Internet Web site, starting at:

   http://www3.gov.ab.ca/env/water/regions/ssrb/wrmmoutput/basin_map.asp

2. "mouse-over" Bow River Sub-Basin portion of the map and select Scenarios, Scenario A1 to display a sub-basin map;

3. "mouse-over" the reach below the Carseland diversion (Carseland Weir to Bassano Dam) and select **Instream, Results By Year**.

4. A chart for 1928 appears, displaying the Simulated Flow and Target IO. Click the checkboxes below the chart to show IFN and Natural Flow. Click the **Refresh** button. Use the Navigation hyperlinks to cycle through the years. Alternatively, type a year between 1928 and 1995 beside the Refresh button to go directly to a desired year.

5. Return to the sub-basin map by clicking on the hyperlink "**Sub-Basin Map**" beneath the chart. "Mouse-over" the reach "**Bassano Dam To Mouth**" and repeat the above procedure to display charts for this reach.

6. Click on the hyperlink "Basin Map" beneath the chart to return to the starting Internet page and repeat the above procedure to display similar charts for reaches in other sub-basins.

Charts from the website for the two reaches used above for 1936 (a dry year) and 1995 (a wet year) are shown in Appendix 3.

Exceedances By Week – Scenario B1

Scenario B1 is chosen since it represents the maximum legal possibility of imposing IFNs on licences where provision to backfit exists and on future consumption commitments. In order to gain some appreciation of the degree to which IFNs are achieved, 10 reaches and 3 weeks are selected for scrutiny.

The reaches are:

Red Deer River below SAWSP withdrawal location and below Bindloss (2 reaches);

Bow River below Carseland weir and below Bassano (2 reaches);

Oldman River below LNID weir and below St Mary River confluence (2 reaches);

Waterton River at the mouth;

Belly River above Waterton river confluence;

St. Mary River at the mouth;

South Saskatchewan River below Medicine Hat.

The selected weeks are:

18 (week ending 6-May);

29 (week ending 22-July);

38 (week ending 23-September).

The procedure is:

On the Internet Web site, starting at:

http://www3.gov.ab.ca/env/water/regions/ssrb/wrmmoutput/basin_map.asp

1. "mouse-over" Red Deer River Sub-Basin portion of the map and select Scenarios, Scenario B1 to display a sub-basin map;

2. "mouse-over" the reach below the SAWSP diversion (Delburne to Drumheller) and select Instream, Exceedances by Week.

3. A chart for Week 1 (week ending January 7th) appears, displaying the Natural, IFN, Scenario B1 and Existing IO flows in exceedance format. Type "18" in the text box immediately to the left of the grey "Refresh" button and click the "Refresh" button. The chart for Week 18 (week ending 6-May) appears. Use the text box to move to weeks 29 and 38.

4. Return to the sub-basin map by clicking on the hyperlink "Sub-Basin Map" beneath the chart. "Mouse-over" the reach "Downstream of Bindloss" and repeat the above procedure to display charts for this reach.

5. Click on the hyperlink "Basin Map" beneath the chart to return to the starting Internet page. Charts for the two Bow reaches can be shown starting from the "Bow River Sub-Basin" portion of the map. Charts for the two Oldman reaches and the Waterton, Belly

and St. Mary reaches can be shown starting from the “Oldman River Sub-Basin” portion of the map. Charts for the South Saskatchewan River downstream of Medicine Hat can be shown starting from the “South Saskatchewan River Sub-Basin” portion of the map.

The charts show the considerable increase in IFNs compared to current IOs. The IFNs are a substantial portion of the natural flow.

In the Red Deer basin, the Scenario B1 simulation (red line) indicates that any new WCO could be substantially increased from the current IO value(s) before deficits to junior and future allocations begin to occur.

In all other sub-basins, the situation varies considerably by location and time of year. However, any increased instream flows result in frequent and substantial deficits to junior allocations and commitments. Careful analysis will be required for any WCO that is an increase over current IO values. When considering “back-fitting” a WCO into a licence, it will be necessary to ensure that the licence effectiveness is not significantly degraded.

Charts from the website showing exceedance values for week 29 for the 10 reaches listed above are shown in Appendix 4.

REFERENCES

Alberta Environment. 2002. South Saskatchewan River Basin Water Management Plan Phase One, Water Allocation Transfers. Calgary, Alberta

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APPENDIX 1
Result Summary Tables For Sub-Basins

Table A1.1 – Red Deer River Main Stem Results Summary

(Dickson Dam to Mouth)
Number of deficit years out of 68 (1928-1995 Period)

Scenario	A1	A2	A3	B1	B2	B3	B4	B5
Irrigation:								
Senior Non-District	0	0	0	0	20	0	0	0
Junior Non-District (not subject to WCO)	1	1	4	0	41	0	0	0
Future Non-District	n/a	4	9	n/a	n/a	n/a	n/a	66
Non-Irrigation:								
Senior	0	0	0	0	n/a	0	0	0
Junior (not subject to WCO)	2	4	8	5	68	3	0	5
Junior (subject to WCO)	2	4	10	68	68	68	0	68
Future	n/a	n/a	22	n/a	n/a	n/a	n/a	n/a
Existing & Future Projects:								
Sheerness	1	3	7	4	68	2	0	4
Deadfish	2	3	8	1	67	1	0	1
SAWSP	n/a	8	22	n/a	n/a	n/a	n/a	68

[1] IFNs are Instream Flow Needs required to ensure Water Quality (assuming current Effluent Treatment Technology), Fish Habitat, Riparian Vegetation and Channel Maintanance.

[2] Water Conservation Objectives. These are the future Instream Objectives (IOs) to be established for stream reaches in the SSRB. In this analysis (Phase 2, Part1) they are the IFNs.

Table A1.2 – Bow River Main Stem Results Summary

(Bearspaw Reservoir to Mouth)

Number of deficit years out of 68 (1928-1995 Period)

Scenario	A1	A2	A3	B1	B2	B3	B4	B5
Irrigation:								
Western Irrigation District	20	9	13	20	68	5	20	19
Bow River Irrigation District	0	0	0	0	68	0	0	0
Eastern Irrigation District	0	0	0	0	64	0	0	0
Senior Non-District	0	0	0	0	67	0	0	0
Junior Non-District	8	8	14	66	67	64	13	66
Future Non-District	n/a	28	35	n/a	n/a	n/a	n/a	67
Non-Irrigation:								
Senior	0	0	0	0	n/a	0	0	0
Junior	22	22	28	68	68	68	23	68
Future	n/a	n/a	51	n/a	n/a	n/a	n/a	n/a
Existing & Future Projects:								
Siksika	0	0	0	0	67	0	0	0
Siksika Expansion	35	37	43	67	67	65	36	67

[1] IFNs are Instream Flow Needs required to ensure Water Quality (assuming current Effluent Treatment Technology), Fish Habitat, Riparian Vegetation and Channel Maintanance.

[2] Water Conservation Objectives. These are the future Instream Objectives (IOs) to be established for stream reaches in the SSRB. In this analysis (Phase 2, Part1) they are the IFNs.

Table A1.3 – Oldman River Main Stem Results Summary

(Oldman Dam to Mouth)
Number of deficit years out of 68 (1928-1995 Period)

Scenario	A1	A2	A3	B1	B2	B3	B4	B5
Irrigation:								
LNID	0	0	2	23	65	6	2	24
Senior Non-District	0	0	0	0	64	0	0	0
Junior Non-District	0	2	33	65	65	64	34	65
Future Non-District	n/a	5	45	n/a	n/a	n/a	n/a	66
Non-Irrigation:								
Senior	0	0	0	0	n/a	0	0	0
Junior	8	12	66	68	68	68	66	68
Future	n/a	n/a	67	n/a	n/a	n/a	n/a	n/a
Existing & Future Projects:								
Piikani Irrigation	0	5	55	65	65	64	57	65
Piikani Non-Irrigation	8	12	67	68	68	68	67	68

[1] IFNs are Instream Flow Needs required to ensure Water Quality (assuming current Effluent Treatment Technology), Fish Habitat, Riparian Vegetation and Channel Maintanance.

[2] Water Conservation Objectives. These are the future Instream Objectives (IOs) to be established for stream reaches in the SSRB. In this analysis (Phase 2, Part1) they are the IFNs.

Table A1.4 – Southern Tributary Summary Results Summary

Number of deficit years out of 68 (1928-1995 Period)

Scenario	A1	A2	A3	B1	B2	B3	B4	B5
Irrigation:								
St. Mary Project	1	1	3	53	66	28	1	53
MVLA Irrigation Districts	0	1	2	2	62	0	0	2
UID	0	0	0	16	63	3	0	16
Senior Non-District	0	0	0	0	56	0	0	0
Junior Non-District	0	0	0	52	35	49	0	52
Applications	n/a	30	34	n/a	n/a	n/a	n/a	62
Non-Irrigation:								
Senior	0	0	0	0	n/a	0	0	0
Junior	21	20	24	68	68	68	21	68
Applications	n/a	n/a	68	n/a	n/a	n/a	n/a	n/a
Existing & Future Projects:								
Blood Tribe Irrigation	2	3	4	59	61	55	2	59

[1] IFNs are Instream Flow Needs required to ensure Water Quality (assuming current Effluent Treatment Technology), Fish Habitat, Riparian Vegetation and Channel Maintanance.

[2] Water Conservation Objectives. These are the future Instream Objectives (IOs) to be established for stream reaches in the SSRB. In this analysis (Phase 2, Part1) they are the IFNs.

Table A1.5 – South Saskatchewan River Main Stem Results Summary

Number of deficit years out of 68 (1928-1995 Period)

Scenario	A1	A2	A3	B1	B2	B3	B4	B5
Irrigation:								
Senior Non-District	0	0	0	0	60	0	0	0
Junior Non-District	1	2	8	67	61	65	9	67
Future Non-District	n/a	3	16	n/a	n/a	n/a	n/a	67
Non-Irrigation:								
Senior	0	0	0	0	n/a	0	0	0
Junior	2	4	12	68	67	68	11	68
Future	n/a	n/a	26	n/a	n/a	n/a	n/a	n/a

[1] IFNs are Instream Flow Needs required to ensure Water Quality (assuming current Effluent Treatment Technology), Fish Habitat, Riparian Vegetation and Channel Maintanance.

[2] Water Conservation Objectives. These are the future Instream Objectives (IOs) to be established for stream reaches in the SSRB. In this analysis (Phase 2, Part1) they are the IFNs.

APPENDIX 2
Red Deer River Minimum Flows Required To Meet Apportionment Contribution

Table A2.1 – Red Deer Apportionment Contribution – Scenario A1		
Year	**Volume Required from Red Deer (dam3)**	**% Red Deer Natural (%)**
1928	0	0
1929	0	0
1930	385505	42
1931	700553	66
1932	227752	13
1933	499365	34
1934	0	0
1935	633563	47
1936	702917	52
1937	760014	81
1938	567834	43
1939	422719	29
1940	620634	49
1941	441201	52
1942	0	0
1943	311032	16
1944	956700	53
1945	480299	31
1946	274131	16
1947	0	0
1948	0	0
1949	524071	69
1950	160807	17
1951	0	0
1952	0	0
1953	0	0
1954	0	0
1955	0	0
1956	0	0
1957	708	0
1958	151588	9
1959	0	0
1960	369418	25
1961	356601	37
1962	483284	44
1963	24606	2
1964	0	0
1965	0	0

Table A2.1 – Red Deer Apportionment Contribution – Scenario A1		
Year	**Volume Required from Red Deer (dam3)**	**% Red Deer Natural (%)**
1966	0	0
1967	0	0
1968	69210	6
1969	0	0
1970	534382	30
1971	643227	30
1972	0	0
1973	490221	27
1974	108314	4
1975	0	0
1976	0	0
1977	435150	42
1978	0	0
1979	132216	16
1980	529513	35
1981	0	0
1982	685533	38
1983	652958	53
1984	584144	74
1985	721680	62
1986	512760	23
1987	467479	41
1988	526410	59
1989	917900	63
1990	128238	5
1991	0	0
1992	0	0
1993	0	0
1994	67994	5
1995	0	0

Table A2.2 – Red Deer Apportionment Contribution – Scenario A2		
Year	Volume Required from Red Deer (dam3)	% Red Deer Natural (%)
1928	0	0
1929	0	0
1930	487178	53
1931	708511	67
1932	287360	16
1933	618429	42
1934	0	0
1935	689093	52
1936	743746	55
1937	727580	78
1938	650044	49
1939	454301	32
1940	662995	53
1941	380247	45
1942	0	0
1943	384010	20
1944	977888	54
1945	516037	34
1946	329010	19
1947	0	0
1948	0	0
1949	497137	66
1950	343562	35
1951	0	0
1952	0	0
1953	0	0
1954	0	0
1955	0	0
1956	0	0
1957	46951	3
1958	234371	13
1959	0	0
1960	440296	29
1961	441890	45
1962	551612	50
1963	88537	6
1964	0	0
1965	0	0

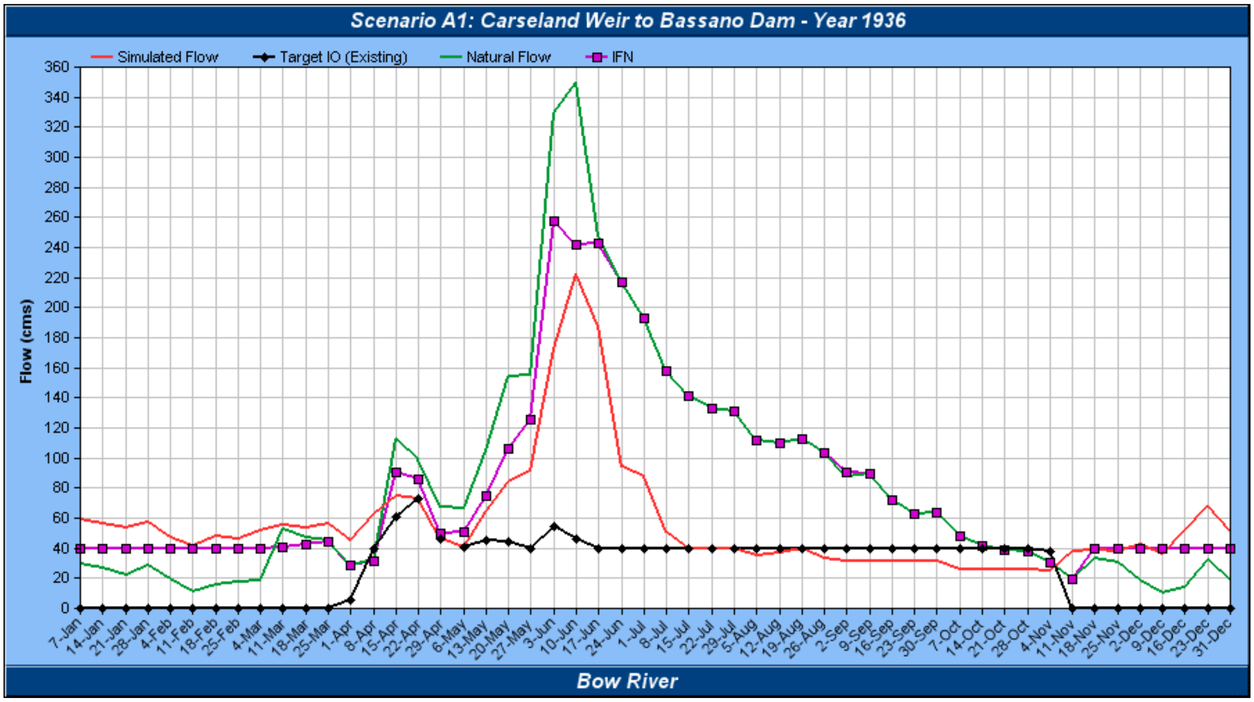
Table A2.2 – Red Deer Apportionment Contribution – Scenario A2		
Year	**Volume Required from Red Deer (dam3)**	**% Red Deer Natural (%)**
1966	0	0
1967	0	0
1968	145230	13
1969	0	0
1970	654476	35
1971	733960	35
1972	0	0
1973	543429	29
1974	209715	8
1975	0	0
1976	0	0
1977	453780	44
1978	0	0
1979	172183	20
1980	584108	39
1981	0	0
1982	742292	41
1983	715849	59
1984	566339	72
1985	745319	64
1986	557682	25
1987	518556	45
1988	492796	55
1989	830258	57
1990	373936	14
1991	0	0
1992	0	0
1993	0	0
1994	106206	7
1995	0	0

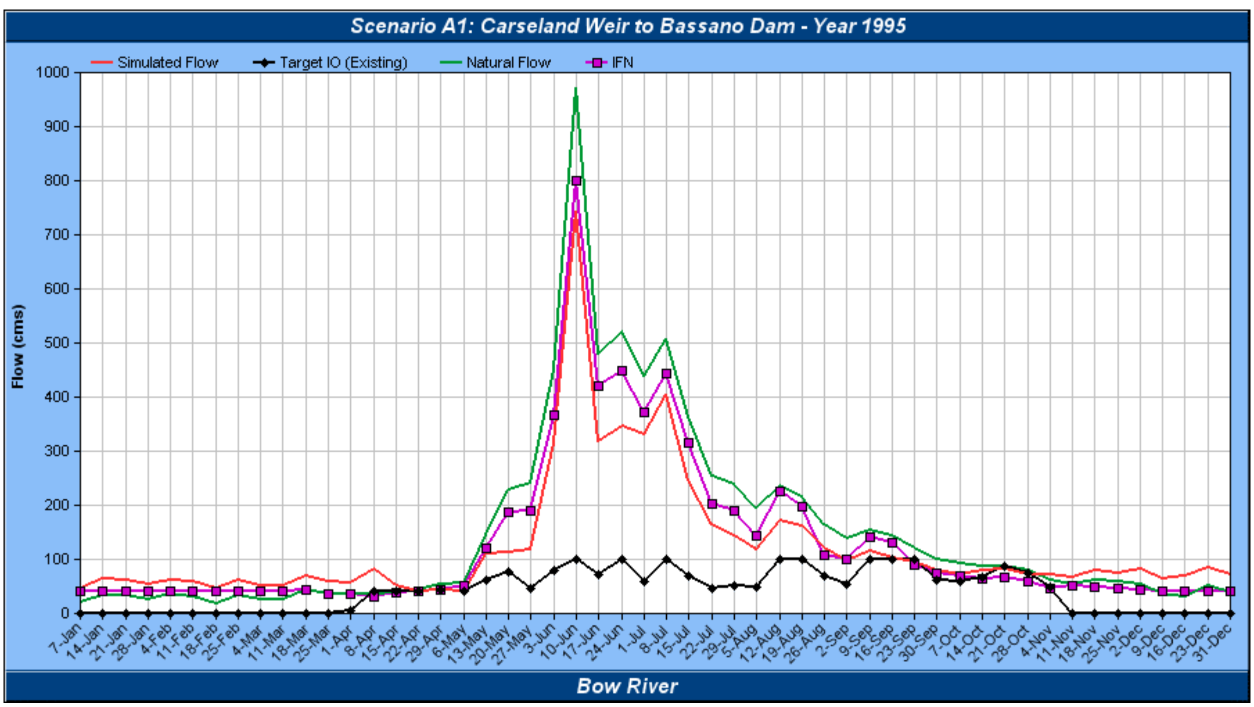
Table A2.3 – Red Deer Apportionment Contribution – Scenario A3		
Year	**Volume Required from Red Deer (dam3)**	**% Red Deer Natural (%)**
1928	0	0
1929	20999	2
1930	528534	57
1931	761080	72
1932	696058	38
1933	794176	54
1934	12619	1
1935	875453	66
1936	832529	62
1937	730011	78
1938	751221	56
1939	694832	48
1940	830756	66
1941	542297	64
1942	0	0
1943	576875	30
1944	1212308	67
1945	610509	40
1946	495881	29
1947	0	0
1948	0	0
1949	484051	64
1950	592154	60
1951	0	0
1952	0	0
1953	0	0
1954	276370	7
1955	227758	10
1956	0	0
1957	274425	20
1958	444265	25
1959	0	0
1960	638160	42
1961	513280	53
1962	702401	64
1963	455578	30
1964	25692	2
1965	0	0

Table A2.3 – Red Deer Apportionment Contribution – Scenario A3		
Year	**Volume Required from Red Deer (dam3)**	**% Red Deer Natural (%)**
1966	0	0
1967	0	0
1968	454693	39
1969	0	0
1970	758669	40
1971	1034668	49
1972	0	0
1973	778977	42
1974	465624	19
1975	0	0
1976	0	0
1977	617723	60
1978	78500	5
1979	307910	36
1980	792879	53
1981	0	0
1982	930313	52
1983	817636	67
1984	588531	74
1985	827447	71
1986	833895	38
1987	726793	63
1988	628793	70
1989	1085473	74
1990	512456	19
1991	0	0
1992	61239	4
1993	0	0
1994	333233	23
1995	0	0

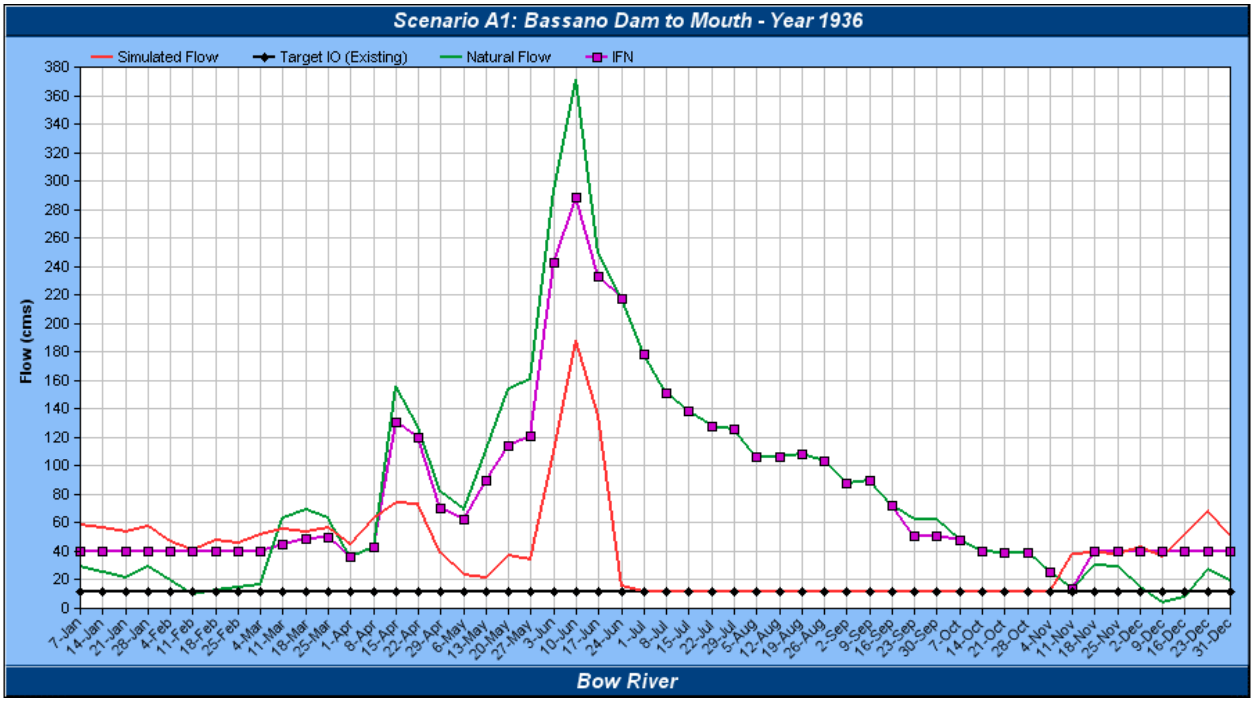
APPENDIX 3
Instream Flow Results By Year – Example Charts

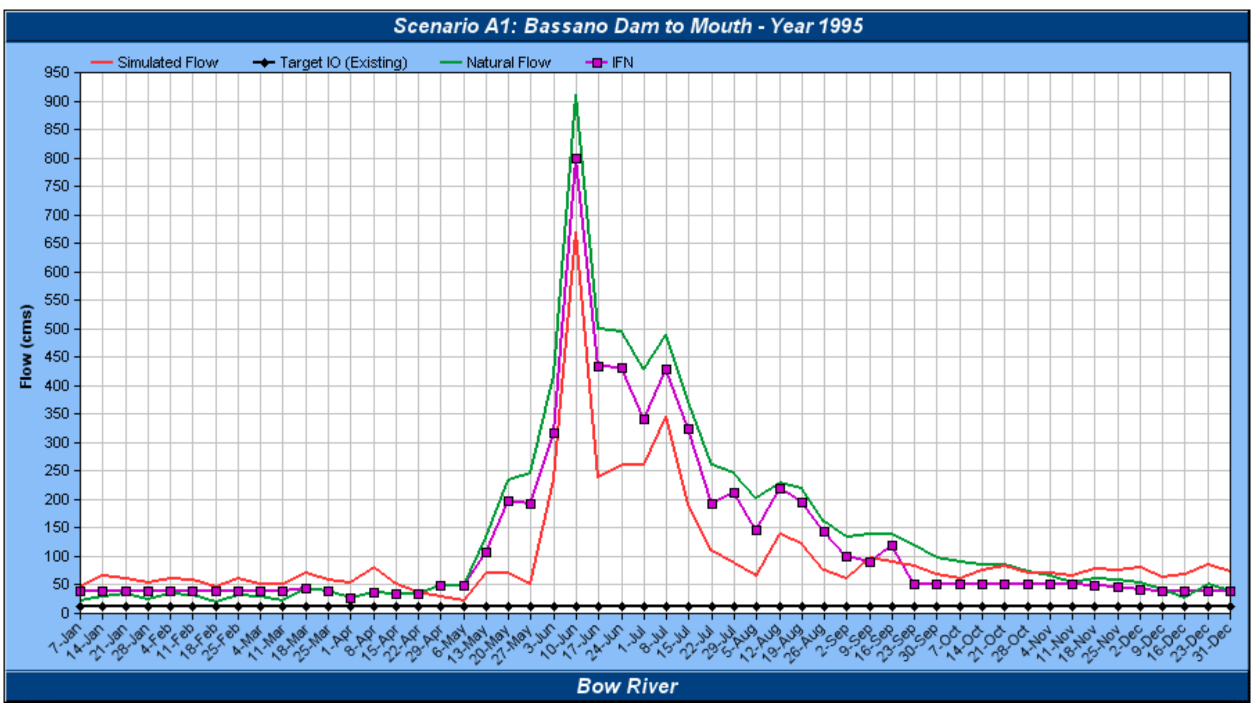
Bow River – Carseland Weir to Bassano Dam (1936 and 1995)



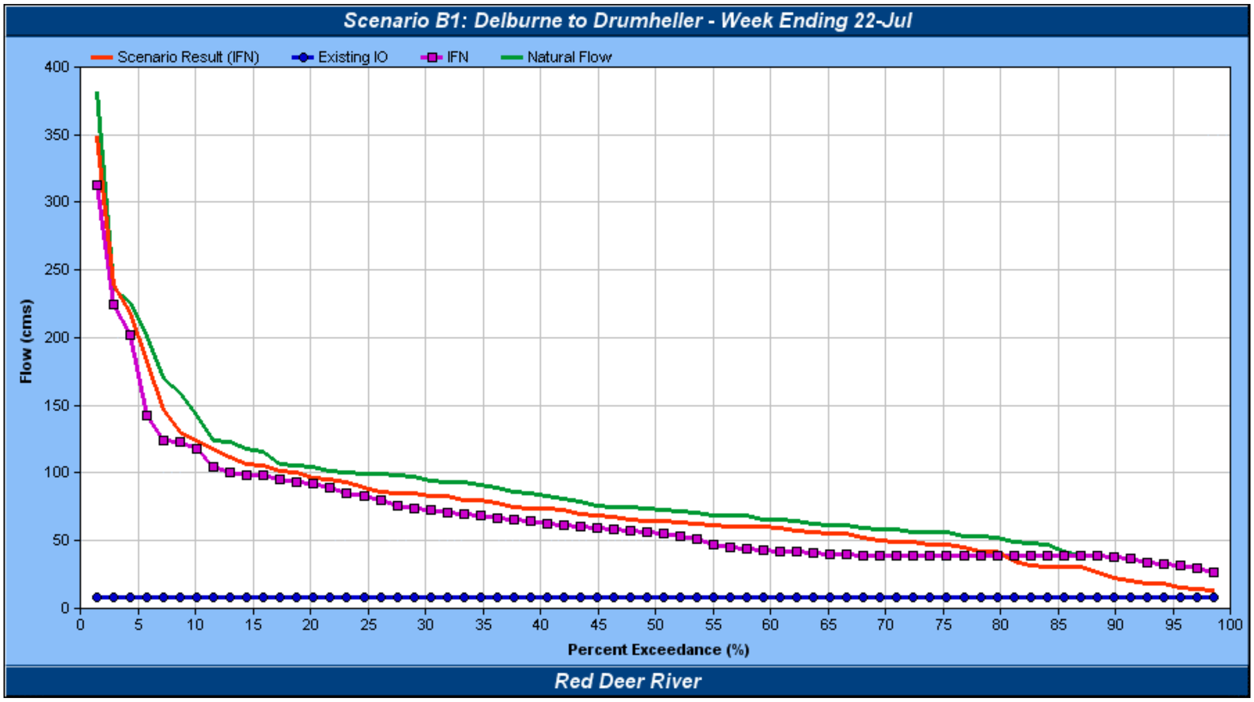


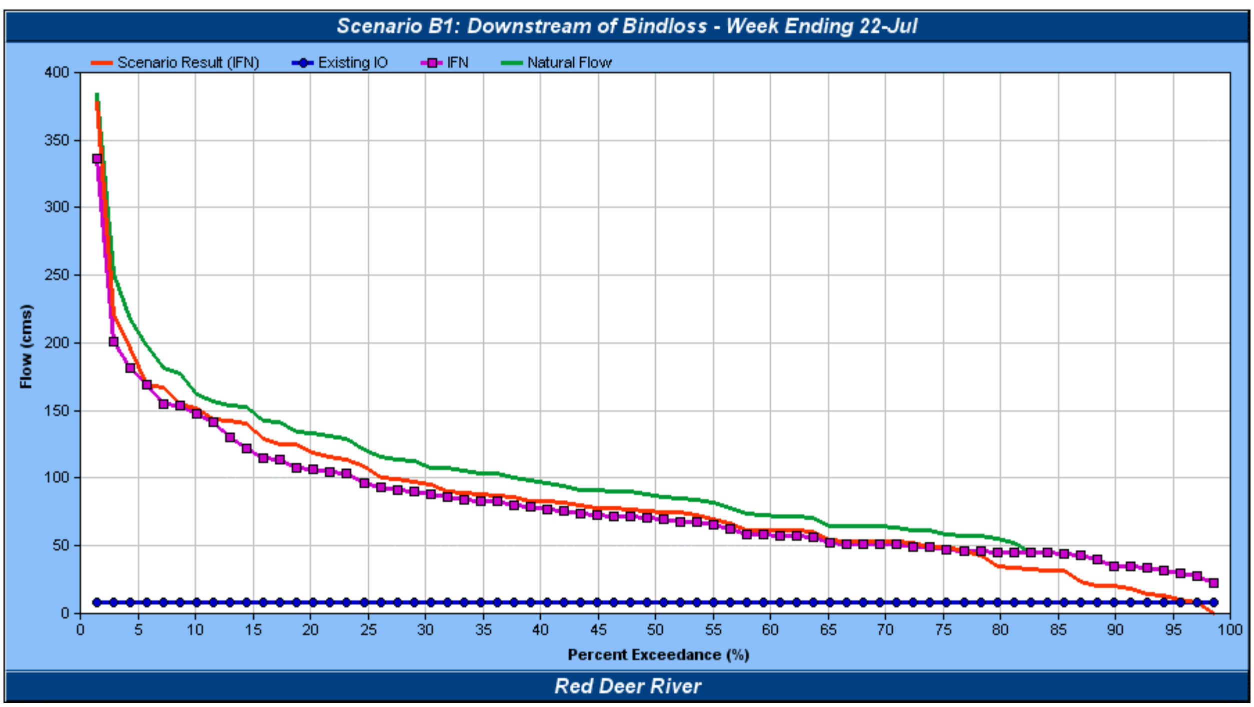
Bow River – Bassano Dam to the Mouth (1936 and 1995)

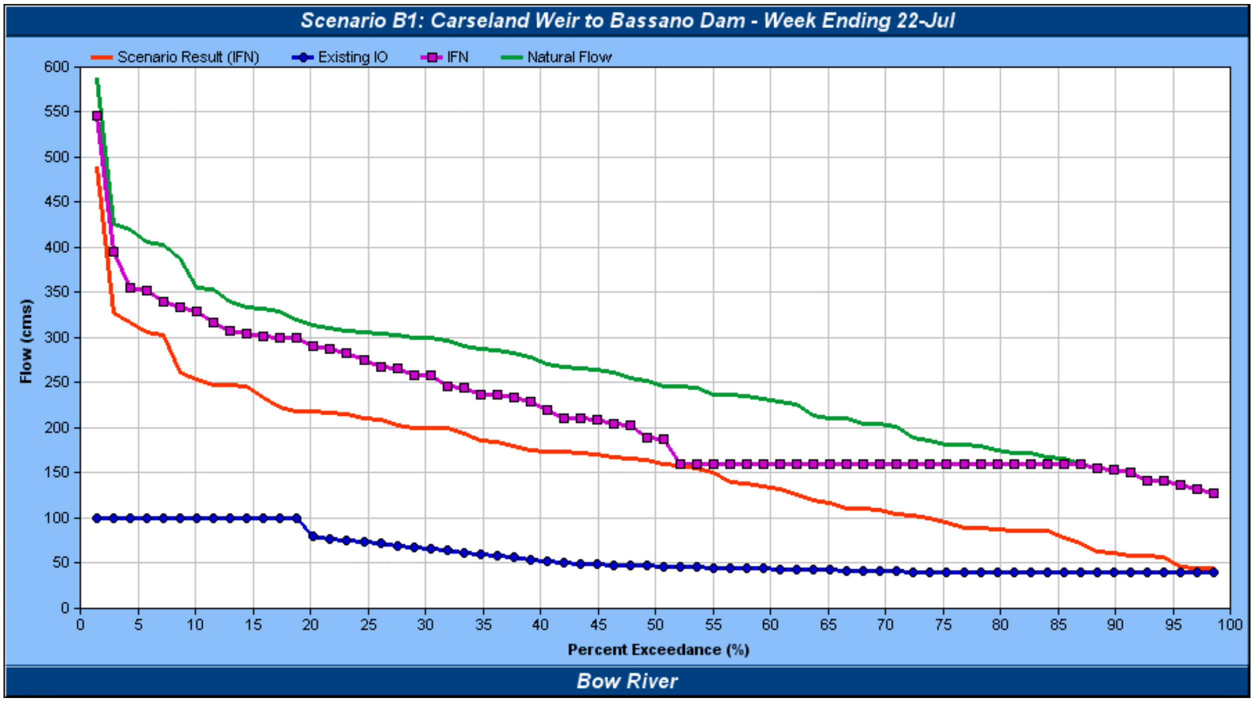


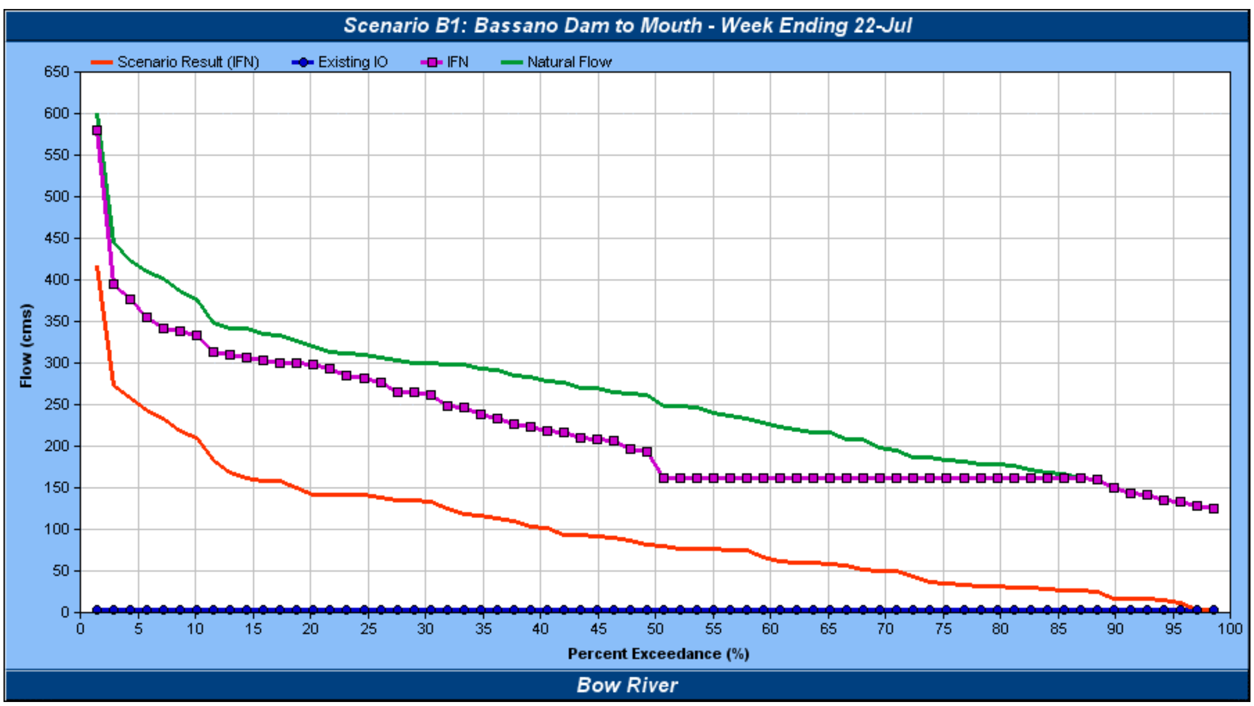


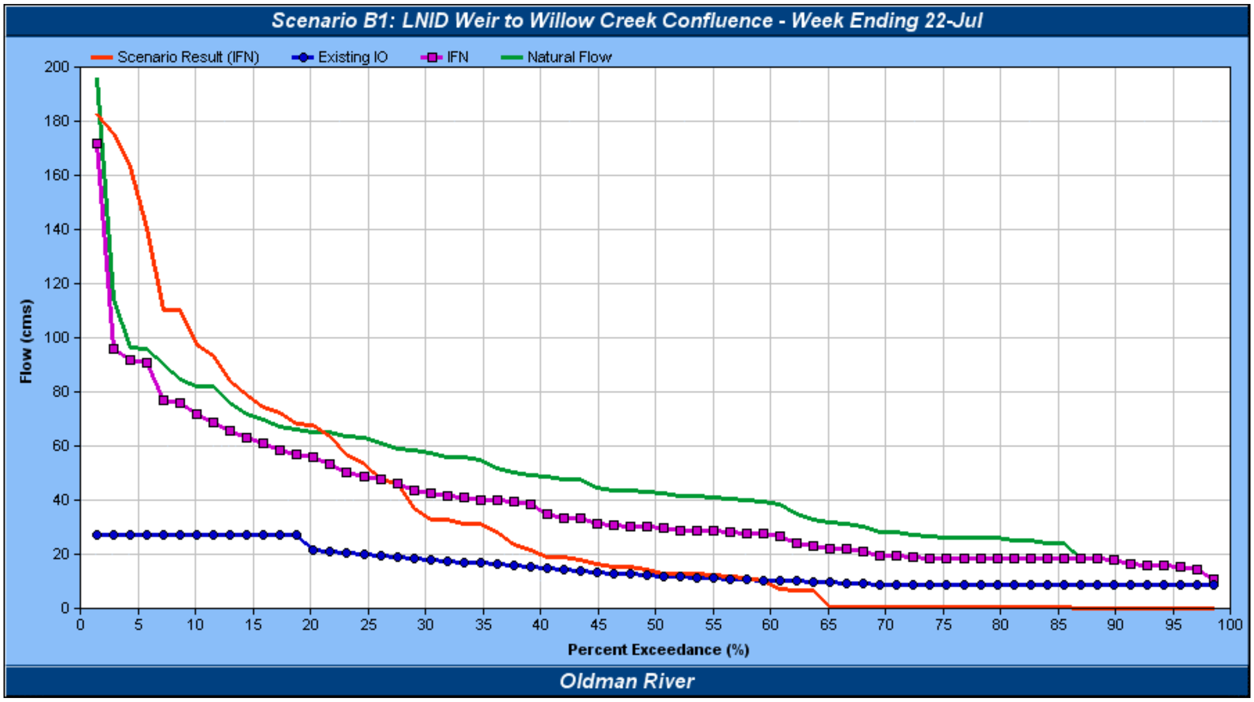
APPENDIX 4
Instream Flow Exceedance By Week – Example Charts

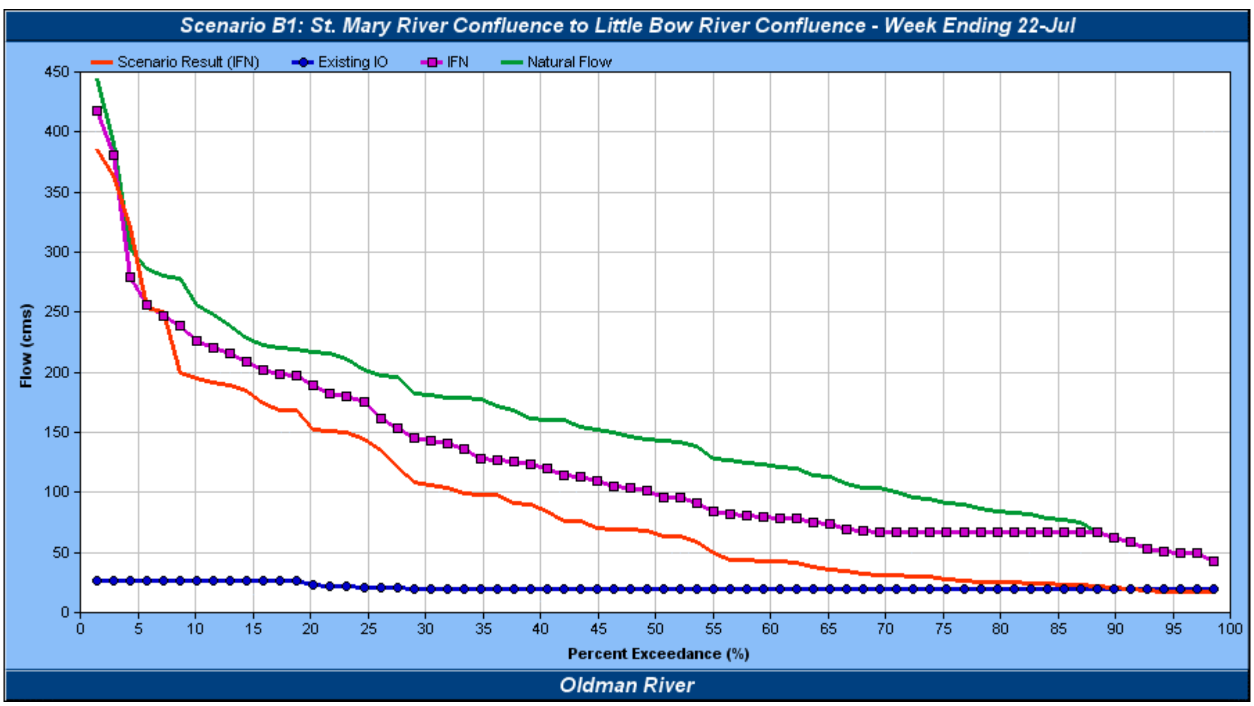

Scenario B1: Delburne to Drumheller - Week Ending 22-Jul
Scenario Result (IFN)
Existing IO
IFN
Natural Flow
Flow (cms)
400
350
300
250
200
150
100
50
0
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Percent Exceedance (%)
Red Deer River

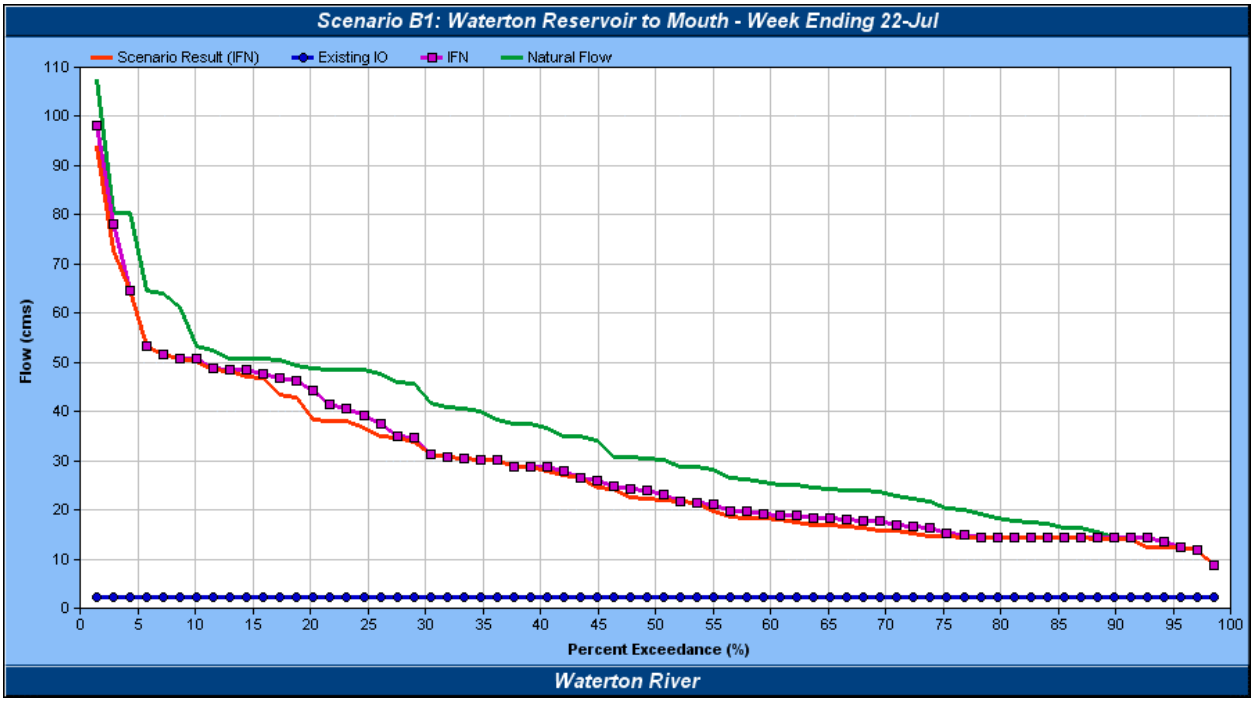

Scenario B1: Downstream of Bindloss - Week Ending 22-Jul
Scenario Result (IFN)
Existing IO
IFN
Natural Flow
Flow (cms)
400
350
300
250
200
150
100
50
0
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Percent Exceedance (%)
Red Deer River

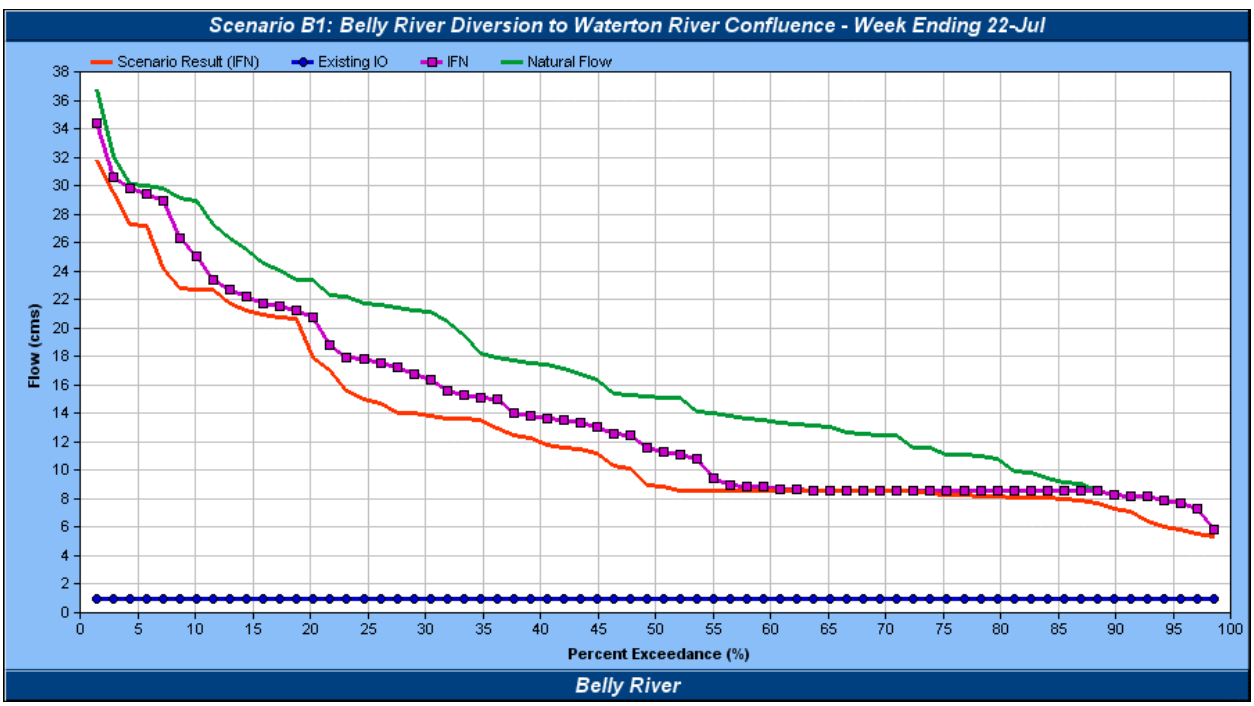

Scenario B1: Carseland Weir to Bassano Dam - Week Ending 22-Jul
Scenario Result (IFN)
Existing IO
IFN
Natural Flow
Flow (cms)
600
550
500
450
400
350
300
250
200
150
100
50
0
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Percent Exceedance (%)
Bow River

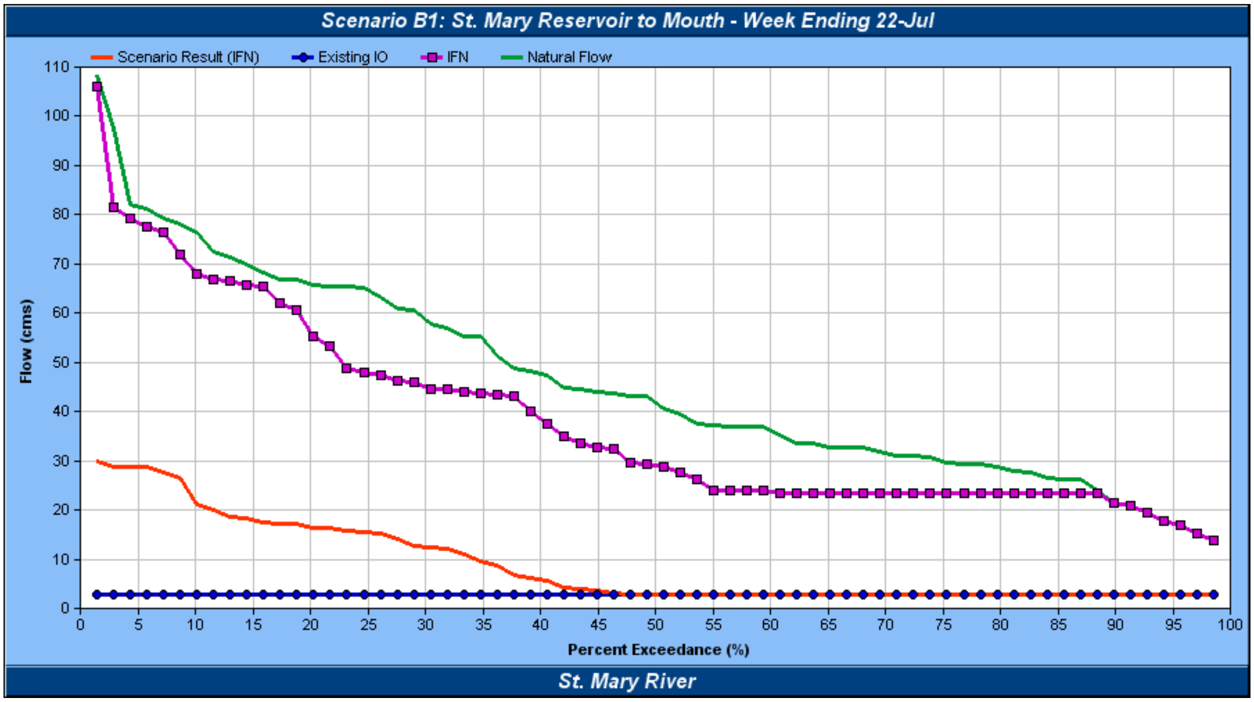

Scenario B1: Bassano Dam to Mouth - Week Ending 22-Jul
Scenario Result (IFN)
Existing IO
IFN
Natural Flow
Flow (cms)
650
600
550
500
450
400
350
300
250
200
150
100
50
0
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Percent Exceedance (%)
Bow River

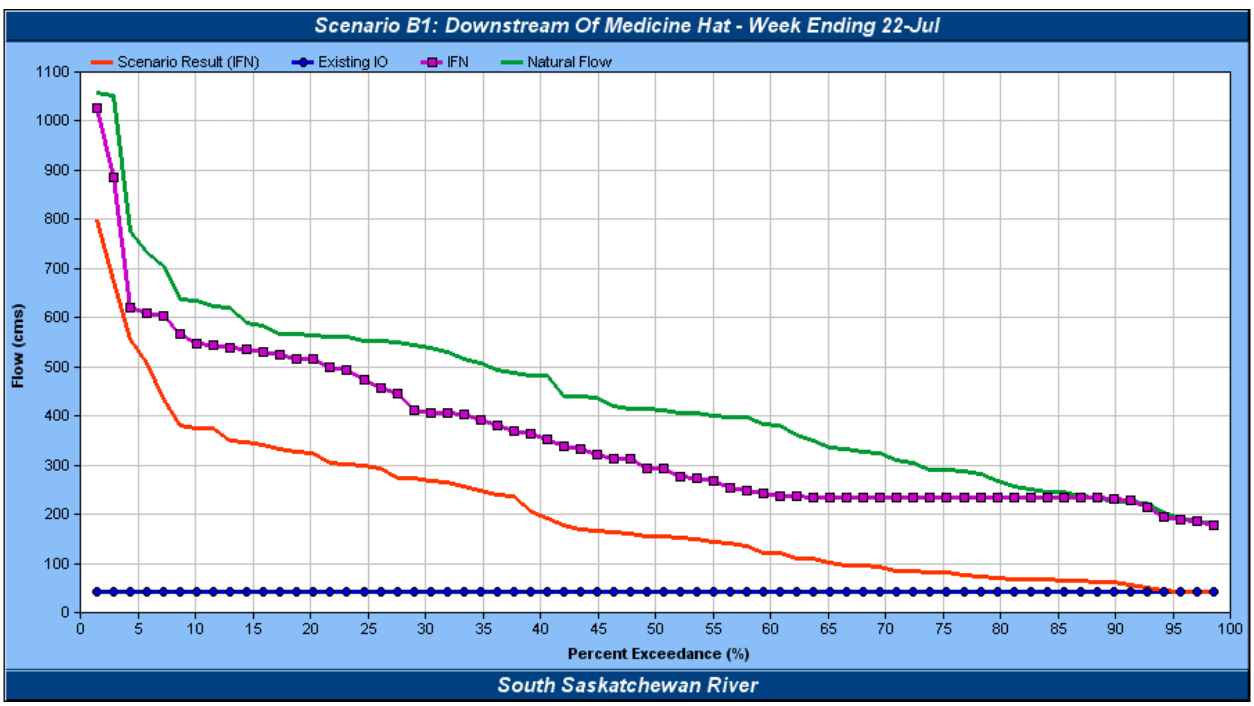

Scenario B1: LNID Weir to Willow Creek Confluence - Week Ending 22-Jul
Scenario Result (IFN)
Existing IO
IFN
Natural Flow
Flow (cms)
Percent Exceedance (%)
Oldman River


Scenario B1: St. Mary River Confluence to Little Bow River Confluence - Week Ending 22-Jul
Scenario Result (IFN)
Existing IO
IFN
Natural Flow
Flow (cms)
Percent Exceedance (%)
Oldman River


Scenario B1: Waterton Reservoir to Mouth - Week Ending 22-Jul
Scenario Result (IFN)
Existing IO
IFN
Natural Flow
Flow (cms)
Percent Exceedance (%)
Waterton River


Scenario B1: Belly River Diversion to Waterton River Confluence - Week Ending 22-Jul
Scenario Result (IFN)
Existing IO
IFN
Natural Flow
Flow (cms)
Percent Exceedance (%)
Belly River


Scenario B1: St. Mary Reservoir to Mouth - Week Ending 22-Jul
Scenario Result (IFN)
Existing IO
IFN
Natural Flow
Flow (cms)
0
10
20
30
40
50
60
70
80
90
100
110
Percent Exceedance (%)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
St. Mary River


Scenario B1: Downstream Of Medicine Hat - Week Ending 22-Jul
Scenario Result (IFN)
Existing IO
IFN
Natural Flow
Flow (cms)
0
100
200
300
400
500
600
700
800
900
1000
1100
Percent Exceedance (%)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
South Saskatchewan River