APPENDIX D
Performance Measure Results

This appendix displays the full set of Performance Measures results across the four scenarios of the Bow River Operational Model versus the Base Case:

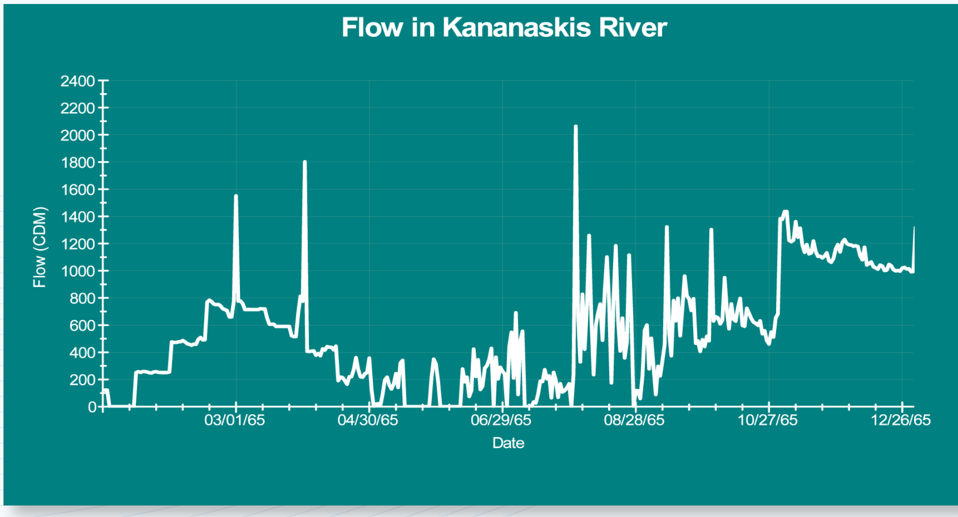
Base Case
Scenario 1. Stabilized Lower Kananaskis and Kananaskis River
Scenario 2. Water Bank at 40,000 af
Scenario 3. Water Bank at 60,000 af
Scenario 4. Integrated Scenario

The performance measures include:

1. Flow in Kananaskis River
2. Flows in various reaches
3. Flow frequency curves for various reaches
4. Flow frequency curves for various reaches
5. Master Agreement on Apportionment
6. Flood events in Calgary
7. Diversion difficulty days
8. Low flow diversion restriction shortages9. Stage frequency curves for various reservoirs
10a. Stage probability plot
12a. Shortages
12b. Shortages (as a percent of the request)
12c. Shortage frequency curves
13. Number of days of shortages
14. Consecutive-day shortages
18. Stages for Walleye spawning
20. Frequency curve of the percentage of the WCO met
21. Frequency curve of the percentage of the IFN met
23. Flow at the mouth of the Bow
24. Flow frequency curve for the mouth of the Bow
30. Power Revenue
31, 32. Total power revenue and power generation Box and Whisker Plots
40. Flood events
50. Glenmore recreation season
51, 52, 53. Travers, McGregor, and Little Bow Recreation
54, 55. Travers and McGregor pump intake problems
56a. Rafting/kayaking hours (daily and annual)
56b. Rafting/kayaking days
57. Annual stage variation (aggregated across record)
58. Annual stage variation (by-year)
59. Hydropeaking
60. Siksika demands
61. IFN flow duration curves
62. Bassano flow classifications
64. Percent of natural flow before the Bow/Oldman confluence

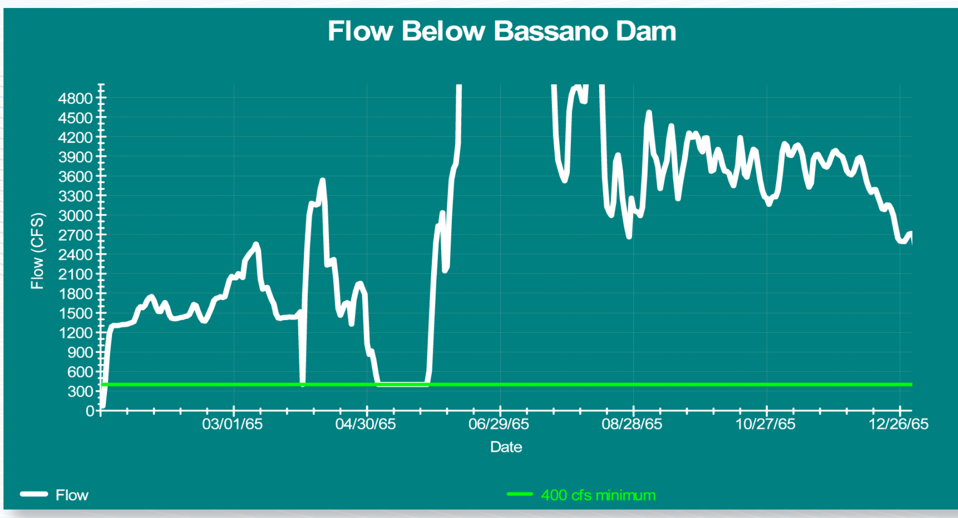
1. FLOW IN KANANASKIS RIVER

This PM is generated by the OASIS graphical use interface (GUI). The model outputs the flow in the Kananaskis River between Lower Kananaskis and Barrier. The chart below provides an example of the PM information generated by the model.



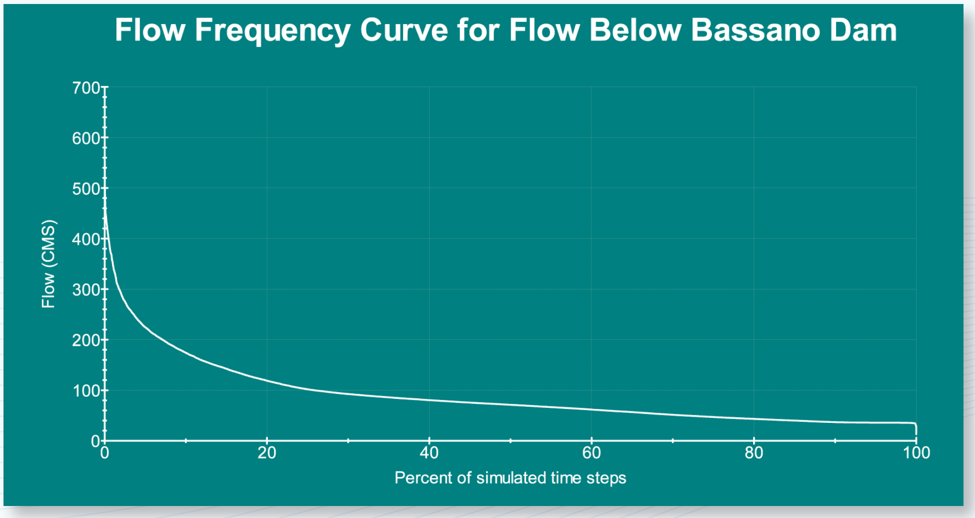
2. FLOWS IN VARIOUS REACHES

This PM is generated by the OASIS GUI. The model outputs the flow in the Bow River below Bassano Dam. Initially the idea was to include multiple reaches on one plot; however, during the CAN process it became clear that stakeholders preferred comparing one reach's performance across a number of alternatives instead. The PM can be generated within seconds for any reach in the model. The chart below provides an example of the PM information generated by the model.



3. FLOW FREQUENCY CURVES FOR VARIOUS REACHES

This PM is generated by the OASIS GUI. The model outputs the frequencies of flows in the Bow River below Bassano Dam by sorting the flows largest to smallest and assigning an exceedance probability to each data value. For each percentage of time considered, the plot displays the probability that the flow is greater than or equal to a given flow. The PM can be generated within seconds for any reach in the model. The chart below provides an example of the PM information generated by the model.



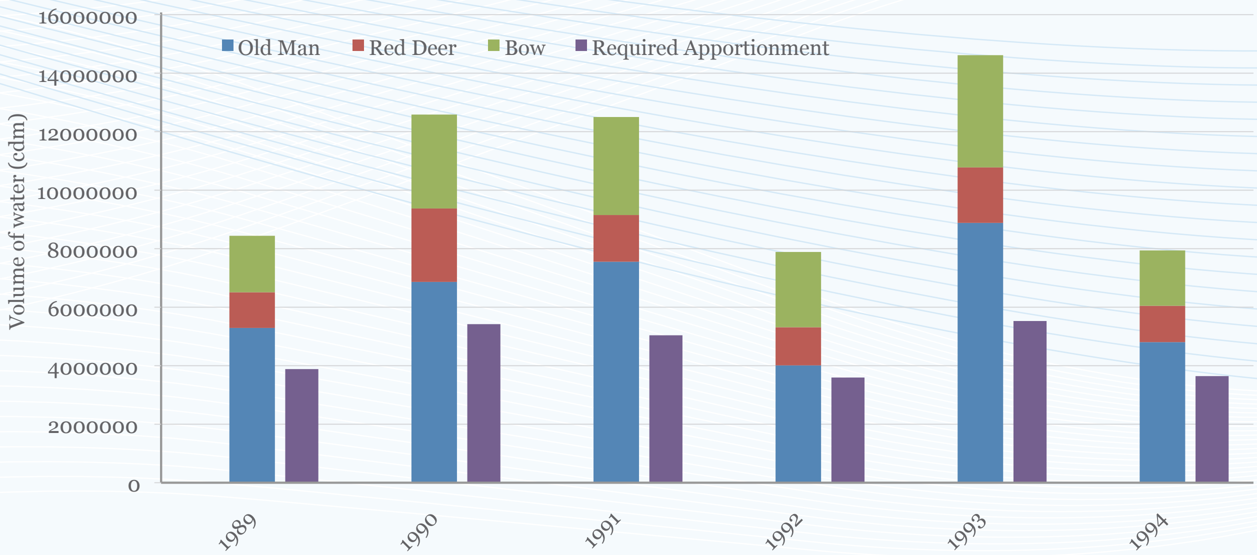
4. FLOW FREQUENCY CURVES FOR VARIOUS REACHES

The plot and description of this PM is captured in PM 3. Initially the idea was to include multiple reaches on one plot; however, during the CAN process it became clear that stakeholders preferred comparing just one reach's performance across a number of alternatives instead. The PM can be generated within seconds for any reach in the model. The chart above provides an example of the PM information generated by the model.

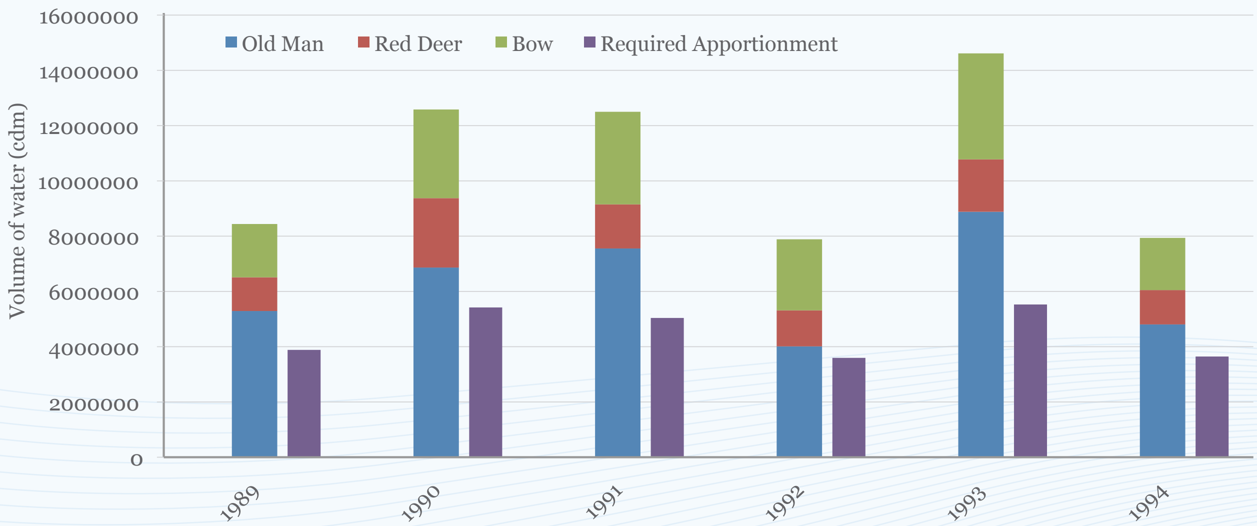
5. MASTER AGREEMENT ON APPORTIONMENT

The model tracks the daily contributions for the Bow, Oldman, and Red Deer Rivers toward the flow into Saskatchewan. The contributions are summed annually and displayed with the total required apportionment for comparison.

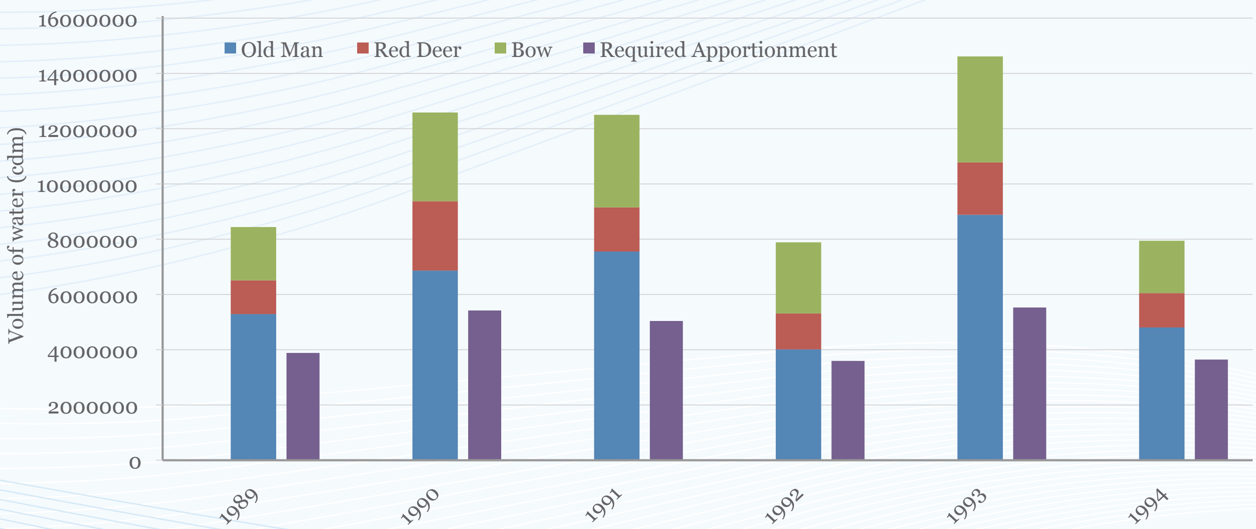
Contribution to Saskatchewan by Source: Current Operations Base Case



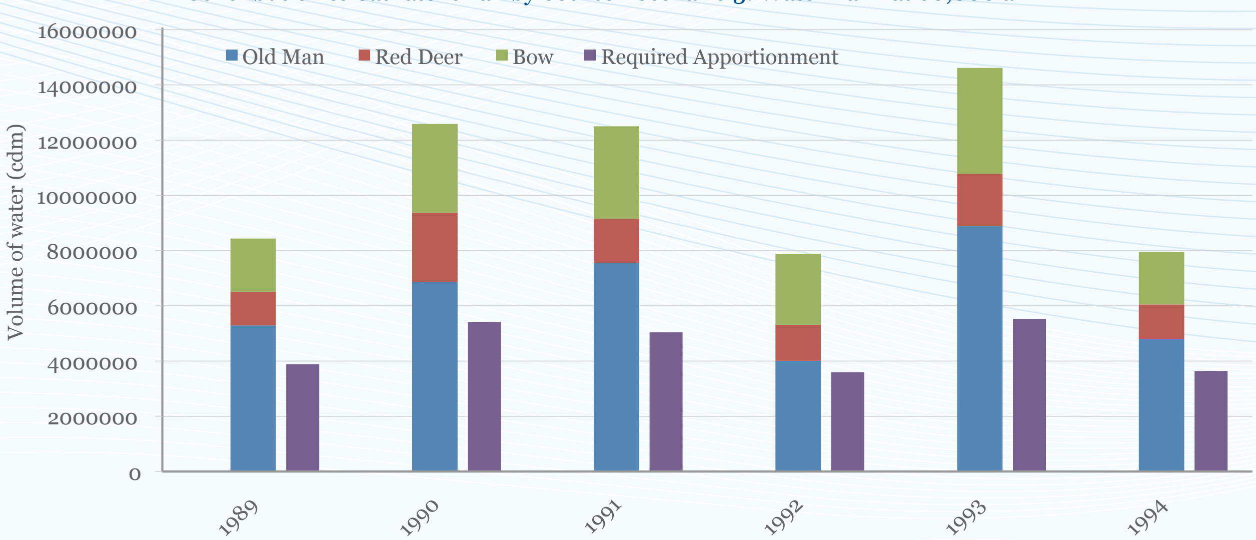
Contribution to Saskatchewan by Source - Scenario 1: Stabilized Lower Kananaskis Lake and Kananaskis River

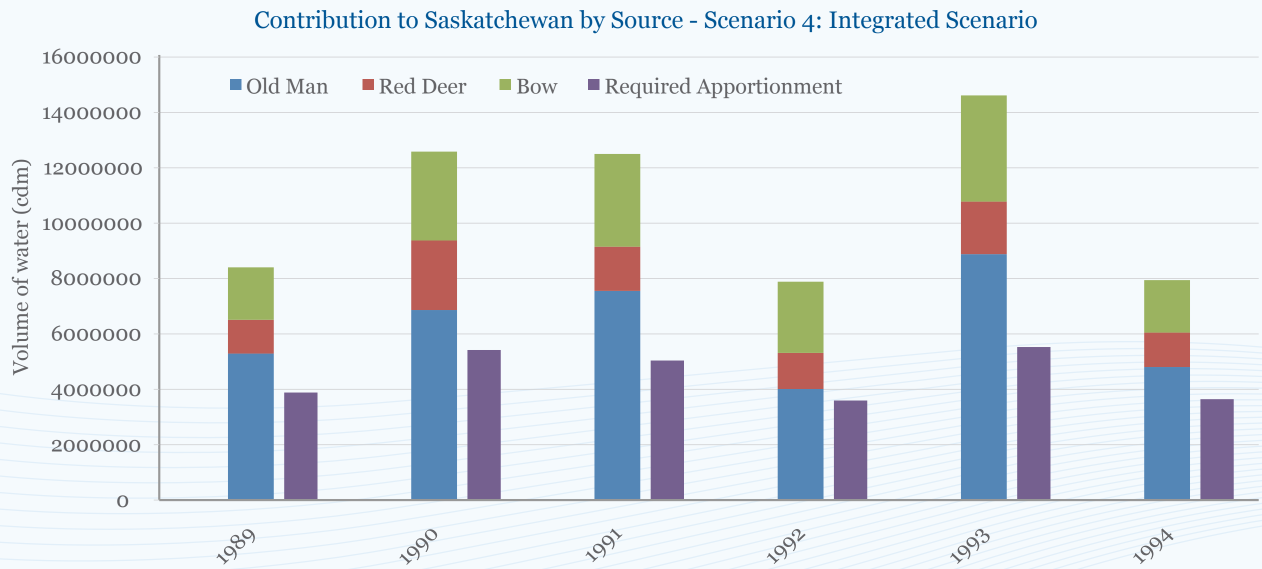


Contribution to Saskatchewan by Source - Scenario 2: Water Bank at 40,000 af



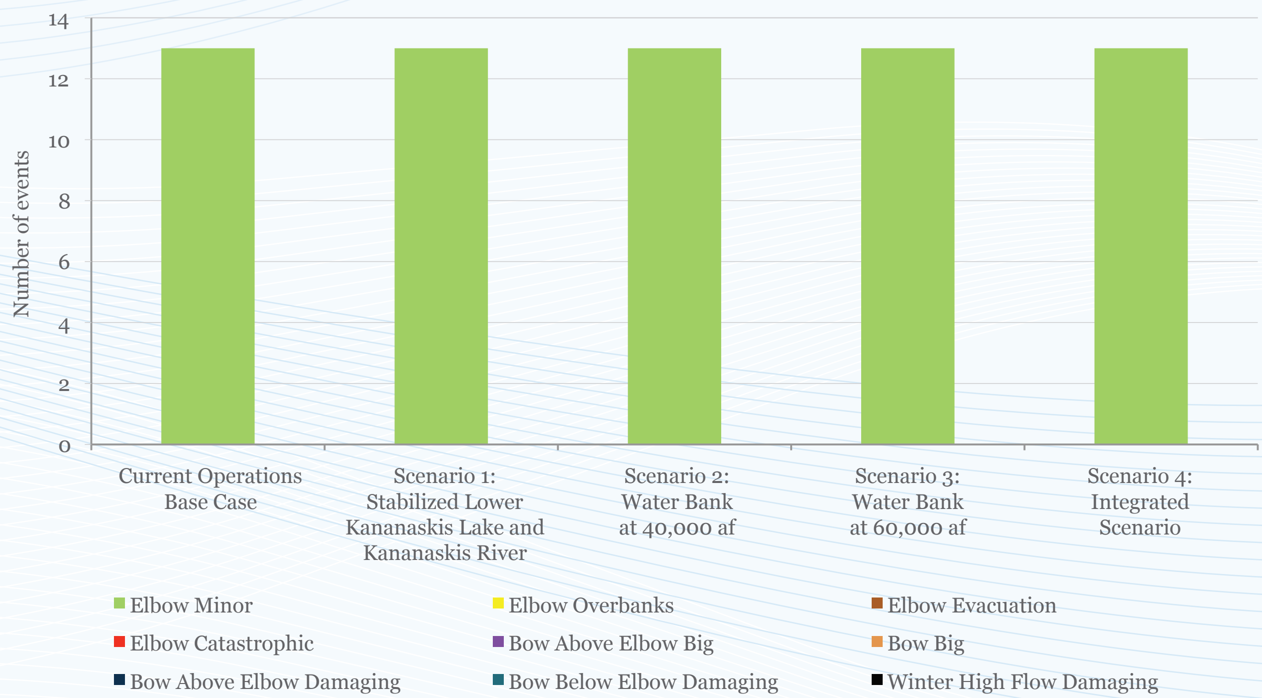
Contribution to Saskatchewan by Source - Scenario 3: Water Bank at 60,000 af





6. FLOOD EVENTS IN CALGARY

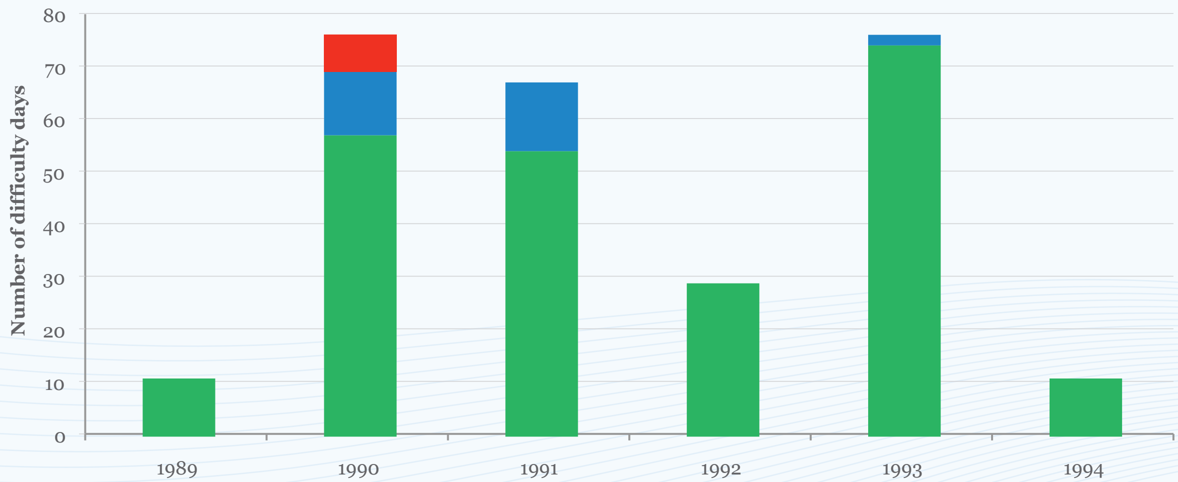
The model counts the number of flood flow events across the simulation period according to flood flow classifications provided by the City of Calgary. Flood flow events are counted for floods on the Bow River as well as floods on the Elbow River. There are a large number of categories on the plot; however, the simulation runs considered so far have only produced minor floods on the Elbow.



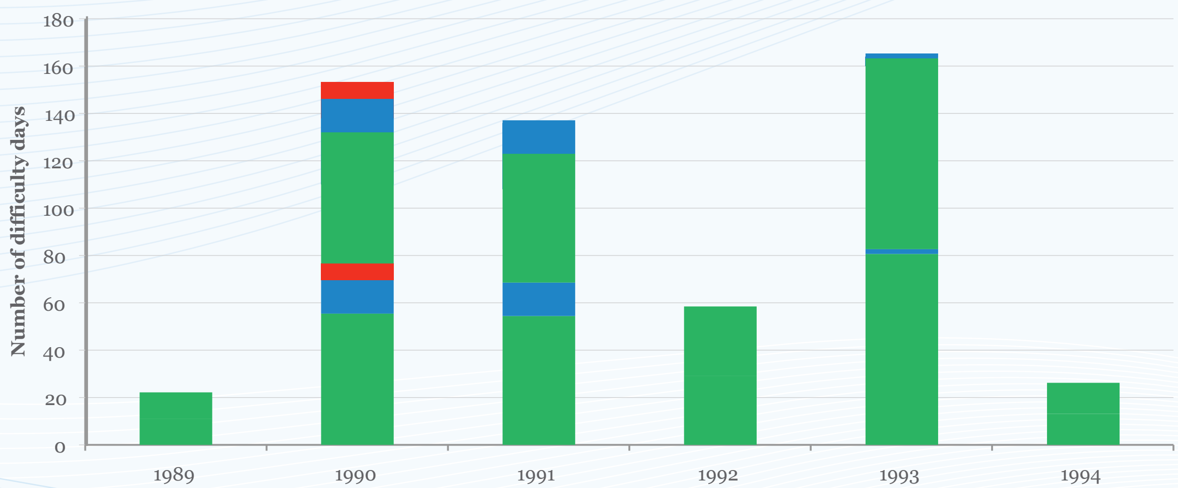
7. DIVERSION DIFFICULTY DAYS

The model will count the number of flow events in each year which, according to criteria specified by BRID, describe flows that cause diversion difficulty. During high flow events the sediment load and debris present in the water column can damage irrigation equipment and the diversions are shut off to prevent damage. During low flows the aquatic vegetation can make diversions difficult.

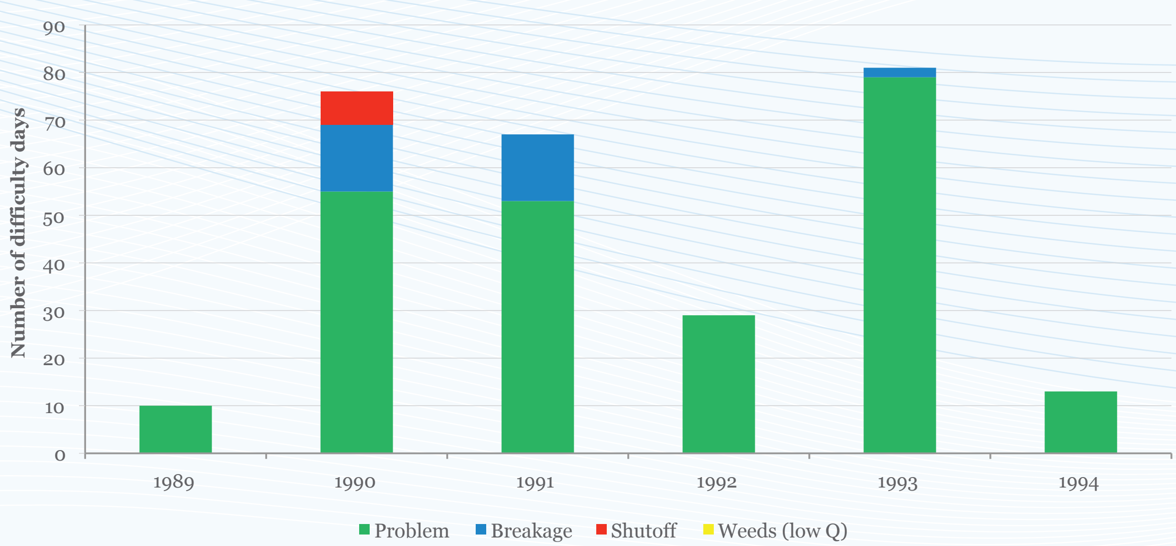
Diversion Difficulty Days - Current Operations Base Case

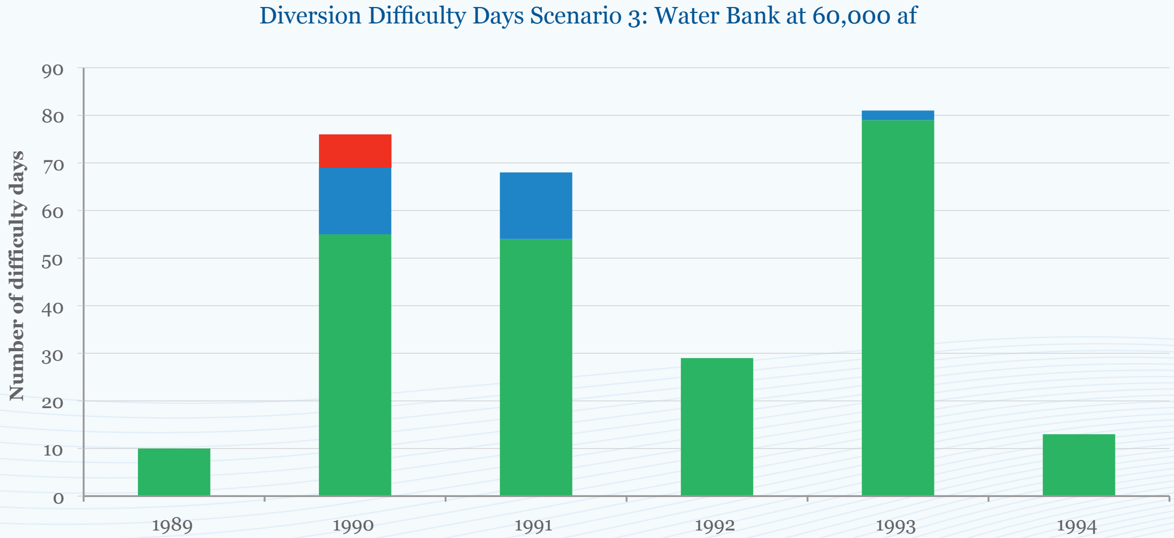


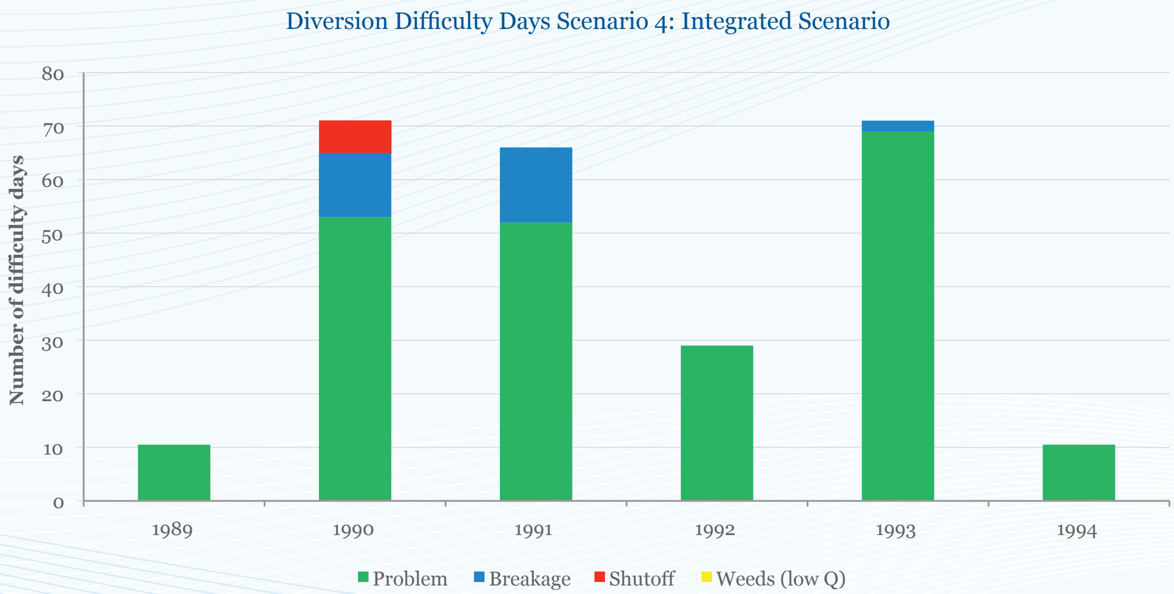
Diversion Difficulty Days Scenario 1: Stabilized Lower Kananaskis Lake and Kananaskis River



Diversion Difficulty Days Scenario 2: Water Bank at 40,000 af





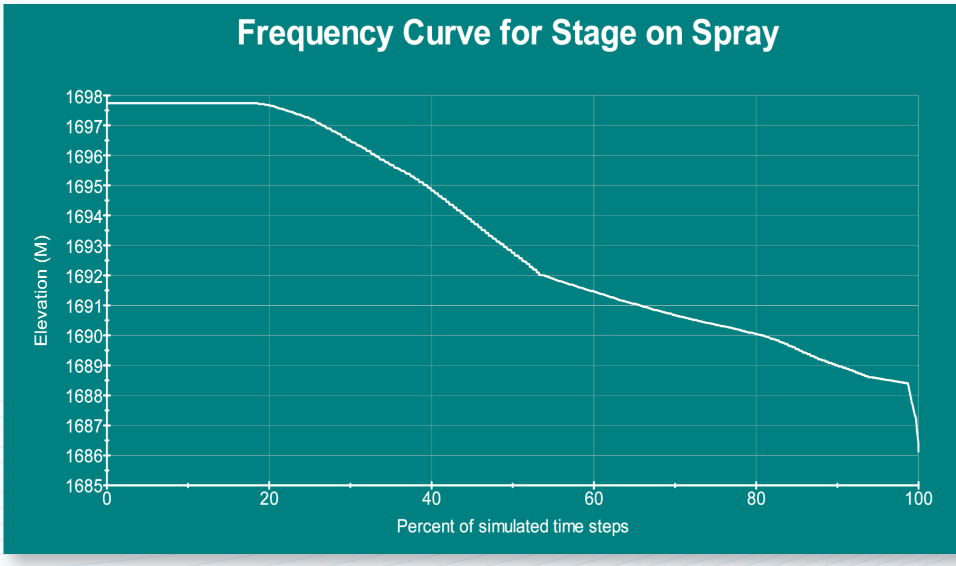


8. LOW FLOW DIVERSION RESTRICTION SHORTAGES – ROLLED INTO PM 7

This PM was going to show a count of the days where the BRID diversion experienced impact because of low flows. The PM has been rolled into PM 7 which shows all days where BRID experienced some diversion difficulty.

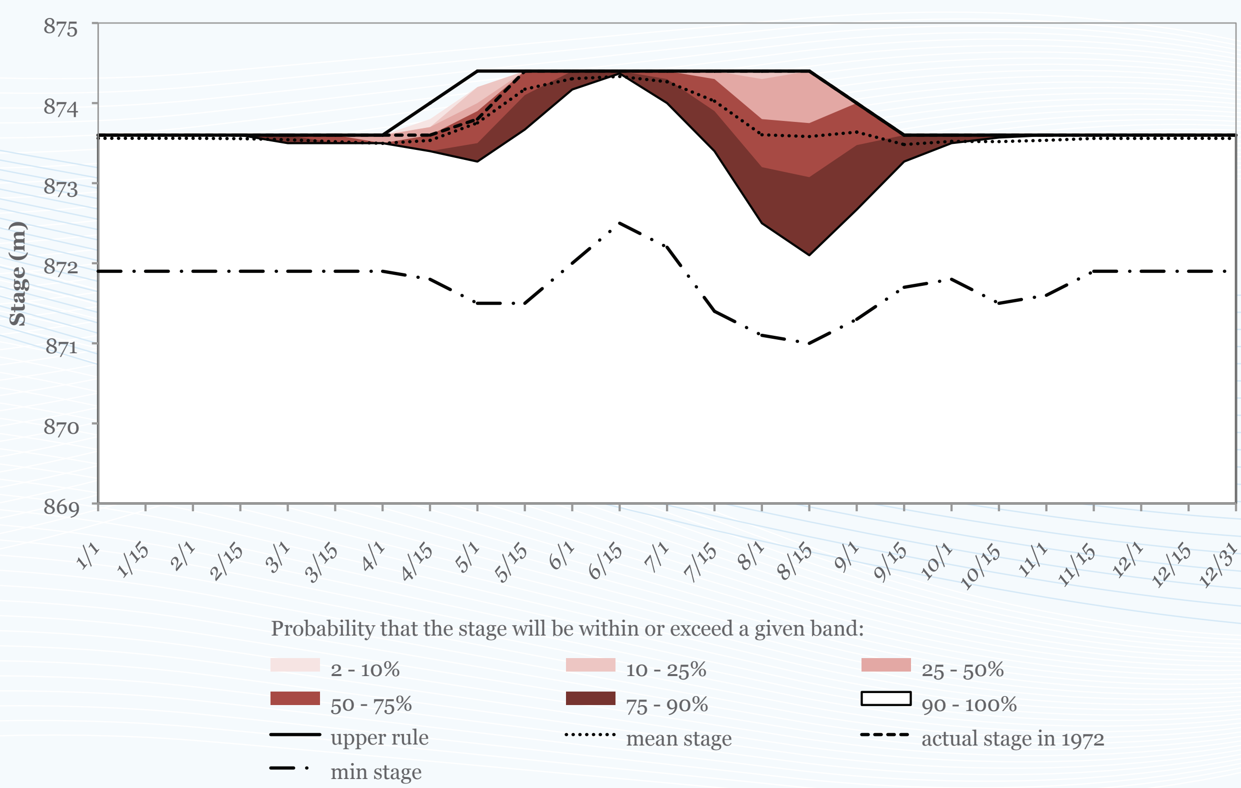
9. STAGE FREQUENCY CURVES FOR VARIOUS RESERVOIRS

This PM is generated by the OASIS GUI. The model outputs the frequencies of stages on Spray reservoir by sorting the stages largest to smallest and assigning an exceedance probability to each data value. For each percentage of time considered, the plot displays the probability that the stage is greater than or equal to a given stage. The PM can be generated within seconds for any reservoir in the model. The chart below provides an example of the PM information generated by the model.



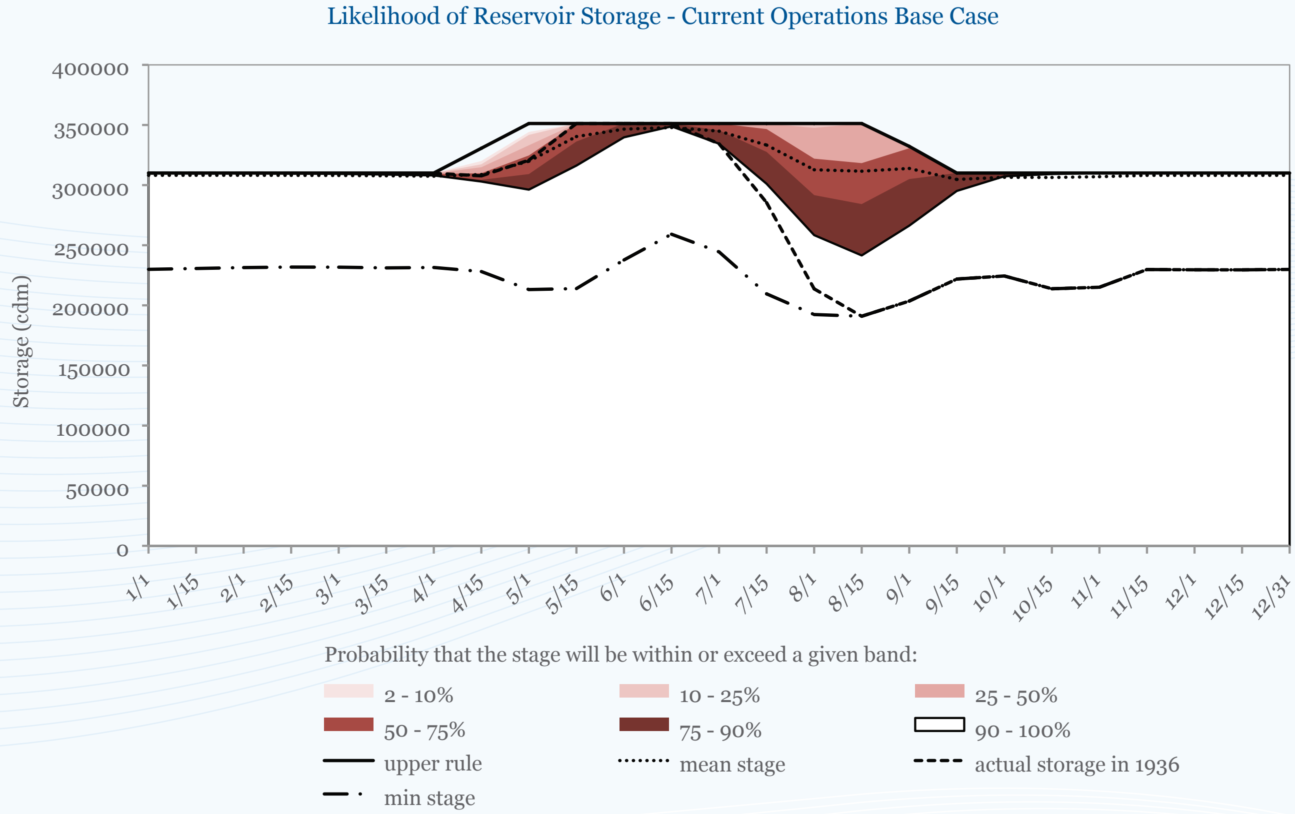
10A. STAGE PROBABILITY PLOT

The model provides the timeseries output of a given reservoir's stage, under the base case or alternate scenarios, across the simulation period in two week increments. For each captured day a collection of stage percentiles are determined; with each percentile corresponding to a band in the rainbow plot. The plot indicates the likelihood that the reservoir stage will be within or above a given band. The PM is generated for a collection of model nodes: 65, 80, 130, 145, 155, 185, 195, 218, 262, 340, 342, 344, 347, 352, 357, 523, 532, 534, 535, 536, 547, and 548. The example plot below is for McGregor, node 340, under the Current Operations Base Case.



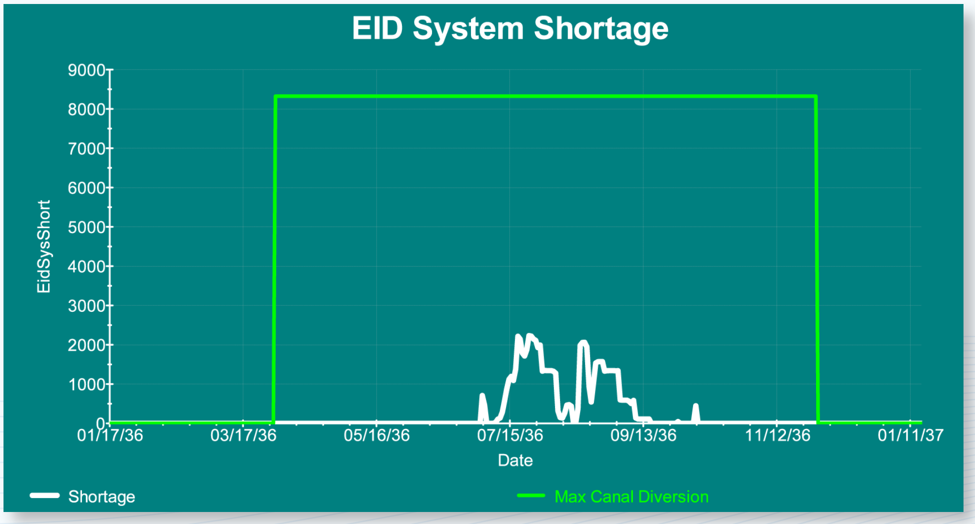
10B. STORAGE PROBABILITY PLOT

This PM is generated in a similar fashion and for the same collection of nodes as in PM 10a. The example plot below is for McGregor, node 340, under the Current Operations Base Case.



12A. SHORTAGES

The model outputs the daily shortage and maximum diversion for each of the irrigation districts and Calgary. Each entity's shortages are plotted on separate plots so that the performance of different runs may be directly compared. There are shortage plots for EID, WID, BRID, Calgary, and the entire system. The chart below provides an example of the PM information generated by the model.

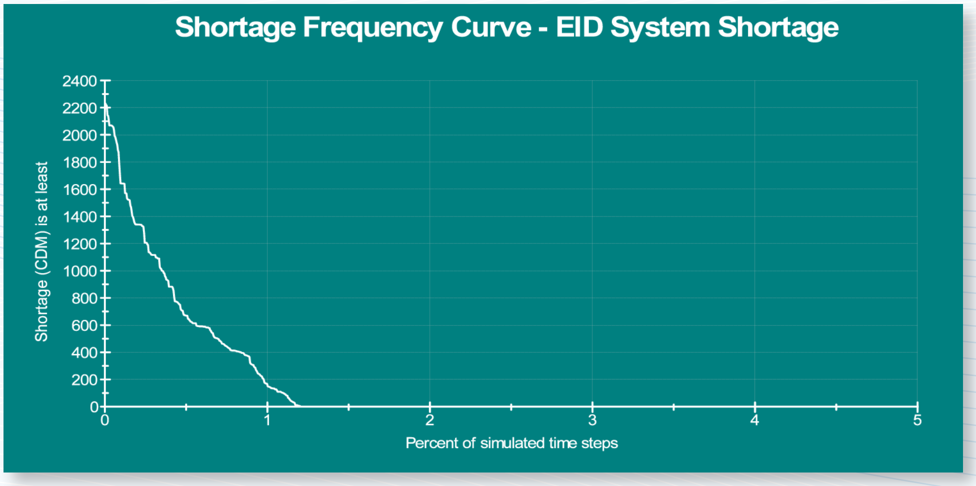


12B. SHORTAGES (AS A PERCENT OF THE REQUEST)

The model outputs the shortages, under each of the base case and alternate scenarios, as a percent of the total request for each of the irrigation districts and Calgary. This chart is available in BROM however, it was not tyoically used. PM12A was found to be more useful.

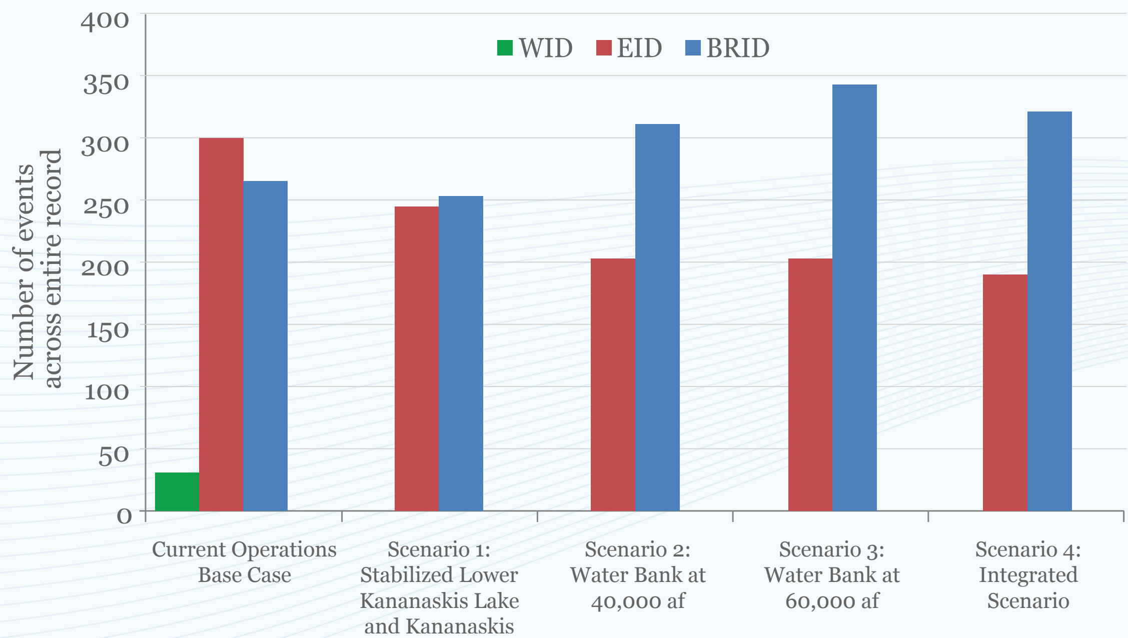
12C. SHORTAGE FREQUENCY CURVES

This PM is generated by the OASIS GUI. The model outputs the frequencies of shortages in EID by sorting the shortages largest to smallest and assigning an exceedance probability to each data value. For each percentage of time considered, the plot displays the probability that the shortage is greater than or equal to a given shortage. The PM can be generated within seconds for any of the irrigation districts, Calgary, or the total system. The chart below provides an example of the PM information generated by the model.



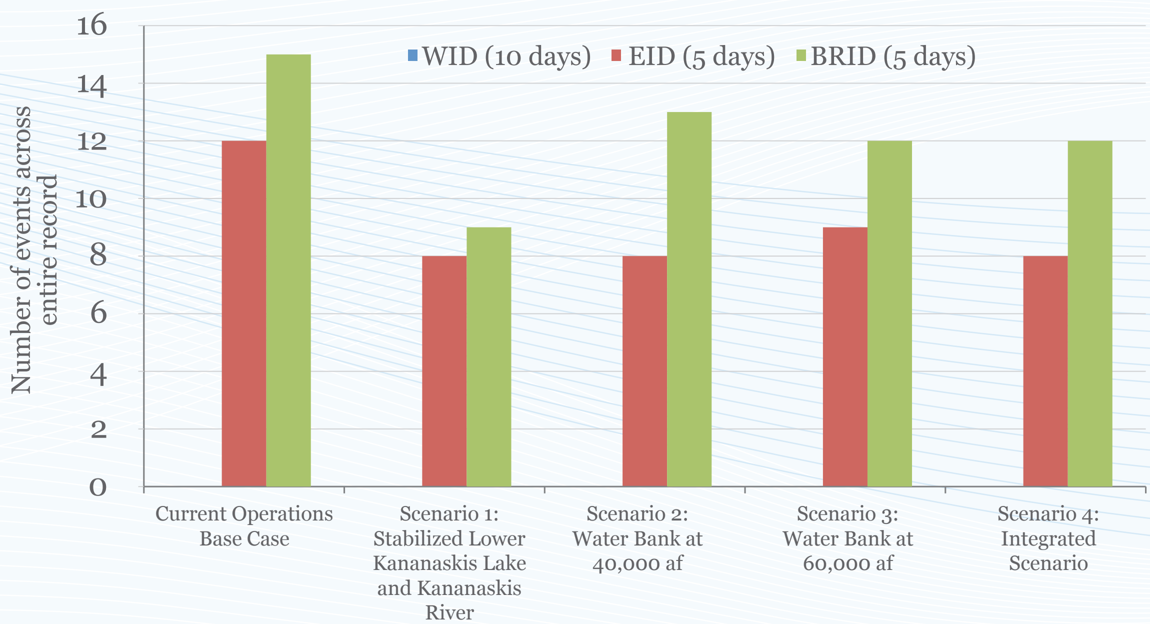
13. NUMBER OF DAYS OF SHORTAGES

The model counts the number of days where there is some shortage (>0.01cdm) in EID, WID, BRID, Calgary, and the total system.



14. CONSECUTIVE-DAY SHORTAGES

The model tracks the number of consecutive day shortage events for each of the irrigation districts.

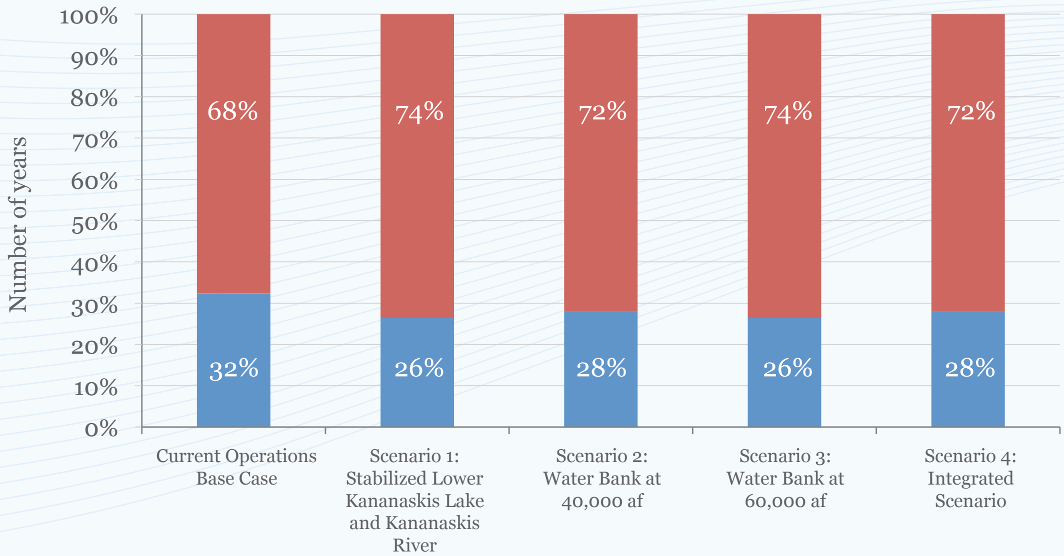


18. STAGES FOR WALLEYE SPAWNING

The Walleye spawning is assessed by counting the number of good years where the reservoir stage on June 1 has not fallen below the reservoir stage on April 1. This is an indicator that the Walleye eggs have been protected. This PM is implemented for Crawling Valley, Lake Newell, McGregor, and Travers reservoirs.

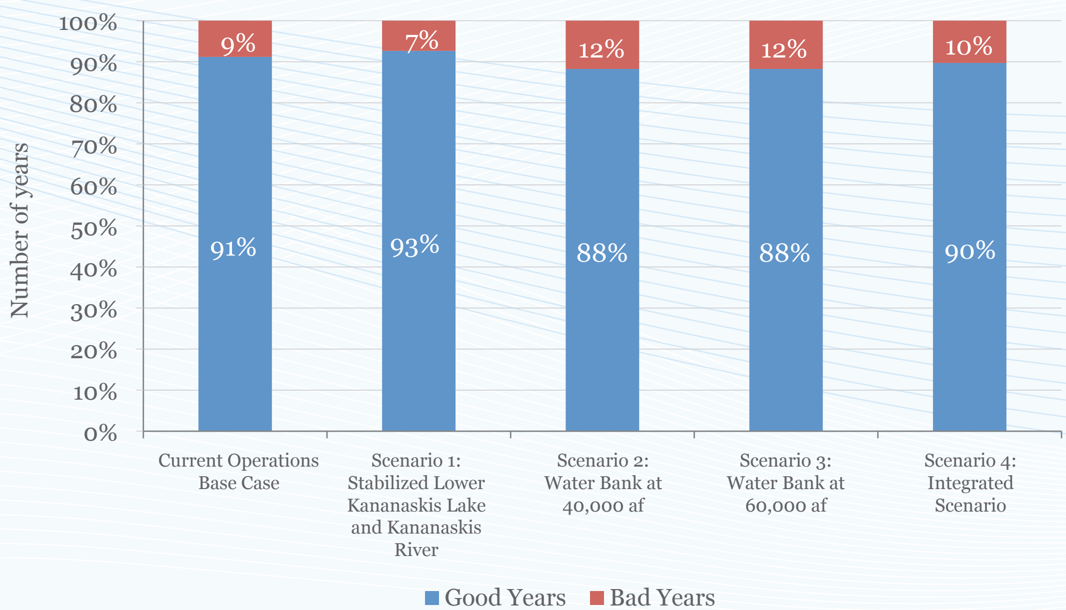
Walleye Spawning Stages - Crawling Valley

If the stage on June 1 is lower than that on April 1 then the walleye eggs have not been protected and the year is considered bad for walleye spawning. Pike spawning needs are similar to walleye.



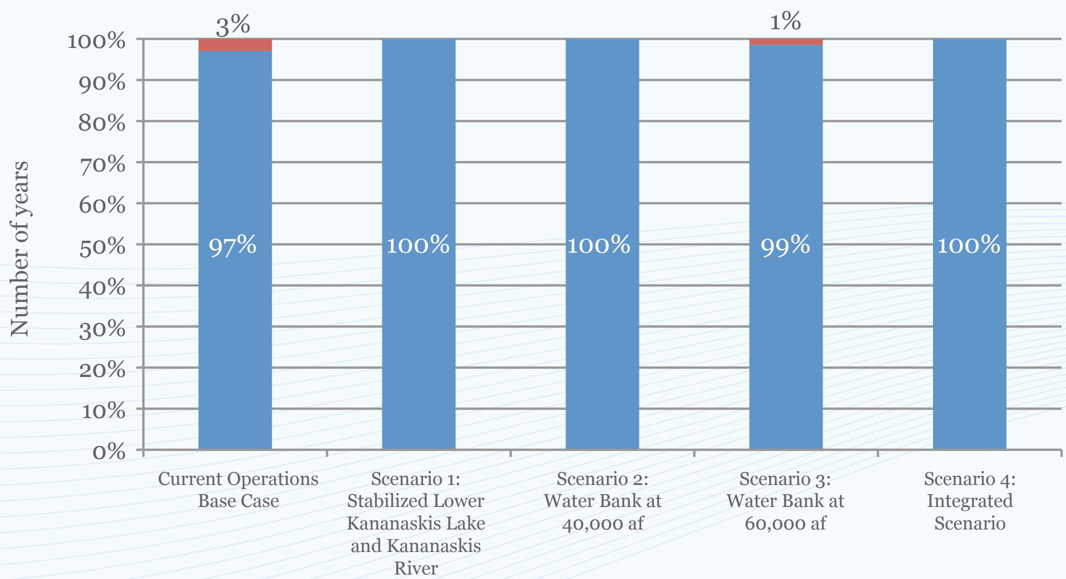
Walleye Spawning Stages - Lake Newell

If the stage on June 1 is lower than that on April 1 then the walleye eggs have not been protected and the year is considered bad for walleye spawning. Pike spawning needs are similar to walleye.



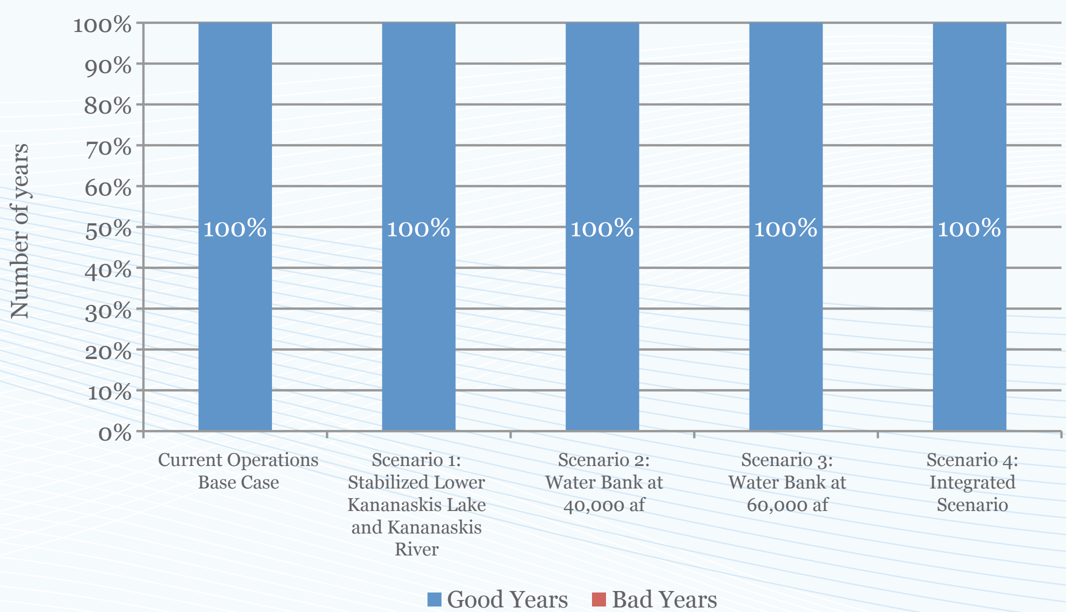
Walleye Spawning Stages - McGregor

If the stage on June 1 is lower than that on April 1 then the walleye eggs have not been protected and the year is considered bad for walleye spawning. Pike spawning needs are similar to walleye.



Walleye Spawning Stages - Travers

If the stage on June 1 is lower than that on April 1 then the walleye eggs have not been protected and the year is considered bad for walleye spawning. Pike spawning needs are similar to walleye.

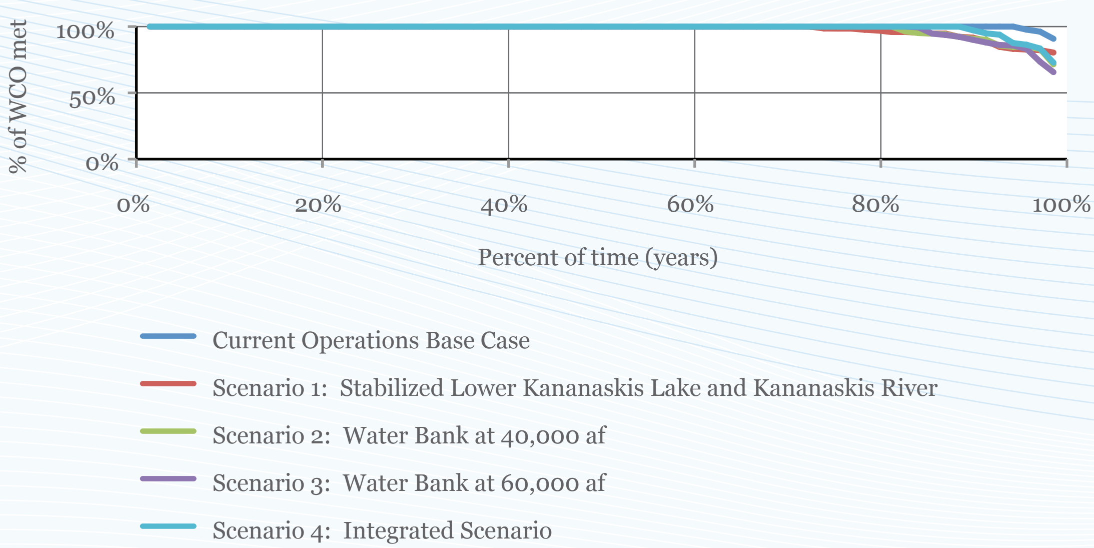


20. FREQUENCY CURVE OF THE PERCENTAGE OF THE WCO MET

The model outputs the frequencies of the WCO-percentage-met by sorting values largest to smallest and assigning an exceedance probability to each data value. For each percentage of time considered, the plot displays the probability that the percentage of the WCO met is greater than or equal to a given percentage. The PM is generated for each reach that has an Instream Objective (IO), because the IO is necessary to determine the WCO. The WCO is defined as the greater of (1) 110% of the IO, or (2) 45% of the natural flow. The PM is generated for the following reaches for each week in the year:

IO Number	OASIS Arc	Upstream / Downstream Name
1	210.22	Below Bearspaw to Calgary
2	220.249	Calgary to Pine Creek/Bonnybrook
3	250.28	Pine Creek/Bonnybrook to Highwood confluence
4	280.289	Highwood confluence to Carseland
5	290.319	Carseland to Bassano
6	342.506	Travers to Little Bow South of Travers
17	570.58	Bow-Oldman confluence to Medicine Hat
30	320.56	Bassano to Scandia

The full set of WCO curves can be viewed in the BROM WCO Plotmaker. The example chart below is for IO-1 (Below Bearspaw to Calgary) for Week 15:

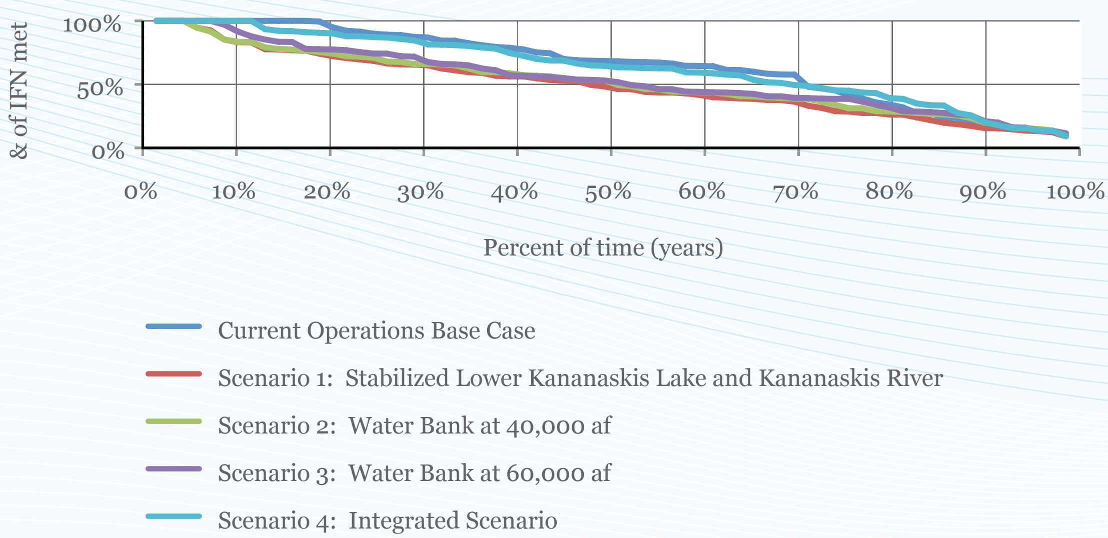


21. FREQUENCY CURVE OF THE PERCENTAGE OF THE IFN MET

The model outputs the frequencies of the IFN-percentage-met by sorting values largest to smallest and assigning an exceedance probability to each data value. For each percentage of time considered, the plot displays the probability that the percentage of the IFN met is greater than or equal to a given percentage. The PM is generated for the following reaches for each week in the year:

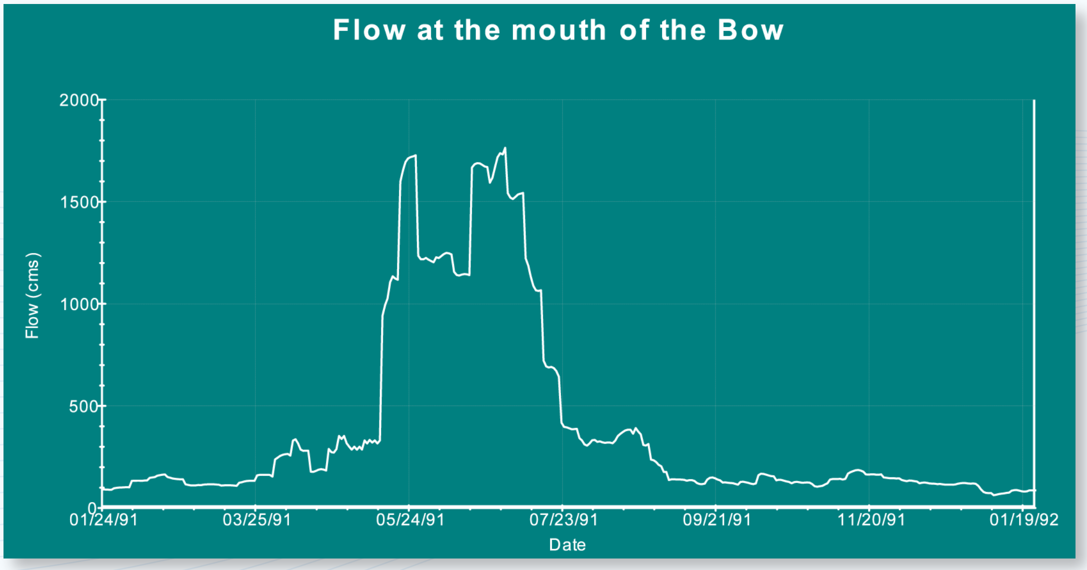
IFN Reach Name	OASIS Arc	Upstream / Downstream Name
BW1A	320.56	Bassano to Scandia (Before EID/BRID return flows)
BW1B	569.57	Scandia to Bow/Oldman confluence (After EID/BRID return flows)
BW2	290.319	Carseland to Bassano
BW3	280.289	Highwood confluence to Carseland
BW4	250.28	Pine Creek/Bonnybrook to Highwood confluence
BW5	210.22	Below Bearspaw to Calgary
BW7	194.195	Ghost to Bearspaw
BW8	184.185	Horseshoe to Ghost
BW9	125.165	Canmore to Kananaskis
BW10	96.125	Bow/Cascade confluence to Canmore
BW11	90.095	Banff to Bow/Cascade confluence
KN1	155.160+155.165	Kananaskis below Barrier
KN3	145.150+145.155	Kananaskis below LKan

The full set of IFN curves can be viewed in the BROM IFN Plotmaker. The example chart below is for IFN Reach BW1A (Bassano to Scandia (Before EID/BRID return flows)) for Week 15:



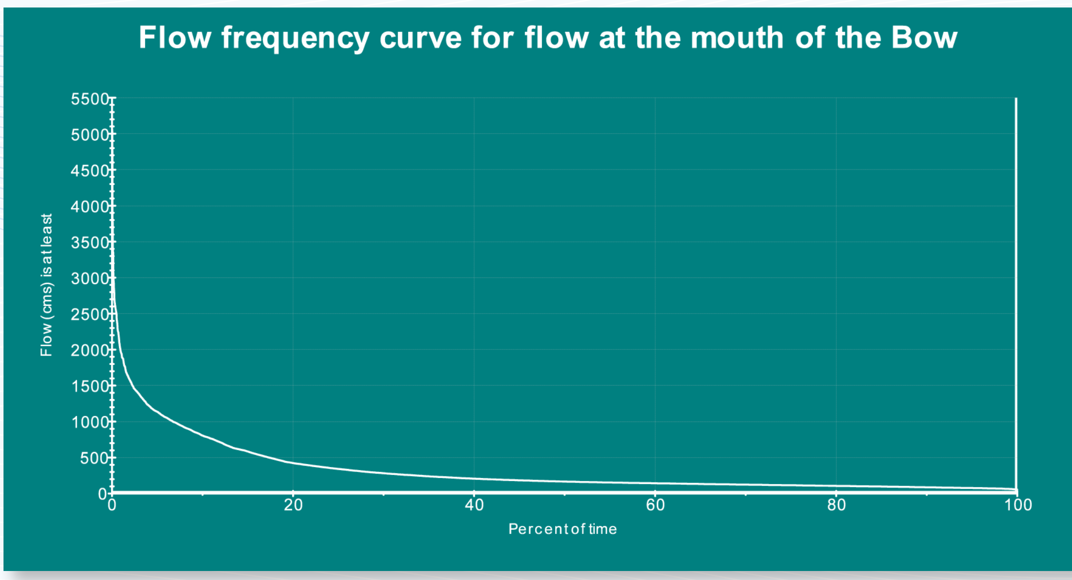
23. FLOW AT THE MOUTH OF THE BOW

This PM is generated by the OASIS GUI. The model outputs the flow in the Bow River below the confluence with the Oldman where the Bow and Oldman form the South Saskatchewan River. The chart below provides an example of the PM information generated by the model.



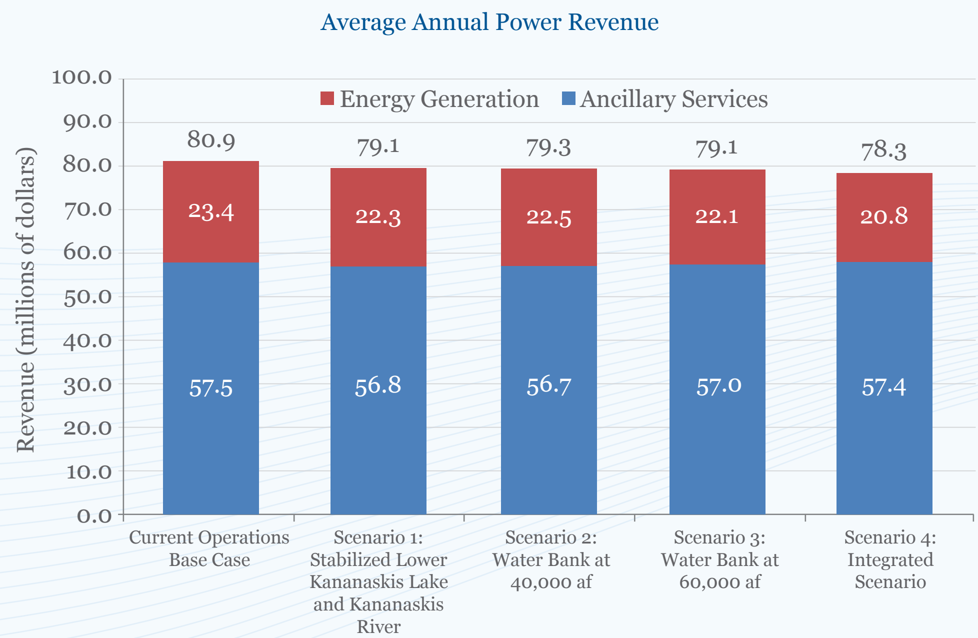
24. FLOW FREQUENCY CURVE FOR THE MOUTH OF THE BOW

This PM is generated by the OASIS GUI. The model outputs the frequencies of flows in the Bow River below the confluence with the Oldman by sorting the flows largest to smallest and assigning an exceedance probability to each data value. For each percentage of time considered, the plot displays the probability that the flow is greater than or equal to a given flow. The chart below provides an example of the PM information generated by the model.



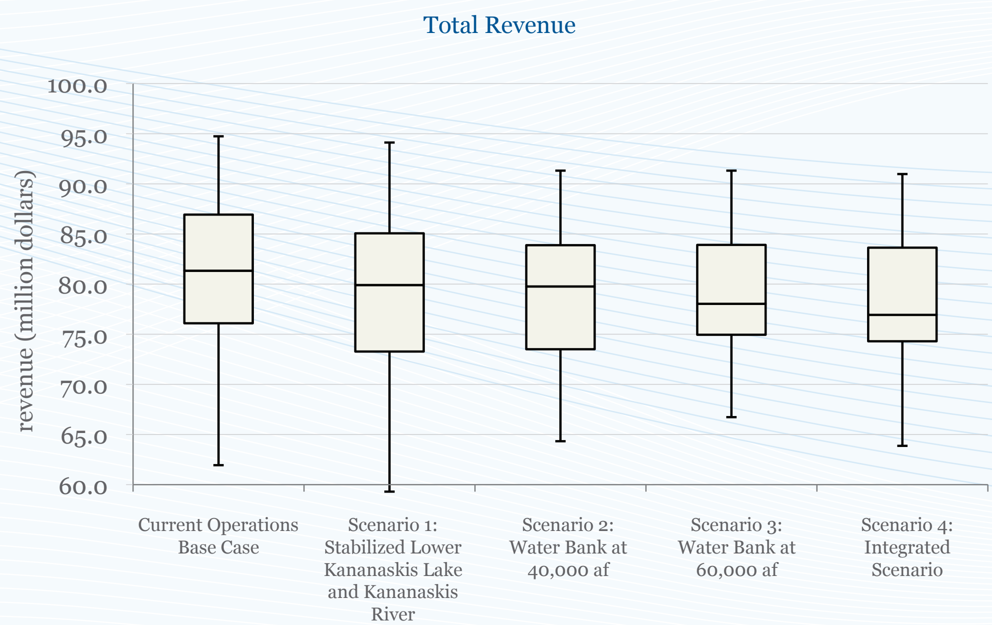
30. POWER REVENUE

The model tracks the average annual power generation revenue and average annual ancillary services revenue for the TransAlta Utilities system in the Upper Bow basin.

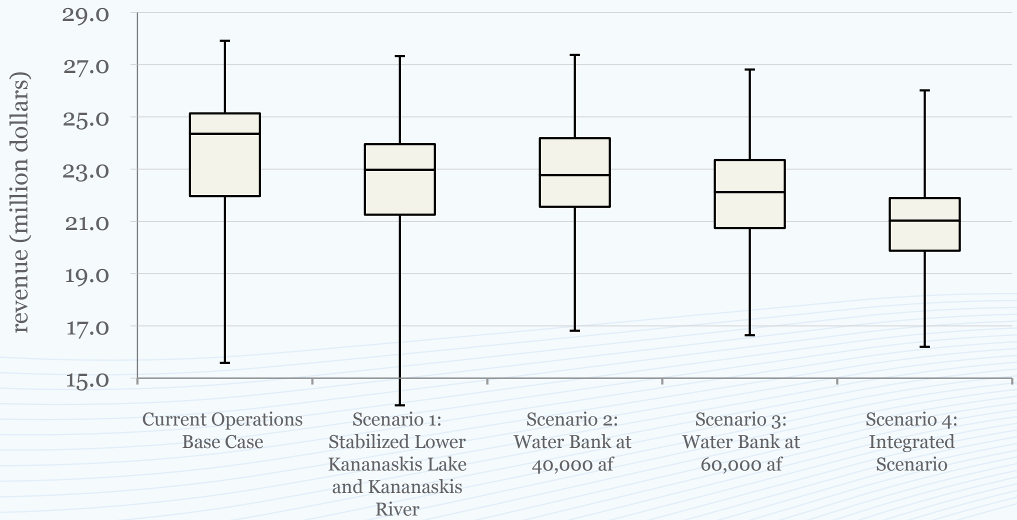


31, 32. TOTAL POWER REVENUE AND POWER GENERATION BOX AND WHISKER PLOTS

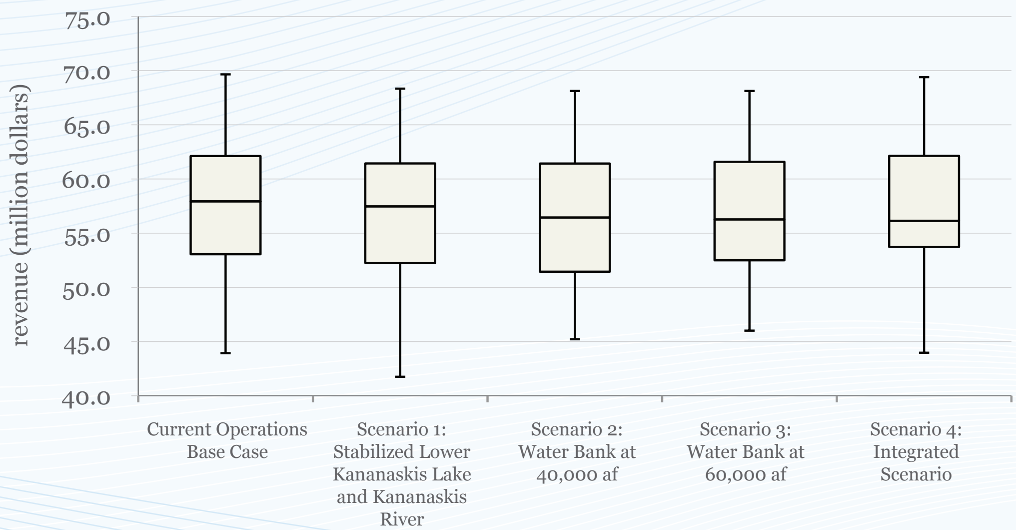
The PM is created for four variables: power generation revenue, ancillary services revenue, total power revenue, and power generation. For each day the model calculates revenue from generation, revenue from ancillary services, and total power generation. For each box and whisker plot the quartiles, minimum, and maximum values are determined based on the corresponding model output.



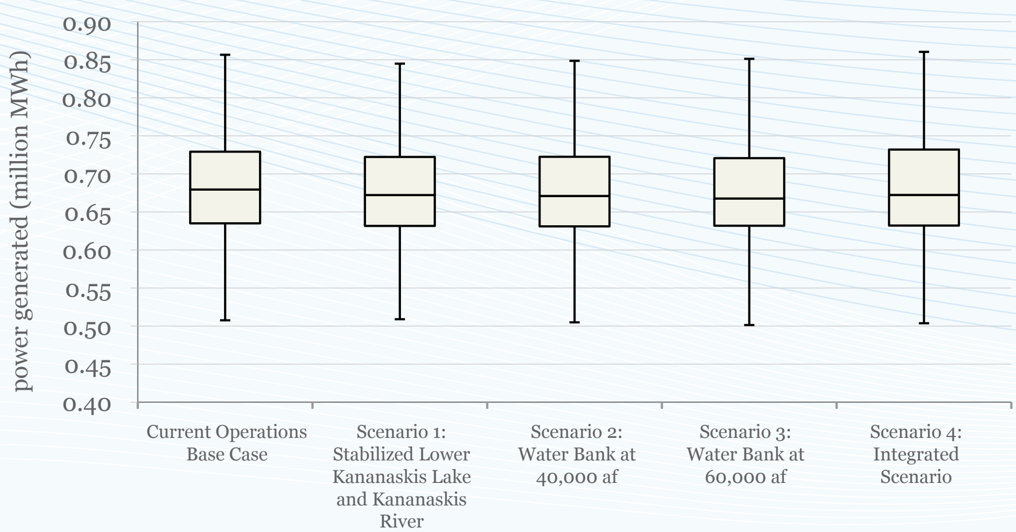
Ancillary Services Revenue



Power Generation Revenue



Power Generation

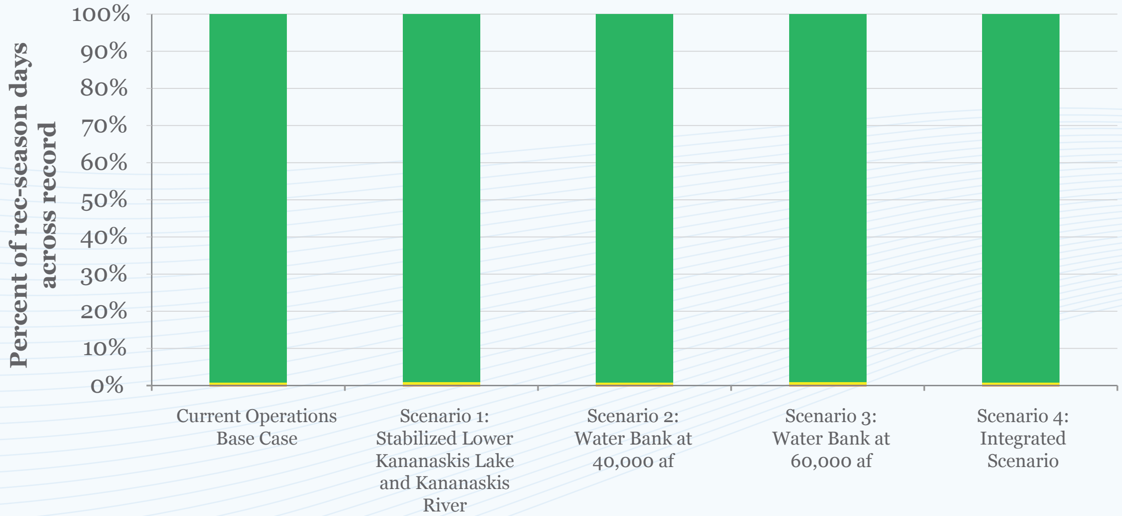


40. FLOOD EVENTS

Those days where the flows are considered flood flows are provided by the model and plotted. The PM is generated for the base case and each alternate scenario, for four reaches: (1) the WID diversion to Highwood confluence, (2) Carseland to Bassano, (3) below Bassano but before ID return flows, and (4) below Bassano but after ID return flows. The example below shows reach (2) Carseland to Bassano, under the current operations base case:

50. GLENMORE RECREATION SEASON

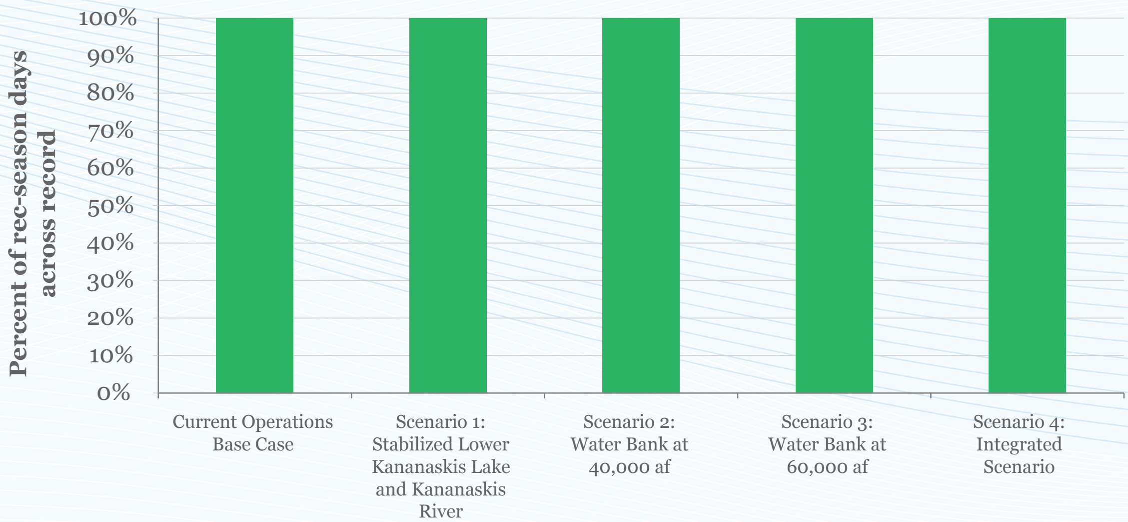
The model counts and classifies each recreation season day on Glenmore according to the following classification criteria provided by the City of Calgary: ideal days are within 1m of 1075.33m, above average days are within 1.5m to 1m of 1075.33m, and acceptable days are within 1.8 to 1.5m of 1075.33m. The percentages are then based on the total number of recreation season days in the simulation.

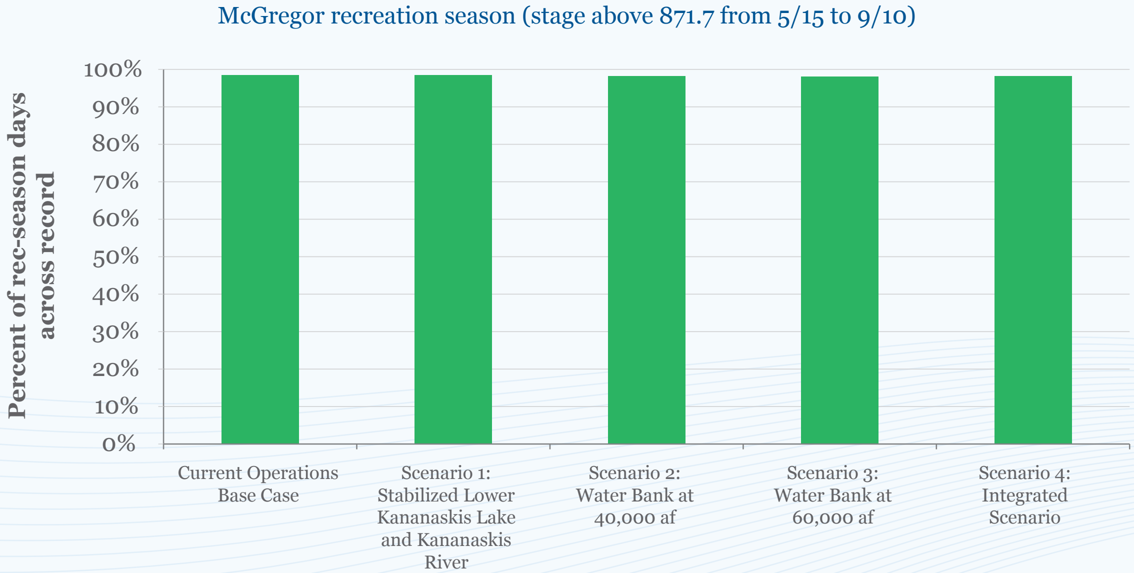


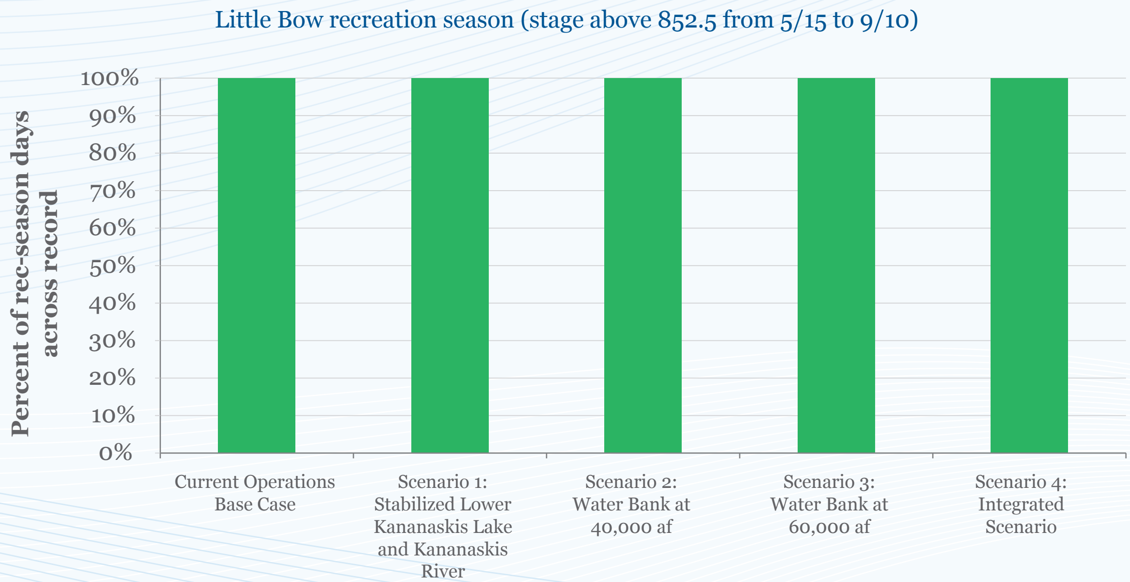
51, 52, 53. TRAVERS, MCGREGOR, AND LITTLE BOW RECREATION

The model counts and classifies each recreation season day on Travers according to the classification criterion provided by the BRID: ideal days are when the stage is above 855.0m. The PM is also generated for recreation on McGregor and Little Bow. For McGregor the criterion is to stay above 871.7m and for Little Bow the criterion is to stay above 852.5m. The percentages are then based on the total number of recreation season days in the simulation. For each year and for all three reservoirs recreation season runs from 5/15 to 9/10.

Travers recreation season (stage above 855.0 from 5/15 to 9/10)







54, 55. TRAVERS AND MCGREGOR PUMP INTAKE PROBLEMS

When stage on Travers or McGregor drops below a certain level there are irrigators whose pump intakes no longer reach the water. The model counts the number of days across the record where the stage is too low in order to determine the percentage of days with pumping problems.