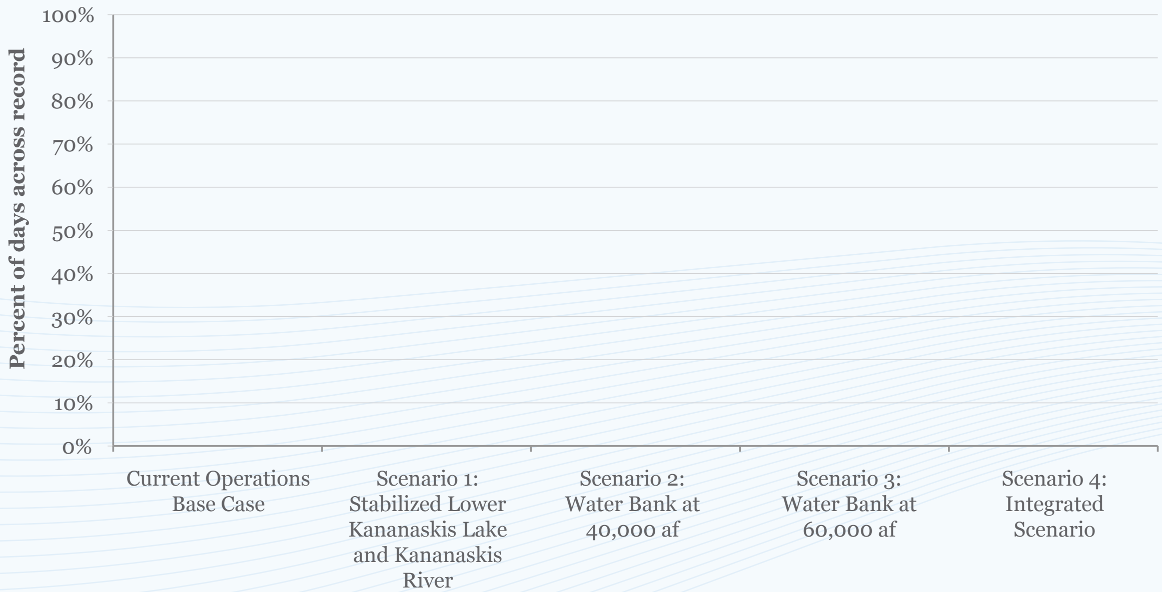
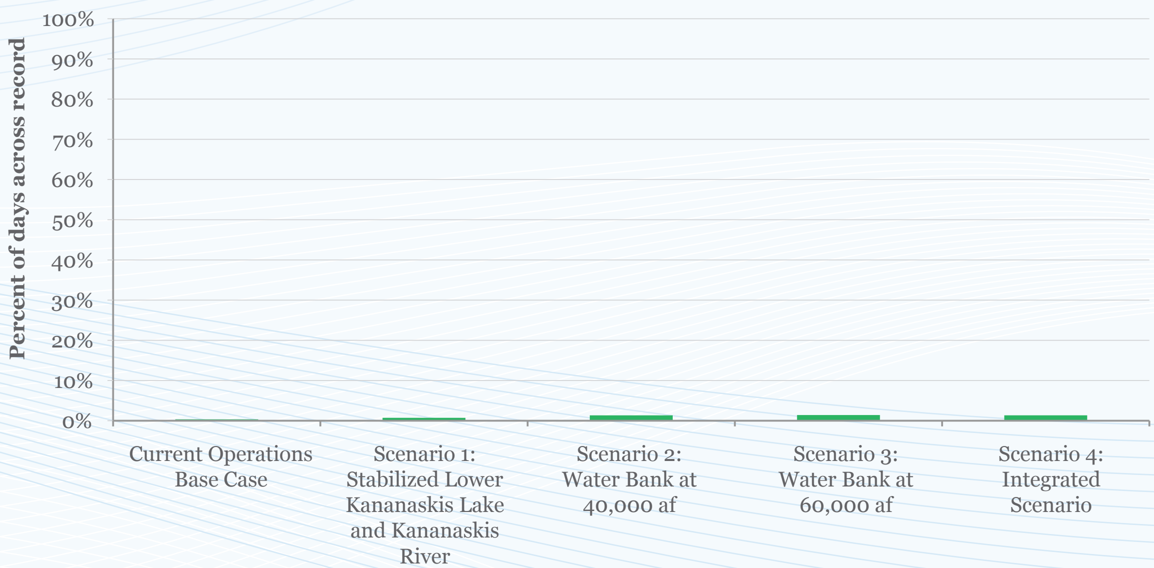
Travers stage below 853.5 meters
(problems with pump intake irrigation withdrawls)



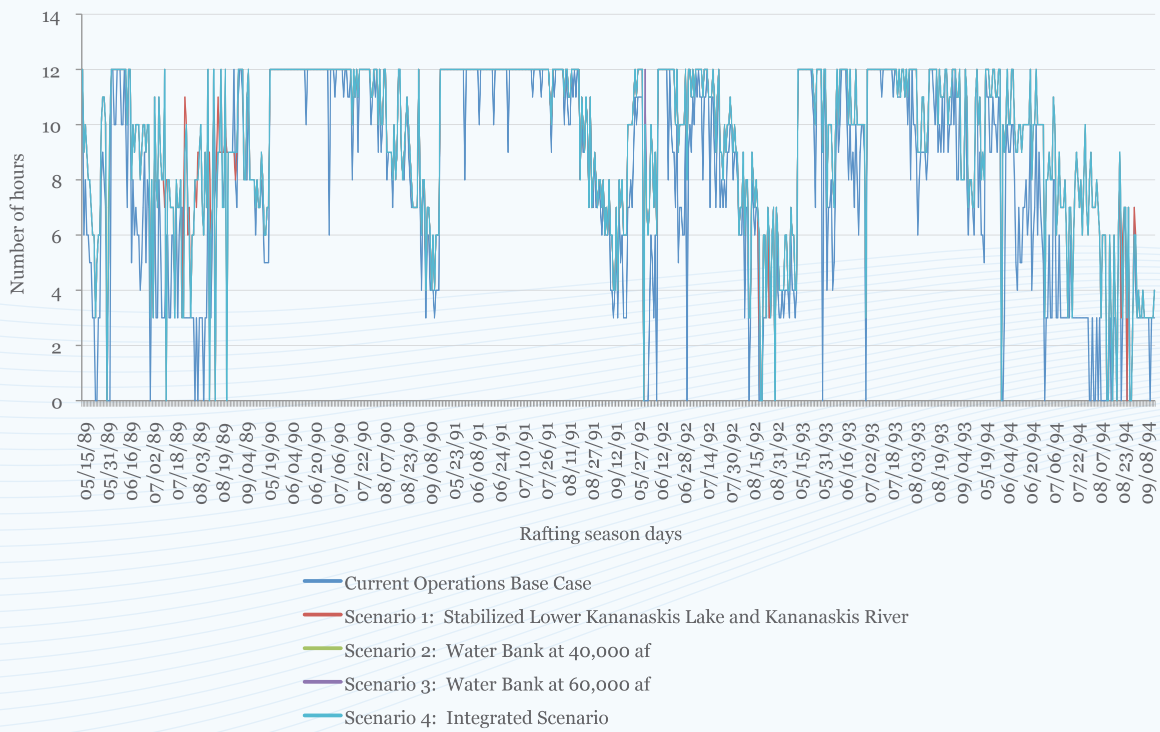
McGregor stage below 871.5 meters
(problems with pump intake irrigation withdrawls)



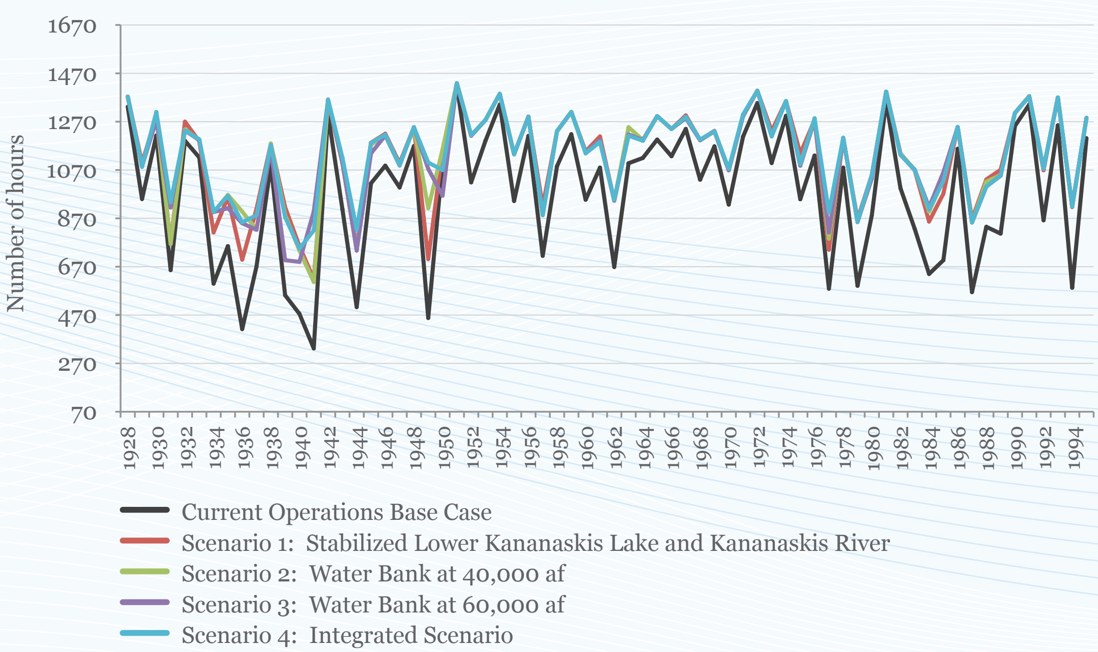
56A, 56C. RAFTING/KAYAKING HOURS (DAILY AND ANNUAL)

The first plot shows rafting and kayaking hours for each rafting season day. Only rafting season days are plotted and so along the x-axis there is a jump from 9/15 of one year to 5/15 of the next year. The second plot shows the annual sum of rafting hours in each year. In order to optimize for power generation in the TransAlta reservoirs the model estimates the flows through the generation plants for each hour in the simulation. Therefore, the model can track the number of hours in each rafting season day where the flow is at least 30cms. Hours are only counted if they belong to a stretch of at least three hours within the hours of 9AM to 9PM to ensure that the rafting hours are usable by rafters. Rafting and kayaking season runs from 5/15 to 9/15. The two PMs below are generated for the Kananaskis River below Barrier Reservoir.

Rafting hours below Barrier (counts only those hours in stretches of at least 3 hours where flow >= 30cms)

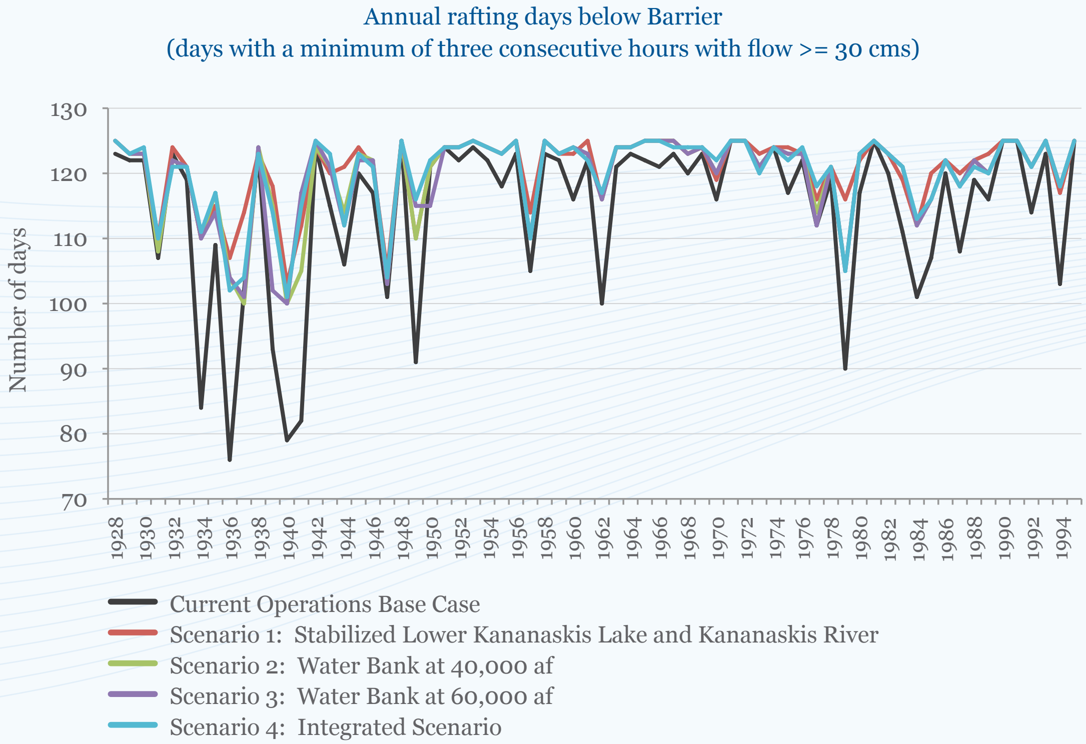


Annual rafting hours below Barrier (counts only those hours in stretches of at least 3 hours where flow >= 30cms)



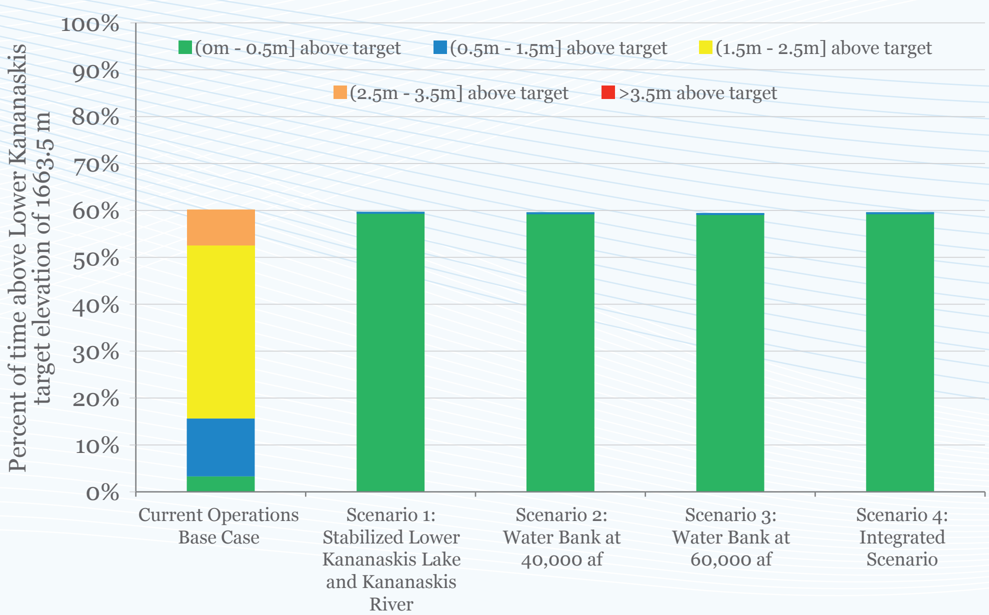
56B. RAFTING/KAYAKING DAYS

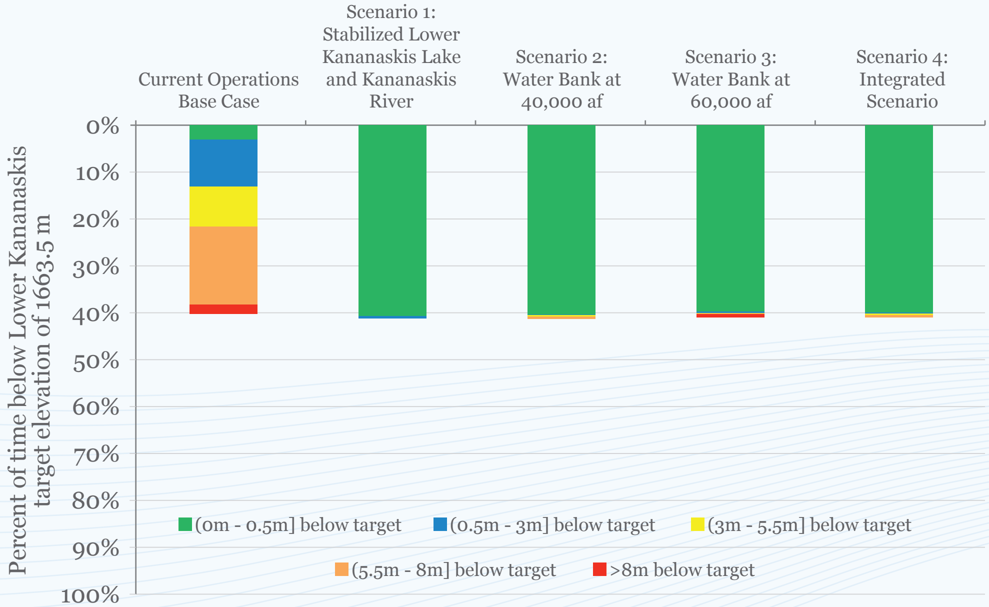
The PM is generated for the Kananaskis River below Barrier Reservoir. The number of rafting/kayaking hours is counted in order to determine the number of rafting days, and the logic for counting rafting hours is the same as that used in PM 56a.



57. ANNUAL STAGE VARIATION (AGGREGATED ACROSS RECORD)

The model determines the minimum and maximum annual stage variation on Lower Kananaskis from the target stage of 1663.5m by finding the lowest and highest stage in each year and calculating the distance of each to the target stage.

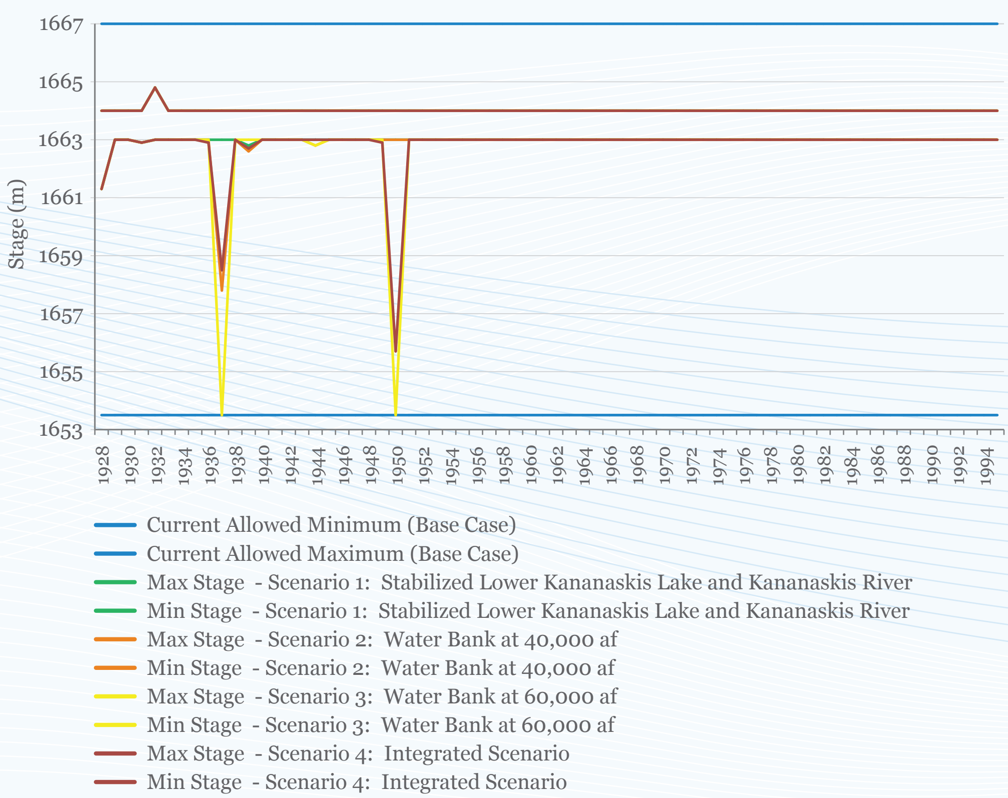




The model determines the minimum and maximum annual stage variation on Lower Kananaskis from the target stage of 1663.5m by finding the lowest and highest stage in each year and calculating the distance of each to the target stage.

58. ANNUAL STAGE VARIATION (BY-YEAR)

The model determines the annual minimum and maximum stage on Lower Kananaskis.

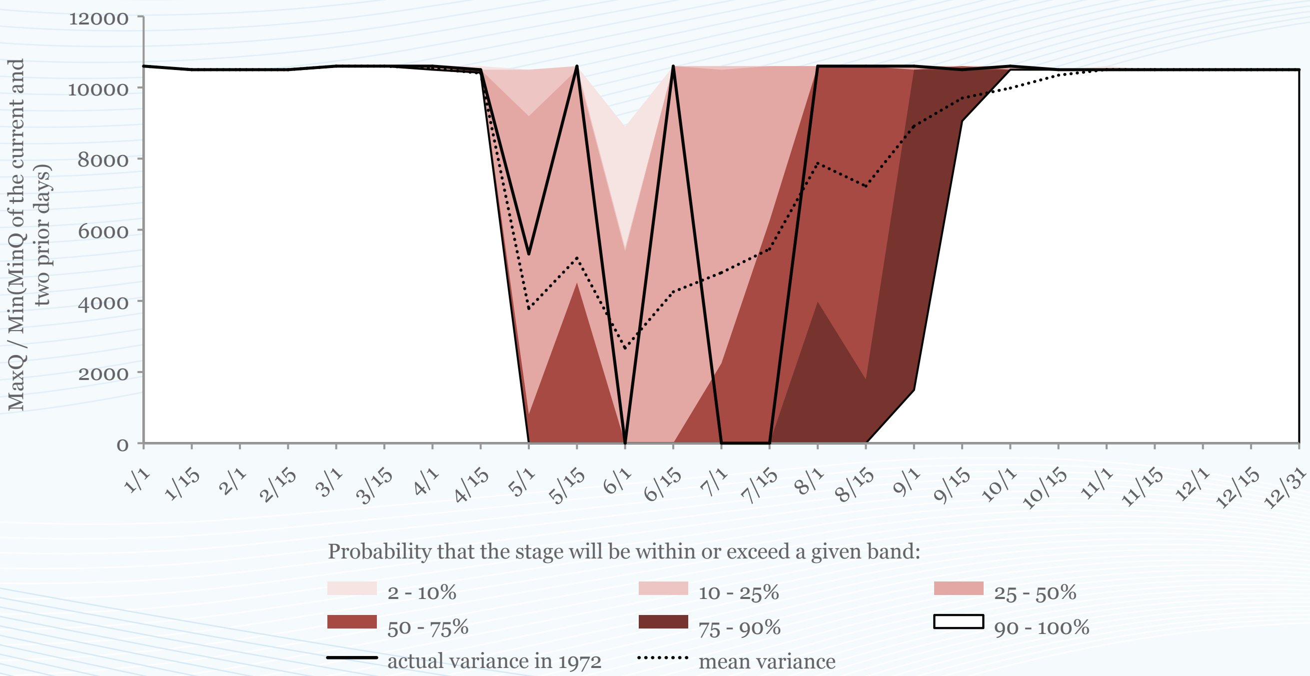


59. HYDROPEAKING

This PM is implemented for the flows out of the Lower Kananaskis generation plant and the Barrier generation plant. The estimated daily variance in flow is computed as the maximum flow in a given day divided by the minimum flow in the current and previous two days. The model provides the timeseries output of this ratio across the simulation period in two week increments. For each captured day a collection of percentiles are determined; with each percentile corresponding to a band in the rainbow plot. The plot indicates the likelihood that the estimated variance will be within or above a given band. Once again, the minimum and maximum daily flows can be estimated because the flows through the TransAlta generation plants are estimated for each hour in the simulation.

The full set of Hydropeaking charts can be viewed in the BROM Hydropeaking Plotmaker. The example chart below is for flows out of the Lower Kananaskis generation plant under the Current Operations Base Case for 1972:

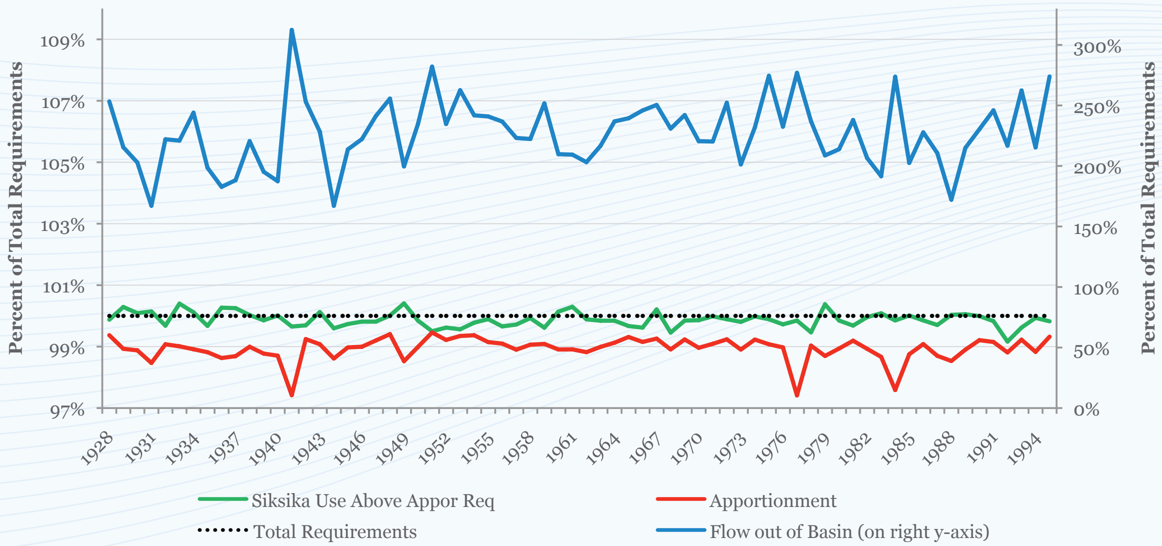
Estimated daily variance in flow
(maximum intra-day flow / minimum intra-day flow) - Current Operations



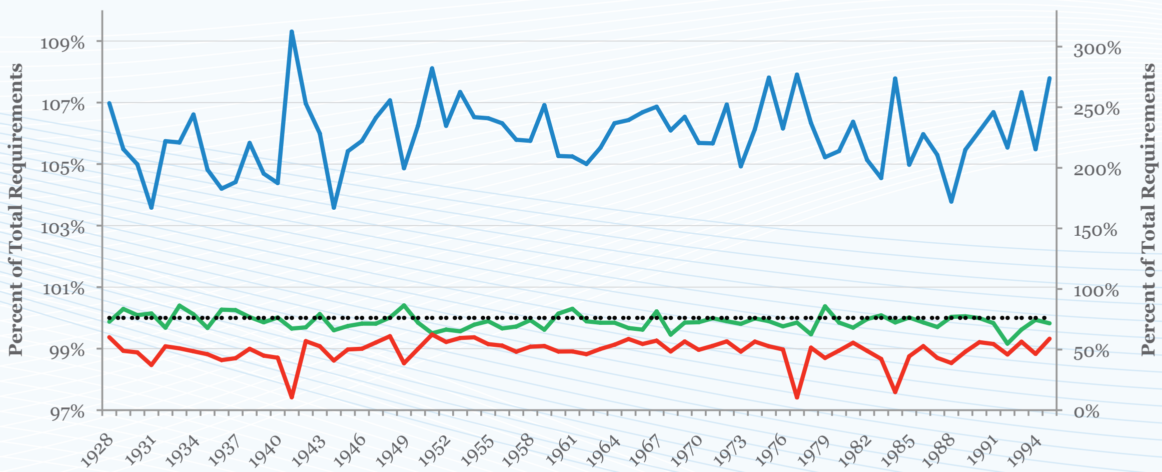
60. SIKSIKA DEMANDS

For each year, the model outputs the volume of water of the required Master Apportionment, the actual Siksika diversion, and the actual flow out of the basin. All of the lines on this PM are displayed as a percentage of the total required flows, where the total required flows are the sum of the annual Master Apportionment and the annual required Siksika diversion of 35,000 acre feet. The flow out of the basin is displayed on the right axis because it is consistently so much higher than the total requirements that were it displayed on the left axis the differences between the red, green, and black lines would be impossible to see.

Siksika demands - Current Operations Base Case

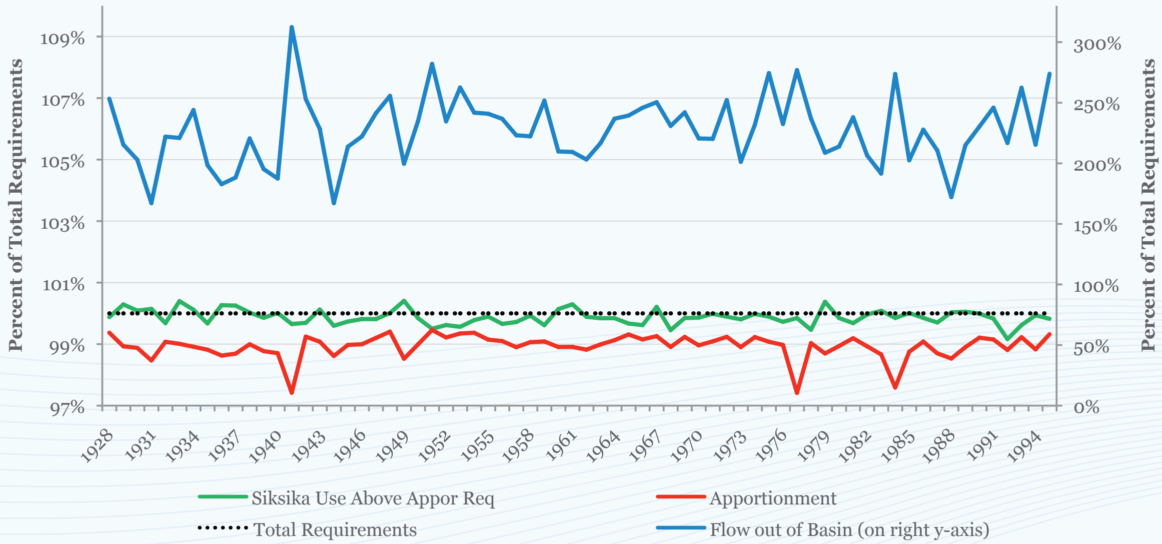


Siksika demands - Scenario 1: Stabilized Lower Kananaskis Lake and Kananaskis River

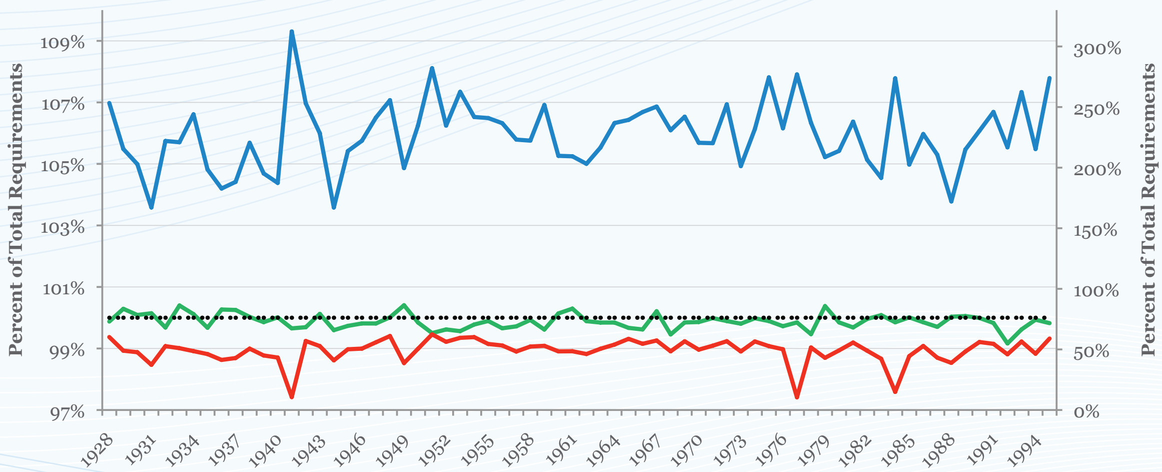


(Total Requirements = the sum of the annual Master Apportionment and the annual required Siksika diversion of 35,000 acrefeet)

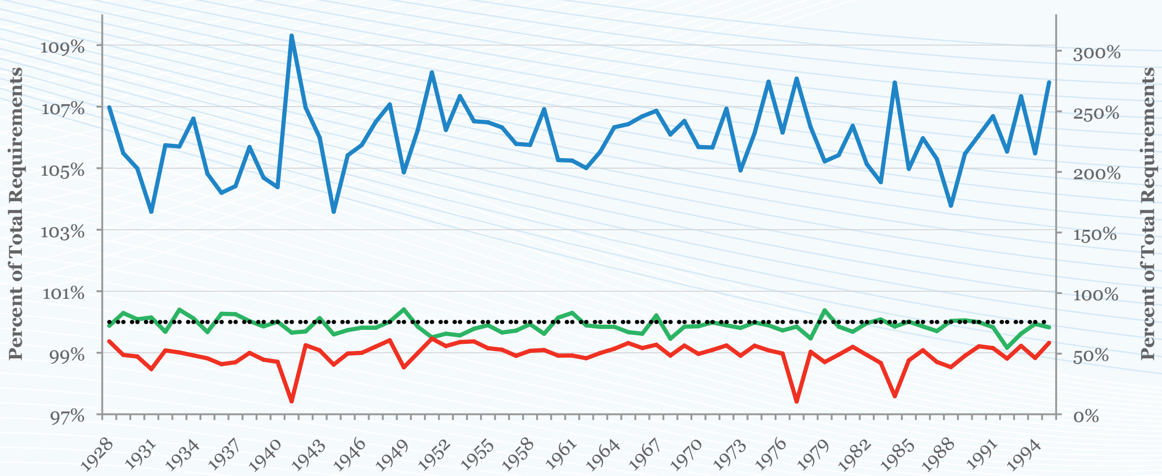
Siksika demands - Scenario 2: Water Bank at 40,000 af



Siksika demands - Scenario 3: Water Bank at 60,000 af



Siksika demands - Scenario 4: Integrated Scenario



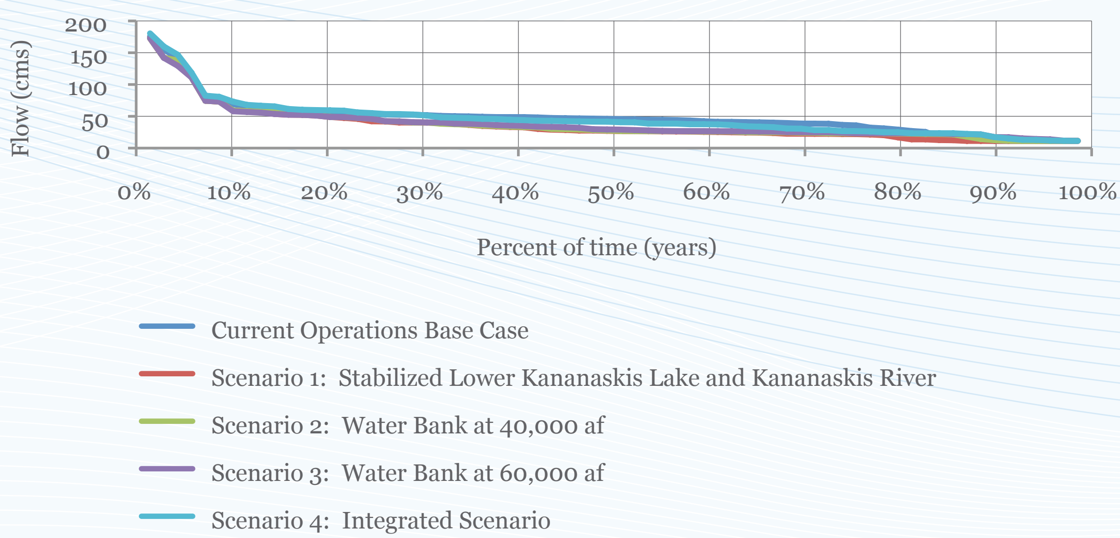
(Total Requirements = the sum of the annual Master Apportionment
and the annual required Siksika diversion of 35,000 acrefeet)

61. IFN FLOW DURATION CURVES

The model outputs the frequencies of flows in the reaches with IFNs 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 flow in the IFN reach is greater than or equal to a given flow. The PM is generated for the following reaches for each week in the year:

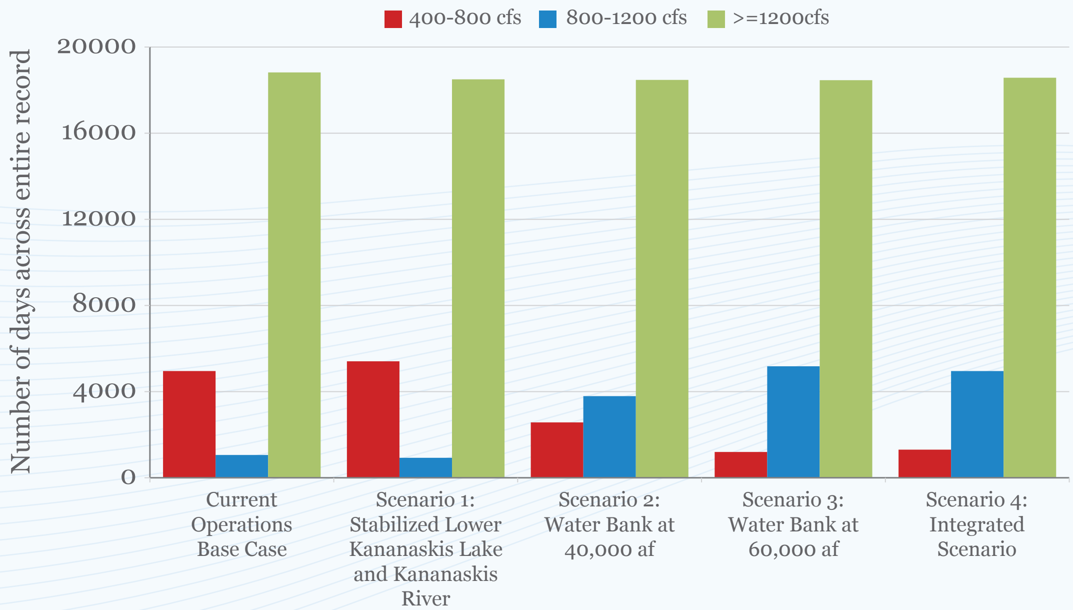
IFN Reach Name	OASIS Arc	Upstream / Downstream Name
BW1A	320.56	Bassano to Scandia (Before EID/BRID return flows)
BW1B	569.57	Scandia to Bow/Oldman confluence (After EID/BRID return flows)
BW2	290.319	Carseland to Bassano
BW3	280.289	Highwood confluence to Carseland
BW4	250.28	Pine Creek/Bonnybrook to 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 flow duration 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:



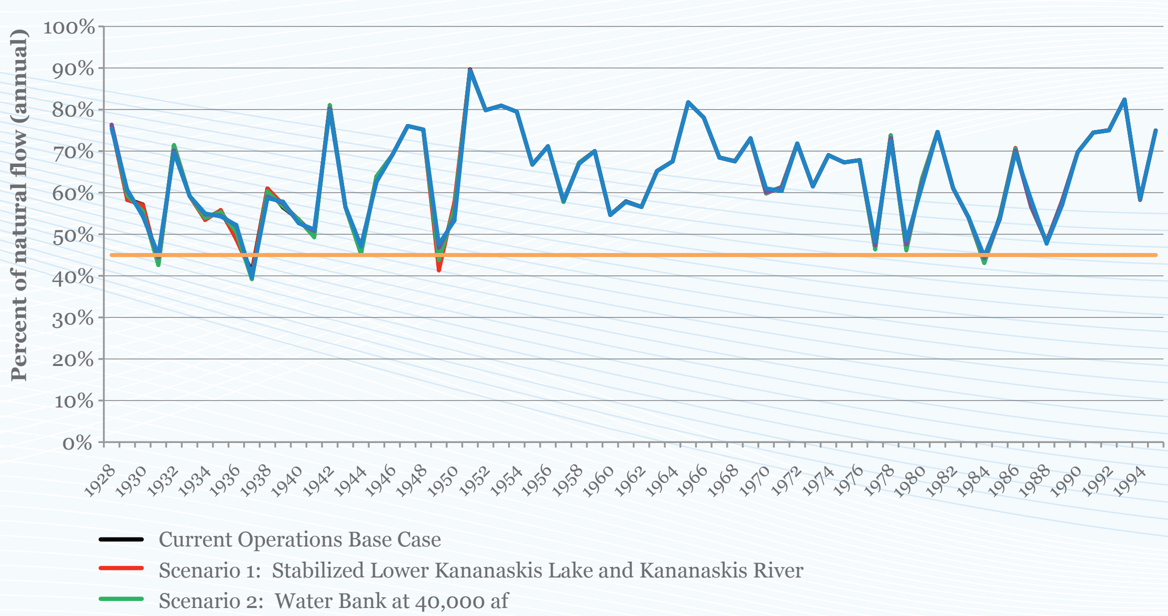
62. BASSANO FLOW CLASSIFICATIONS

The model counts the number of flow events at Bassano across the simulation period. The events are classified into four bins: flows above 1299cfs, flows between 1200cfs and 800cfs, flows between 800cfs and 400cfs, and flows less than 400cfs.



64. PERCENT OF NATURAL FLOW BEFORE THE BOW/OLDMAN CONFLUENCE

The model calculates the percent of natural flow by dividing the annual sum of the flow in the arc before the Bow/Oldman confluence by the annual sum of the naturalized inflows before the confluence.



APPENDIX E: Water Quality Model Results

SCOPE OF STUDY

To test the water quality impacts of an alternate scenario, Alberta Environment agreed to run the OASIS output through its Bow River Water Quality Model (BRWQM), which covers the reaches of the Bow from Bearspaw Dam to Bassano Dam. The BRWQM is an integrated system of selected surface water quality and quantity models that is used to assess and compare the water quality impacts of different scenarios and has been used as part of a number of computer model exercises to support the South Saskatchewan Regional Plan (Government of Alberta, 2010). At the point in the project when the Consortium worked with Alberta Environment to run the BRWQM, it was decided to test the integrated scenario. At that time, the integrated scenario included stabilized Lower Kananaskis Lake and Kananaskis River, and restored Spray; a water bank and increased storage at Langdon reservoir were not part of the integrated scenario when the BRWQM was run.

Alberta Environment took output from the OASIS model for both the base case and the integrated scenario and ran it through the BRWQM. This analysis was done to represent three hydrologically different years, selected by the Consortium: 1982, 1988 and 1993. The assessment nodes, reflecting the three reaches of the river in the model (Bearspaw to Highwood, Highwood to Carseland, and Carseland to Bassano), were Stiers Ranch, Carseland and Bassano, and the parameters were water temperature, dissolved oxygen, and phosphorus. Due to the time constraints of the project, this model run was done using a semi-final version of the data. However, the nature of the subsequent changes to the Bow River Operational Model would not have any significant effect on the BRWQM results. As the Bow River Operational Model is refined over time, there will be future opportunities to again run it through the BRWQM.

ASSUMPTIONS FOR THE BRWQM INPUTS

1. Meteorological conditions: use the recorded meteorological data at Calgary International Airport during 1988, 1990, 1993.
2. All boundary flow conditions are based on the simulated flows from OASIS.
3. Water quality conditions for these corresponding source waters are based on what were defined for the Bow River Water Quality Modelling during calibration/validation stage during the corresponding year. However, 1988 was not simulated in the original water quality model, and as such water quality condition in 2001 was applied for these in 1988.
4. Calgary wastewater loading in 2007 was applied for representing the Calgary wastewater loading in all the three selected years; i.e., 1988, 1990, 1993, for both scenarios.
5. Initial condition (water column and sediment column) were set to be the same between the two scenarios.

BRWQM EXCEEDANCE RULES

		CENTRAL BOW RIVER	LOWER BOW RIVER
Temperature	°C	<24 °C at any time	<29 °C at any time
DO	mg/L	5 mg/L acute daily minimum 6.5 mg/L chronic 7 day running average	5 mg/L acute daily minimum 6.5 mg/L chronic 7 day running average
Ammonia	mg_N/L	Lower of US EPA or 0.2 mg/L during growing season for aquatic vegetation	Lower of US EPA or 0.2 mg/L during growing season for aquatic vegetation
Nitrate	mg_N/L	1.5 mg/L	1.5 mg/L
TDP	mg_P/L	0.015 mg/L during growing season for aquatic vegetation	0.015 mg/L during growing season for aquatic vegetation
TP	mg_P/L	0.028 mg/L	-
TSS	mg/L	if background concentration (assuming 7 day exposure): <25 mg/L then conditions must not exceed a SEV value of 6 >25 mg/L conditions must not exceed an SEV value of 7 >250 mg/L conditions should not increase more than 10% above background level	if background concentration (assuming 7 day exposure): <25 mg/L then conditions must not exceed a SEV value of 6 >25 mg/L conditions must not exceed an SEV value of 7 >250 mg/L conditions should not increase more than 10% above background level

SUMMARY OF BOW RIVER WATER QUALITY MODELLING RESULTS

1. WATER TEMPERATURE

	Evaluation Criteria	Averaging Period	Assessment Node	Water Temperature Exceedance (days)					
				Base Case			Integrated Scenario		
				1988	1990	1993	1988	1990	1993
Central Bow River	<=24° C	instantaneous	Stiers Ranch	0	0	0	0	0	0
			Carseland	0	0	0	0	0	0
Lower Bow River	<=29° C anytime	instantaneous	Bassano	0	0	0	0	0	0

2. DISSOLVED OXYGEN - ACUTE

	Evaluation Criteria	Averaging Period	Assessment Node	Dissolved Oxygen Exceedance - acute (days)					
				Base Case			Integrated Scenario		
				1988	1990	1993	1988	1990	1993
Central Bow River	>=5.0 mg/L	instantaneous	Stiers Ranch	0	0	0	0	0	0
			Carseland	0	0	0	0	0	0
Lower Bow River			Bassano	0	0	0	0	0	0

3. DISSOLVED OXYGEN - CHRONIC

	Evaluation Criteria	Averaging Period	Assessment Node	Dissolved Oxygen Exceedance - chronic (days)					
				Base Case			Integrated Scenario		
				1988	1990	1993	1988	1990	1993
Central Bow River	>=6.5 mg/L	7 day mean	Stiers Ranch	0	0	0	0	0	0
			Carseland	0	0	0	0	0	0
Lower Bow River			Bassano	0	0	0	0	0	0

4. TOTAL DISSOLVED PHOSPHORUS

	Evaluation Criteria	Averaging Period	Assessment Node	Total Dissolved Phosphorus Exceedance					
				Base Case			Integrated Scenario		
				1988	1990	1993	1988	1990	1993
Central Bow River	<=0.015 mg/L	daily mean	Stiers Ranch	169	118	164	167	119	166
			Carseland	131	0	167	131	79	165
Lower Bow River			Bassano	62	63	133	58	65	134

BRWQM PREDICTED TEMPERATURE (°C) AT BASSANO FOR 3 CONSECUTIVE DROUGHT EVENT SCENARIOS