

Appendix to Section 6 - Evaluation of the Alternative Operating Plan Measures Reading Performance Indicator Plots

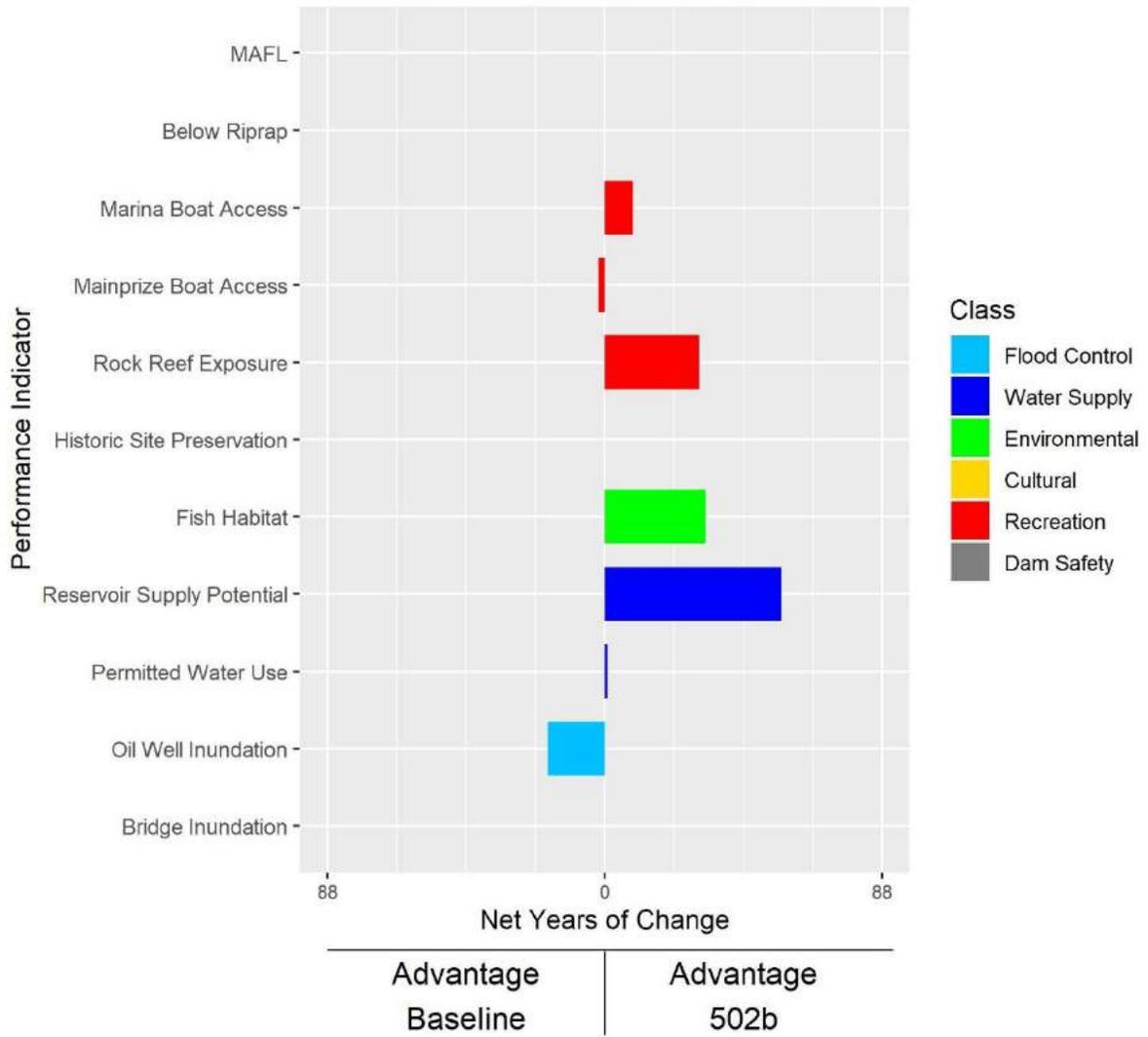
Performance Indicator (PI) plots compare the results of two different HEC-ResSim simulations through the lens of the PIs. A single plot may show a comparison of two simulations for a single reach or a group of reaches. Each PI is represented by a bar on the plot. The x-axis shows the net number of years one simulation outperformed the other. If there is no net difference between the two simulations for a given PI, the bar's height will be equal to zero, and it will not be shown on the plot.

An intuitive way to understand the PI plots is to think of them as showing the final result of a tug-of-war between two simulations. For each year in the simulation, the PI results are computed, and the final score is compared between the two simulations. If simulation A scores better than simulation B (e.g. has fewer agricultural damages, less bridge inundations, or better fish habitat), the bar will be "pulled," one year towards simulation A. If simulation B scores better than simulation A the next year, the bar will be pulled one year towards simulation B. After all years in the simulation are scored, the net result is shown on the plot, and the length of the bar indicates how much better simulation A performed than simulation B, or vice-versa. In other words, the length of the bar shows how much "rope" was pulled to one side or the other at the end of the game. The lack of a bar on the plot for a given PI indicates a tie between the two simulations.

An example PI plot is shown below. This plot compares the Alternative 502b simulation and the Baseline simulation for the period of record (88 years). For the MAFL and Below Riprap PIs, no bars are shown. This indicates neither simulation performed better than the other in these categories. Two recreation PIs, Marina Boat Access and Rock Reef Exposure, favor the side of 502b. This indicates boaters can access the marina more often in the 502b simulation than in the Baseline, and the rock reef is not exposed as often in Alternative 502b. The Fish Habitat and Reservoir Supply Potential PIs also favor Alternative 502b, indicating fish habitat is better and the reservoir pool is higher in Alternative 502b relative to the Baseline. However, the Oil Well Inundation PI favors the Baseline simulation, indicating oil wells are inundated less in the Baseline than they are in Alternative 502b.

Short descriptions of all PIs used in the study are included on the following pages.

Rafferty Reservoir
 Baseline vs. 502b
 Period of Record: 1930-2017 (88 Years)



Performance Indicators

Reservoirs

-  MAFL: A measure of how often the reservoir exceeds its Maximum Allowable Flood Level (MAFL) threshold.
-  Below Riprap: A measure of how often the reservoir falls below the riprap at the base of the dam. Only applicable to Rafferty Reservoir.
-  Mainprize Boat Access: A measure of how often the reservoir elevation is within the range suitable for use of the Mainprize boat access. Only applicable to Rafferty Reservoir.
-  Marina Boat Access: A measure of how often the reservoir elevation is within the range suitable for use of the marina boat access. Only applicable to Rafferty Reservoir.
-  Rock Reef Exposure: A measure of how often the reservoir elevation drops low enough to expose a dangerous rock reef. Only applicable to Rafferty Reservoir.
-  MMPP Boat Access: A measure of how often the reservoir elevation is within the range suitable for use of the Moose Mountain Park boat access. Only applicable to Grant Devine Lake.
-  Boat Launch Access: A measure of how often the reservoir elevation is within the range suitable for use of the boat launch. Only applicable to Boundary Reservoir.
-  Boating & Fishing Access: A measure of how often the boat ramps and other access sites at the reservoir are inundated. Only applicable to Lake Darling.
-  Historic Site Preservation: A measure of how often archaeological sites are inundated around the reservoir.
-  Fish Habitat: A measure of how often the reservoir elevation is within the range most suitable for fish habitat.
-  Fish Habitat (MMC): A measure of how often the flow in Moose Mountain Creek just below Grant Devine Dam is suitable for fish habitat. 'MMC' is specified in this PI name at Grant Devine Lake to differentiate from the Fish Habitat in the reservoir. Only applicable to Grant Devine Lake.
-  Fish Habitat (Reservoir): A measure of how often the reservoir elevation is within the range most suitable for fish habitat. 'Reservoir' is specified in this PI name at Grant Devine Lake to differentiate from the Fish Habitat in Moose Mountain Creek.
-  Fish & Wildlife Habitat: A measure of how often the reservoir elevation is most suitable for fish and wildlife habitat. Only applicable to Lake Darling.
-  Reservoir Supply Potential: A measure of how close the reservoir is to its Full Supply Level (FSL). Does not count days when the reservoir is above FSL.
-  Permitted Water Use: A measure of how often the reservoir elevation is below the level necessary to meet permitted water supply needs.
-  SaskPower Pumping: A measure of how often water must be pumped from Rafferty to Boundary to ensure the reservoir stays high enough to provide cooling water to Boundary Dam Power Station. Only applicable to Boundary Reservoir.
-  Oil Well Inundation: A measure of how often oil wells are inundated around the reservoir.
-  Bridge Inundation: A measure of how often releases from the reservoir inundate bridges immediately downstream of the reservoir. Only applicable to Rafferty Reservoir.
-  MRP Levee Safety: A measure of how often the Mouse River Park levee is overtopped. Only applicable to Lake Darling.
-  MRP Evacuation: A measure of how often Mouse River Park must be evacuated. Only applicable to Lake Darling.
-  MRP 95th St. Safety: A measure of how often 95th Street at Mouse River Park is inundated. Only applicable to Lake Darling.
-  MRP Flood Operations: A measure of how often flood operations must be enacted at Mouse River Park. Only applicable to Lake Darling.

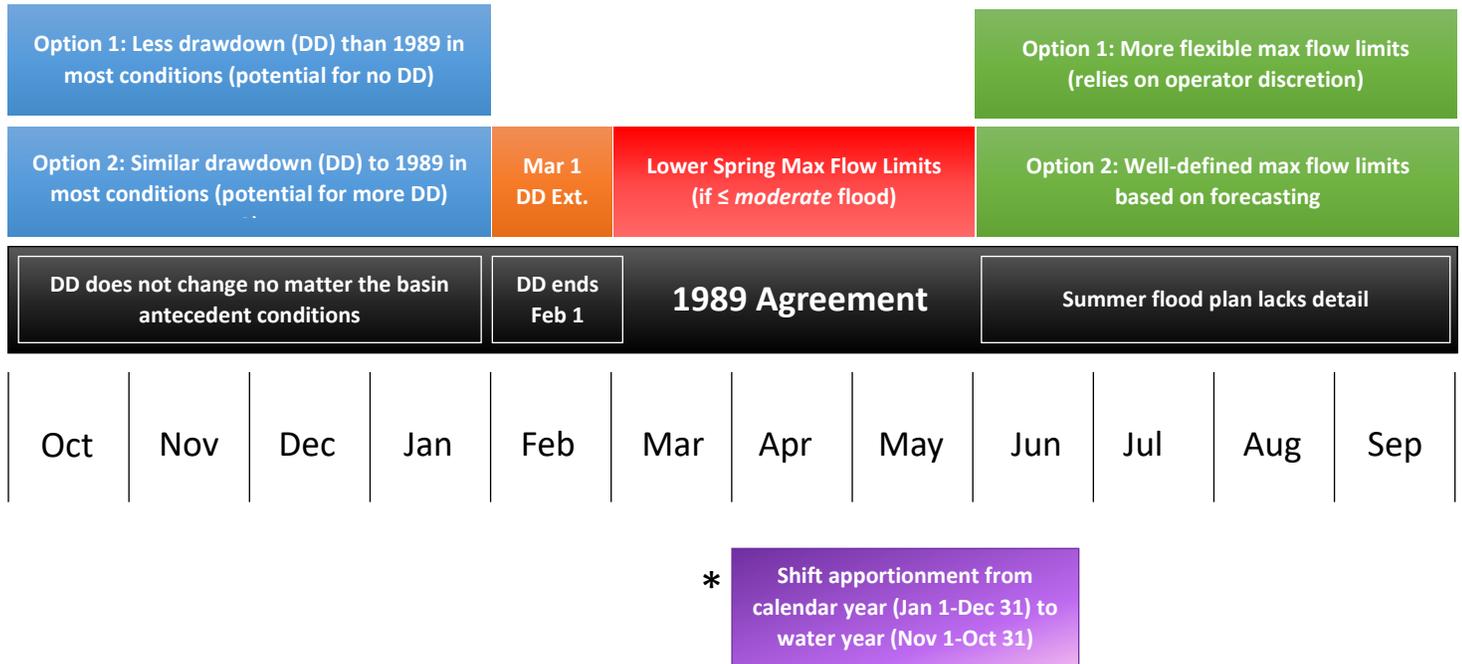
Performance Indicators

Riverine Reaches

-  Total Dissolved Solids, Sulfate, Sodium, and Chloride: A measure of how often target levels for the listed water quality parameter are met.
-  Channel Erosion: A measure of the amount of channel erosion expected.
-  Campground Availability: A measure of how often the Hidden Valley campground is inundated. Only applicable to the City of Estevan reach.
-  Duck Derby Conditions: A measure of how often there is adequate flow in the river for the annual Estevan Duck Derby the first 10 days of September. Only applicable to the City of Estevan reach.
-  Boating & Fishing Access: A measure of how often boating and fishing access sites along the river are inundated.
-  Boating & Fishing Safety: A measure of how often flow in the river is within the range most suitable for safe boating and fishing.
-  Crown Land Protection: A measure of how often Crown lands are inundated in the floodplain. Only applicable to Manitoba.
-  Historic Site Preservation: A measure of how often archaeological sites are inundated in the floodplain.
-  Fish Habitat: A measure of how often flow in the river is within the range most suitable for fish habitat. Only applicable to Saskatchewan.
-  Fish & Wildlife Habitat: A measure of how often flow in the river is within the range most suitable for fish and wildlife habitat. Only applicable to North Dakota.
-  GNB Habitat: A measure of how often ground-nesting bird habitat is inundated in the floodplain. Only applicable to Manitoba.
-  Fish Mortality: A measure of how often flow in the river is low enough to cause widespread fish kills.
-  Permitted Water Use: A measure of how often flow in the river is below the level necessary to meet permitted water supply needs.
-  Bankfull Exceedances: A measure of how often bankfull capacity is exceeded for at least 5 consecutive days.
-  Agricultural Damages: Estimated damages due to inundation of agricultural lands in the floodplain.
-  Coal Stockpile: A measure of the length of time the coal stockpile at Boundary Dam Power Station is expected to be depleted due to the prolonged closure of both coal haul roads. Only applicable to the City of Estevan reach.
-  2nd Coal Crossing: A measure of how often the 2nd coal haul road is overtopped. Only applicable to the City of Estevan reach.
-  1st Coal Crossing: A measure of how often the 1st coal haul road is overtopped. Only applicable to the City of Estevan reach.
-  Oil Well Inundation: A measure of how often oil wells are inundated in the floodplain. Only applicable to Saskatchewan.
-  Bridge Inundation: A measure of how often bridges are overtopped.
-  0.5% Event: A measure of the length of time the 0.5% annual exceedance probability flow is exceeded.
-  1% Event: A measure of the length of time the 1% annual exceedance probability flow is exceeded.
-  Current Protection: A measure of the length of time the current (2020) flood protection infrastructure is overtopped. Only applicable to the City of Minot reach.
-  Railroad Inundation: A measure of the length of time railroad bridges are overtopped.
-  Bridge Detours: A measure of the length of time motorists must spend detouring around bridges that have been overtopped. Only applicable to North Dakota.
-  Structural Damages: Estimated damages due to inundation of structures in the floodplain.

Sequencing the Phase 5 Alternative Measures in Yearly Plans

Phase 5 research culminated in the following possible changes to the 1989 Agreement, and are graphically depicted as follows:



Comparing the PIs of Sequenced Phase 5 Options as Yearly Plans

The next pages show the sequenced yearly plans, comparing Performance Indicators for Reservoirs (Grant Devine, Rafferty, and Lake Darling) and Riverine Reaches (Saskatchewan, North Dakota, and Manitoba).

Performance indicators showing positive benefits for the yearly sequencing are depicted with bars to the right (an “advantage” to the sequence) while negative impacts are depicted to the left (an advantage to the 1989 Agreement). For example, when looking at the Reservoir’s performance indicators, the 502a, 502b, and 502c sequences generally show positive benefits (the most advantages) for water supply, recreation, and environmental PIs; the advantages vary for each reservoir. When looking at the Riverine Reaches in the Regions, the 503a sequence shows the most advantages over 1989 for most PIs.

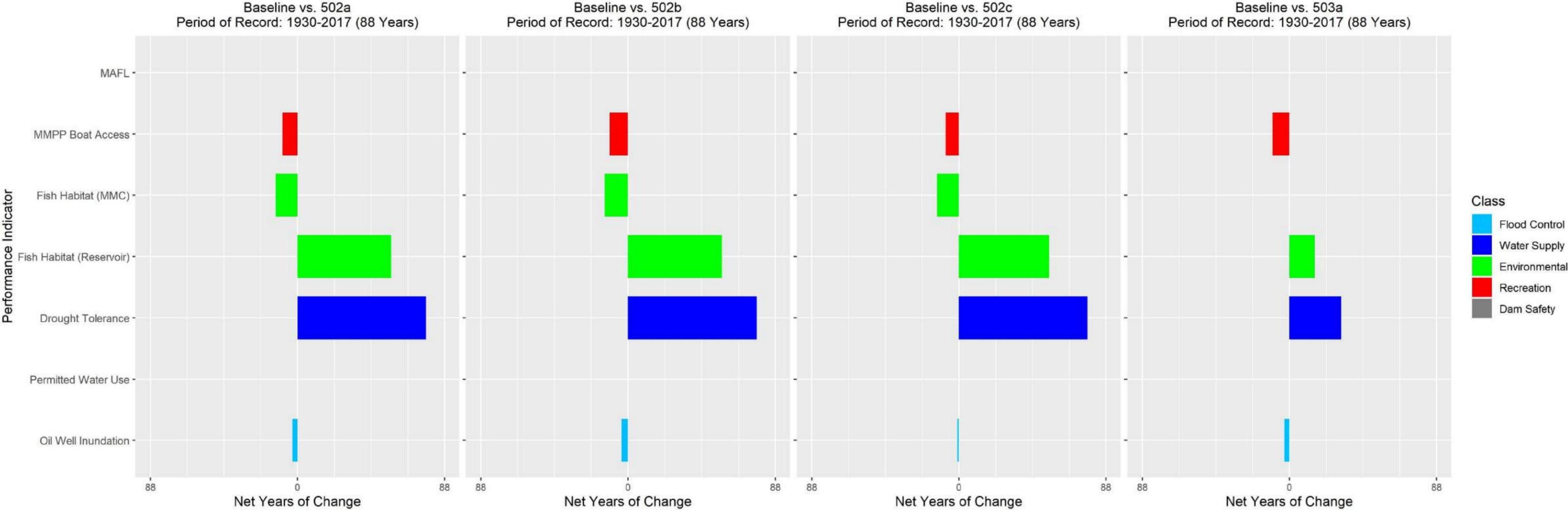
The PIs are not weighted, and impacts or benefits to one are not “equal in value” to another.

Possible future operational plans must consider the benefits and impacts of the changes with an appropriate weighting applied to balance the trade-offs, considering appropriate risks, sensitivity analyses, and resilience factors.

The Study Board makes no recommendation on the preference for depicted sequencing of options. The PI graphics are presented as possibilities of yearly sequencing; analysis of tradeoffs by governments must be considered before making changes to the 1989 Agreement.

Phase 5 Alternatives vs. Baseline PI Comparison

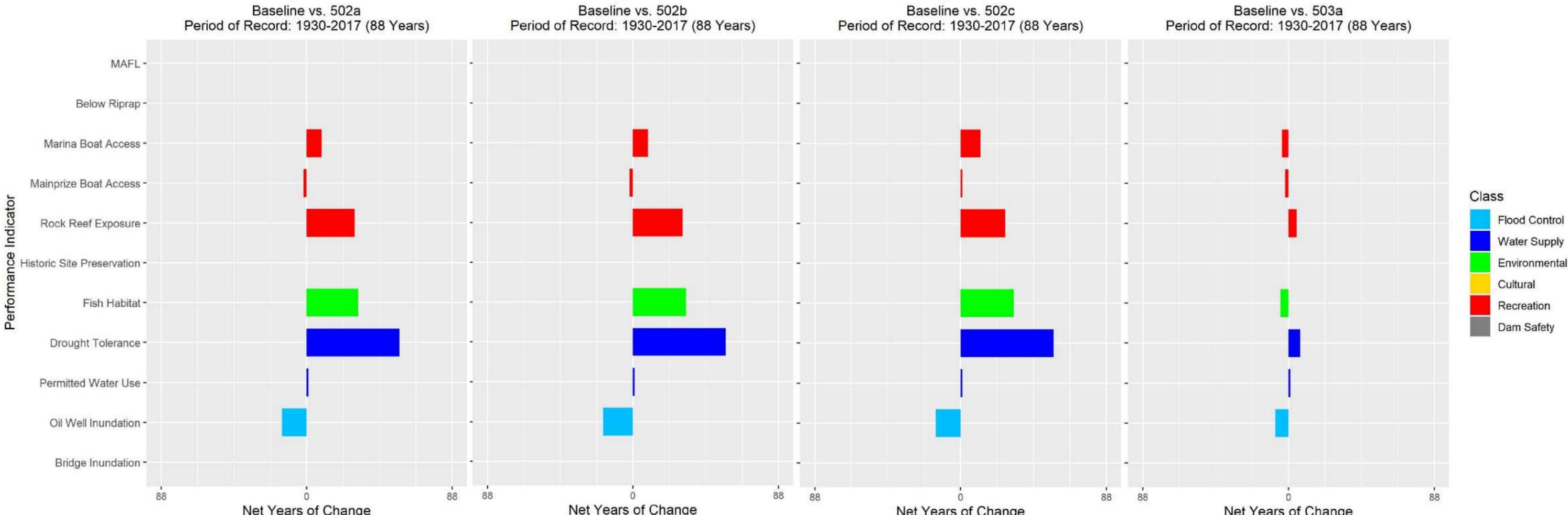
Grant Devine Lake



	Advantage		Advantage		Advantage		Advantage	
	Baseline	502a	Baseline	502b	Baseline	502c	Baseline	503a
Oct-Feb	Normal Drawdown Targets (Option 1)		Normal Drawdown Targets (Option 1)		Normal Drawdown Targets (Option 1)		Normal Drawdown Targets (Option 2)	
Mar	Normal Drawdown Extension							
Apr-May	1989 Agreement		Lower Spring Max Limits		Lower Spring Max Limits		Lower Spring Max Limits	
Jun-Sep	Summer Operating Plan (Option 2)		Summer Operating Plan (Option 2)		Summer Operating Plan (Option 1)		Summer Operating Plan (Option 2)	
All Year	Apportionment Shift		Apportionment Shift		Apportionment Shift		Apportionment Shift	

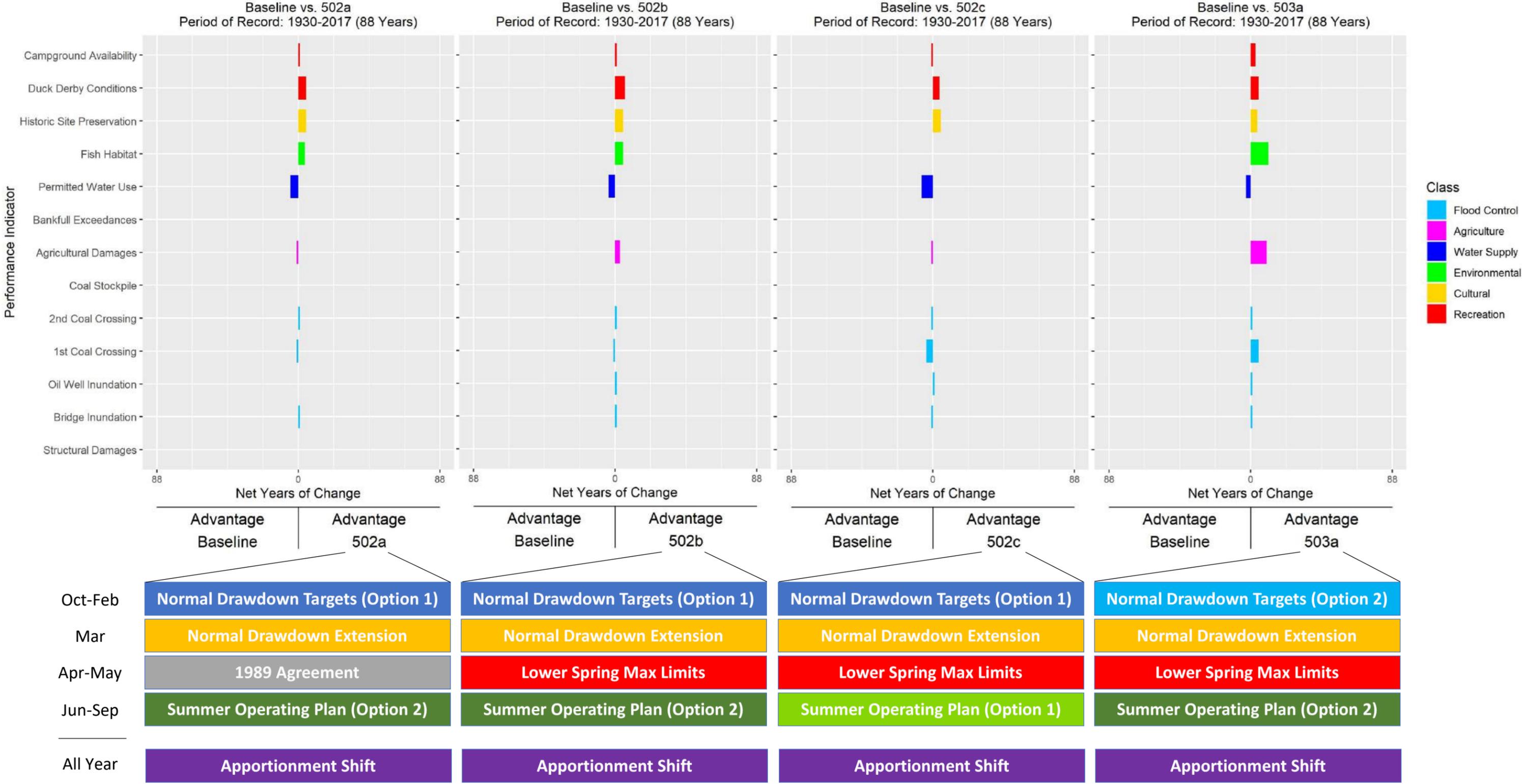
Phase 5 Alternatives vs. Baseline PI Comparison

Rafferty Reservoir



	Baseline vs. 502a Period of Record: 1930-2017 (88 Years)		Baseline vs. 502b Period of Record: 1930-2017 (88 Years)		Baseline vs. 502c Period of Record: 1930-2017 (88 Years)		Baseline vs. 503a Period of Record: 1930-2017 (88 Years)	
	Advantage Baseline	Advantage 502a	Advantage Baseline	Advantage 502b	Advantage Baseline	Advantage 502c	Advantage Baseline	Advantage 503a
Oct-Feb	Normal Drawdown Targets (Option 1)		Normal Drawdown Targets (Option 1)		Normal Drawdown Targets (Option 1)		Normal Drawdown Targets (Option 2)	
Mar	Normal Drawdown Extension							
Apr-May	1989 Agreement		Lower Spring Max Limits		Lower Spring Max Limits		Lower Spring Max Limits	
Jun-Sep	Summer Operating Plan (Option 2)		Summer Operating Plan (Option 2)		Summer Operating Plan (Option 1)		Summer Operating Plan (Option 2)	
All Year	Apportionment Shift		Apportionment Shift		Apportionment Shift		Apportionment Shift	

Phase 5 Alternatives vs. Baseline PI Comparison Saskatchewan Riverine Reaches



Phase 5 Alternatives vs. Baseline PI Comparison

North Dakota Riverine Reaches

