Appendix C-3: Alternative 305

Summer Floods

HEC-ResSim Alternative Assessment

Table of Contents

Figures

Tables

Plates

1. Alternative Description & Objective

Annex A of the International Agreement (Canada and USA, 1989), as it is currently written, does not adequately address how Canada and the United States should cooperatively manage large summer rainfall events. The current operations for the summer months, specified in Annex A, limit flows to a maximum of 400 cfs (11 cms) at Sherwood Crossing and 500 cfs (14 cms) at Minot. Additionally, each reservoir has a maximum allowable flood level (MAFL), or maximum pool elevation, that cannot be exceeded without endangering the structural integrity of the dam. This puts reservoir operators in a bind when operating for particularly large storms that threaten to push a reservoir's pool elevation above its MAFL. In this scenario, common sense would dictate that operators prioritize dam safety over the flow limits at Sherwood or Minot, but there is currently no agreement included in Annex A for how to balance these conflicting priorities during larger summer rain events. Additionally, there is no agreement for how to operate the reservoirs for flood mitigation during large summer storms.

Alternative 305 explores what a future agreement on summer rain operations for flood mitigation may look like. Summer is defined here as running from June 1st through August 31st. Alternative 305 builds off of work that was conducted as part of Alternative 11 in Phase 2, which also explored potential summer rainfall operations.

The Plan Formulation Committee (PFC) decided to carry forward Alternative 11 from Phase 2 to Phase 3 at their May 2019 face-to-face meeting. The PFC was especially interested in expanding on the summer rainfall operations research to include a sensitivity analysis on the operations set developed in Alternative 11. In particular, the PFC wanted to "evaluate the period of record to assess dry/normal/wet conditions & summer operations; define operating rules considering seasonality, elevation triggers, and allowable flow quantities; and assess how frequently the operating plan works" (May 2019 PFC Meeting).

1.1 Alternative Development

The foundation of the operations set developed in Alternative 11 of Phase 2 was the addition of "trigger elevations" in between the full supply levels (FSL) and the MAFLs of the basin's three largest reservoirs, Rafferty, Grant Devine, and Lake Darling. Once a reservoir's pool elevation surpassed a trigger elevation, a flow limit at a downstream flow constraint would be raised so that the reservoir would be allowed to release more water; outflows from a reservoir would increase until its pool rose to MAFL, at which point no release constraints would be applied. The basis of the operations set developed in Alternative 11 was carried forward into the modeling of Alternative 305.

Originally, Alternative 305 had three variants, 305a, 305b, and 305c, that each focused on implementing summer operations at just one reservoir, Rafferty, Grant Devine, and Lake Darling, respectively. At the July face-to-face modeling workshop, after discussing preliminary results from these three alternative variants, the modeling team for Phase 3 decided that this alternative would provide more useful information if all three of the reservoirs had a summer operations set in the same variant. From this, variant 305d was conceived. The rest of this appendix focuses solely on 305d.

Variant 305d was modeled using three different sets of flow constraints for Minot and Sherwood, for a total of three iterations. The different sets were created to allow for highly, moderately, and less aggressive releases from each of the reservoirs. Flow constraints at Sherwood were set to mirror flow

constraints at Minot by a factor of 80%, based on the 400 to 500 cfs ratio currently specified in Annex A. Table 1 summarizes the summertime downstream flow constraints at Sherwood under the highly, moderately, and less aggressive scenarios; Rafferty and Grant Devine were programmed to operate their elevation thresholds for these flow constraints, and those corresponding thresholds are also included in the table.

Table 1. Elevation thresholds at Rafferty and Grant Devine

Elevation Thresholds				**Flow Constraints at Sherwood**					
Rafferty Reservoir		**Grant Devine Reservoir**		**Highly Aggressive**		**Moderately Aggressive**		**Less Aggressive**	
(ft)	(m)	(ft)	(m)	(cfs)	(cms)	(cfs)	(cms)	(cfs)	(cms)
1817.6	554.0	1860.2	567.0	MAFL, No Outflow Constraints, Inflow = Outflow					
1815.9	553.5	1857.9	566.3	8000	227	8000	227	4000	227
1814.3	553.0	1855.5	565.6	6000	113	4000	113	3000	113
1812.7	552.5	1853.2	564.9	4000	79	2000	68	2000	57
1811.0	552.0	1850.8	564.1	2000	57	1200	45	1000	34
1809.4	551.5	1848.5	563.4	1600	45	1000	34	800	28
1807.7	551.0	1846.1	562.7	800	34	800	23	600	17
1806.1	550.5	1843.8	562.0	FSL, Sherwood Flow Constraint = 400 cfs or 11 cms					

Similarly, Table 2 summarizes the summertime downstream flow constraints at Minot under the highly, moderately, and less aggressive scenarios; Lake Darling's elevation thresholds operate for these flow constraints, which are also included in the table.

Table 2. Elevation thresholds at Lake Darling

Lake Darling Elevation Thresholds		**Highly Aggressive**		**Moderately Aggressive**		**Less Aggressive**	
(ft)	(m)	(cfs)	(cms)	(cfs)	(cms)	(cfs)	(cms)
1601.0	488.0	MAFL, No Reservoir Outflow Constraints, Inflow = Outflow					
1600.5	487.8	10000	283	10000	283	10000	283
1600.0	487.7	5000	142	5000	142	5000	142
1599.5	487.5	3500	99	3000	85	2500	71
1599.0	487.4	2500	71	2000	57	1500	42
1598.5	487.2	2000	57	1500	42	1250	35
1598.0	487.1	1500	42	1000	28	750	21
1597.5	486.9	500	14	500	14	500	14
1597.0	486.8	FSL, Minot Max = 500 cfs or 14 cms					

Initial results from Alternative 305 suggested that the Sherwood flow constraint may not be the limiting factor restricting outflows from Rafferty and Grant Devine. To test this, three additional iterations were created with the flow constraints at Estevan and below Grant Devine virtually removed for the summer months and for reservoir elevations above FSL. Aside from this rule change, these three iterations are copies of the highly, moderately, and less aggressive scenarios. It should be noted that this was done simply as a knowledge-seeking exercise. Completely removing the flow constraints at Estevan and below Grant Devine is not a viable alternative being explored by the study team.

1.2 HEC-ResSim Nomenclature

A total of 6 iterations of Alternative 305d were created within HEC-ResSim. Table 3 outlines the nomenclature associated with each iteration of this alternative within the ResSim model, including the scenario name, time window, simulation name, etc. The "H", "M", and "L" at the end of the alternative names stand for "highly", "moderately", and "less" aggressive, respectively, for the three different flow regimes. The "Y" and the "N" stand for "Yes, Estevan and Grant Devine flow constraints" and "No Estevan and Grant Devine flow constraints", respectively, during the summer months for the two different rule sets. Alternative 305d's iterations, and the corresponding changes to the model for each iteration, are described further in Section 2 of this appendix.

Table 3. The nomenclature of model parameters used for Alternative 305d

Scenario	Time Window	ResSim Model Name	Network Name	Alternative Name(s)*	Simulation Name
Baseline	1930-2017	SourisRiverPoS	Base	BL_Norm	1930-2017_BL-1
Summer Rain Operations (305d)	1930-2017	SourisRiverPoS	Base	HH1305d_HY HH1305d_MY HH1305d_LY HH1305d_HN HH1305d_MN HH1305d_LN	HH1_305d_POR2

2. Operational Rules

Running Alternative 305d required making several changes to the script and the reservoir operating rules for each iteration. Table 4 summarizes the changes made to the model's operational rules for each iteration. Section 2.1 discusses changes made to the state variable, "a_fld_MASTER_gc_gd", in greater detail. Sections 2.2, 2.3, and 2.4 discuss changes made to the operational rules at Rafferty, Grant Devine, and Lake Darling, respectively, in greater detail.

Table 4. Summary of rule changes made for each iteration of Alternative 305d

Name of Dam	Name of Rule, IF Statement, Zone, or State Variable Element	Rule Description	Affected Iterations
Rafferty Reservoir	ds_sherwood_sv	Maximum allowable flow at Sherwood, ND	All
	ds_EstevanMax-1	Maximum allowable flow at Estevan, SK	HH1305d_HN HH1305d_MN HH1305d_LN
Boundary Reservoir*	ds_sherwood_sv	Maximum allowable flow at Sherwood, ND	All
	ds_EstevanMax-1	Maximum allowable flow at Estevan, SK	HH1305d_HN HH1305d_MN HH1305d_LN
Grant Devine Reservoir	ds_sherwood_sv	Maximum allowable flow at Sherwood	All
	MaxReleasesGD_Dam	Maximum allowable releases from Grant Devine Dam	HH1305d_HN HH1305d_MN HH1305d_LN
Lake Darling Reservoir	DS_Minot_sv	Maximum allowable flow at Minot, ND	All
	Flood Control	Flood control zone	All
	MAFL	MAFL zone	All

**Note: Because Boundary Reservoir operates for Estevan and Sherwood in the same way Rafferty Reservoir does, the two rule changes applied to Rafferty also apply to Boundary.*

2.1 Changes to the "a_fld_MASTER_gc_gd" Script

Reprogramming the three major reservoirs to operate under 305d's summer operations scheme needed to be done within the state variable "a_fld_MASTER_gc_gd" script. In particular, the logic that directs each reservoir to hold its maximum outflow limit until it returns to FSL could only be programmed into the state variable. Figure 1 shows the changes made to the "Initialization" portion of the "a_fld_MASTER_gc_gd" script. Figure 2 shows changes made to the "Main" portion of the script to set summer operations to always start on June 1st. Figure 3 and Figure 4 show the changes made to the script that create trigger elevations at Rafferty and Grant Devine for raising and resetting the downstream flow constraint at Sherwood. Figure 5 and Figure 6 show the changes made to the script that create trigger elevations at Lake Darling for raising and resetting the downstream flow constraint at Minot.

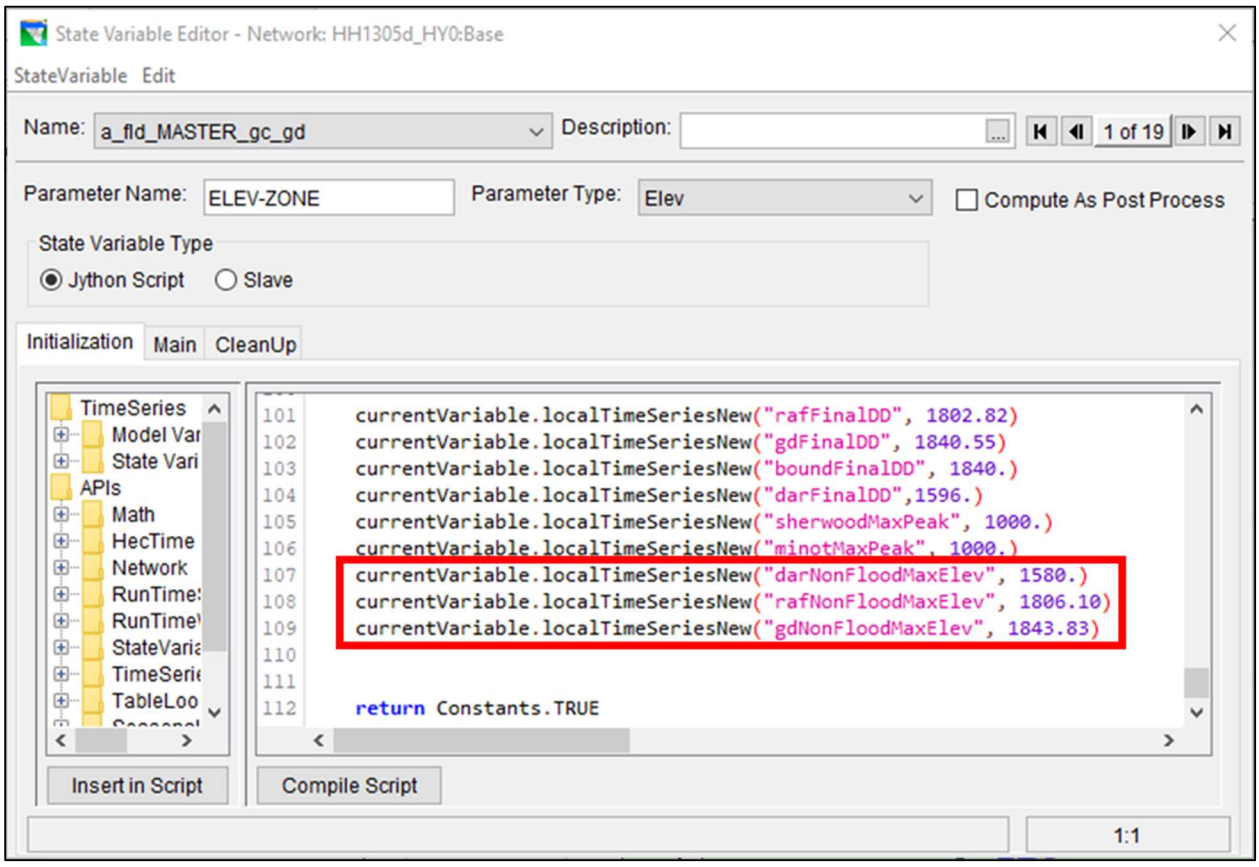


Figure 1. Additions to the "Initialization" portion of the "a_fld_MASTER_gc_gd" script

**Note: This same addition was made to the scripts of all six iterations of Alternative 305d. This portion of the script loads the variables "darNonFloodMaxElev", "rafNonFloodMaxElev", and gdNonFloodMaxElev" into the model and gives each of them initial values.*

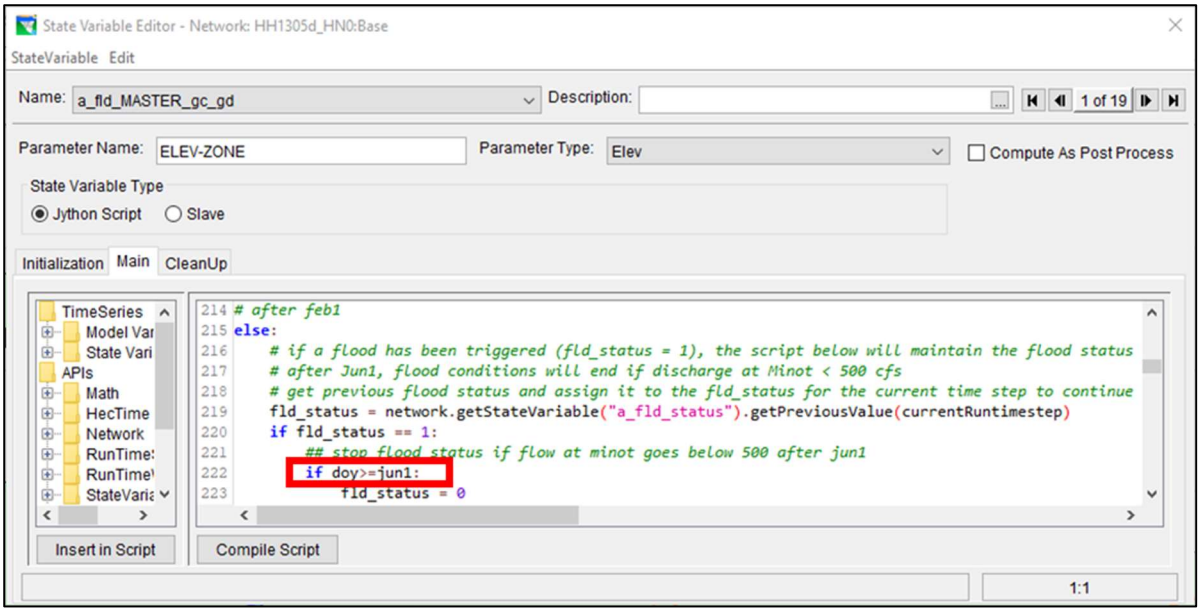


Figure 2. Changes made to the script to set summer operations to always start on June 1st

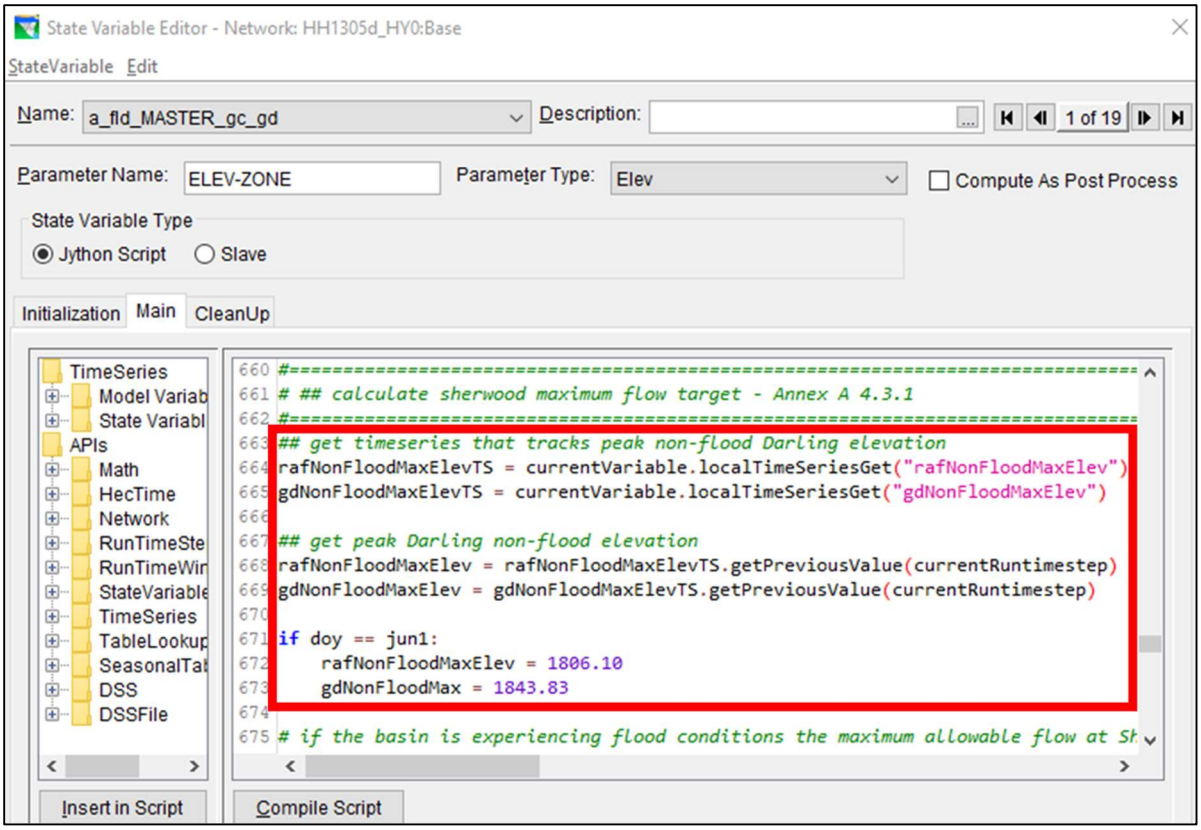


Figure 3. Additions to the "Main" portion of the "a_fld_MASTER_gc_gd" script

**Note: This same addition was made to the scripts for all six iterations of Alternative 305d. This portion of the script tracks the "peak non-flood elevations" at Rafferty and Grant Devine reservoirs. This is necessary for summer operations and for starting these operations on June 1st each year.*

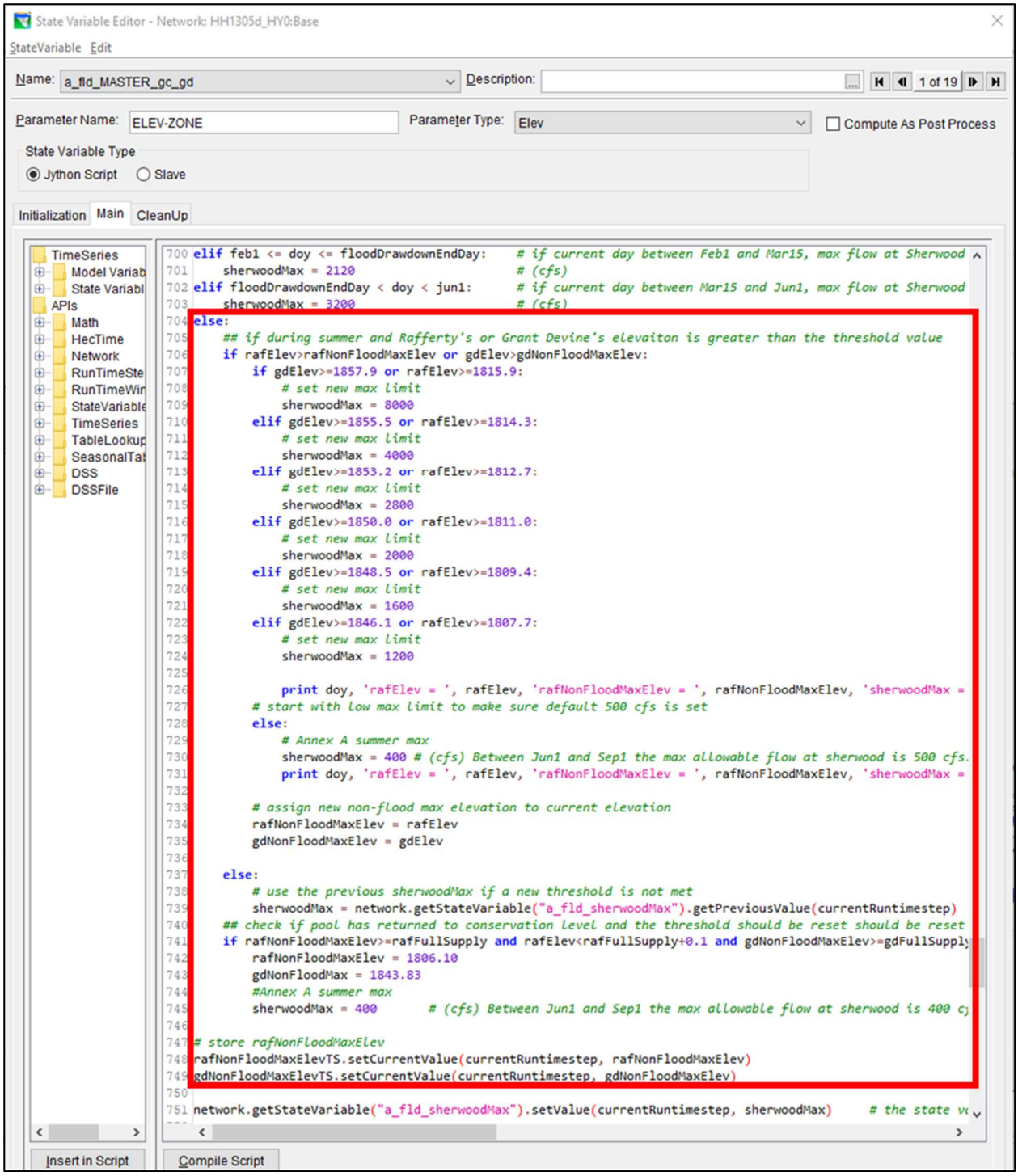


Figure 4. Additions to the "Main" portion of the "a_fld_MASTER_gc_gd" script

**Note: The example shown is for iteration "HH1305d_HY", but essentially the same addition was made to the scripts for all six iterations of Alternative 305d, with the only difference being the values following each of the "sherwoodMax = " elements. This portion of the script sets the elevation thresholds, and corresponding maximum flow constraints at Sherwood, for Rafferty and Grant Devine reservoirs. It also sets the start date of these operations to be June 1st. (Only the left half of the screen is shown for legibility).*

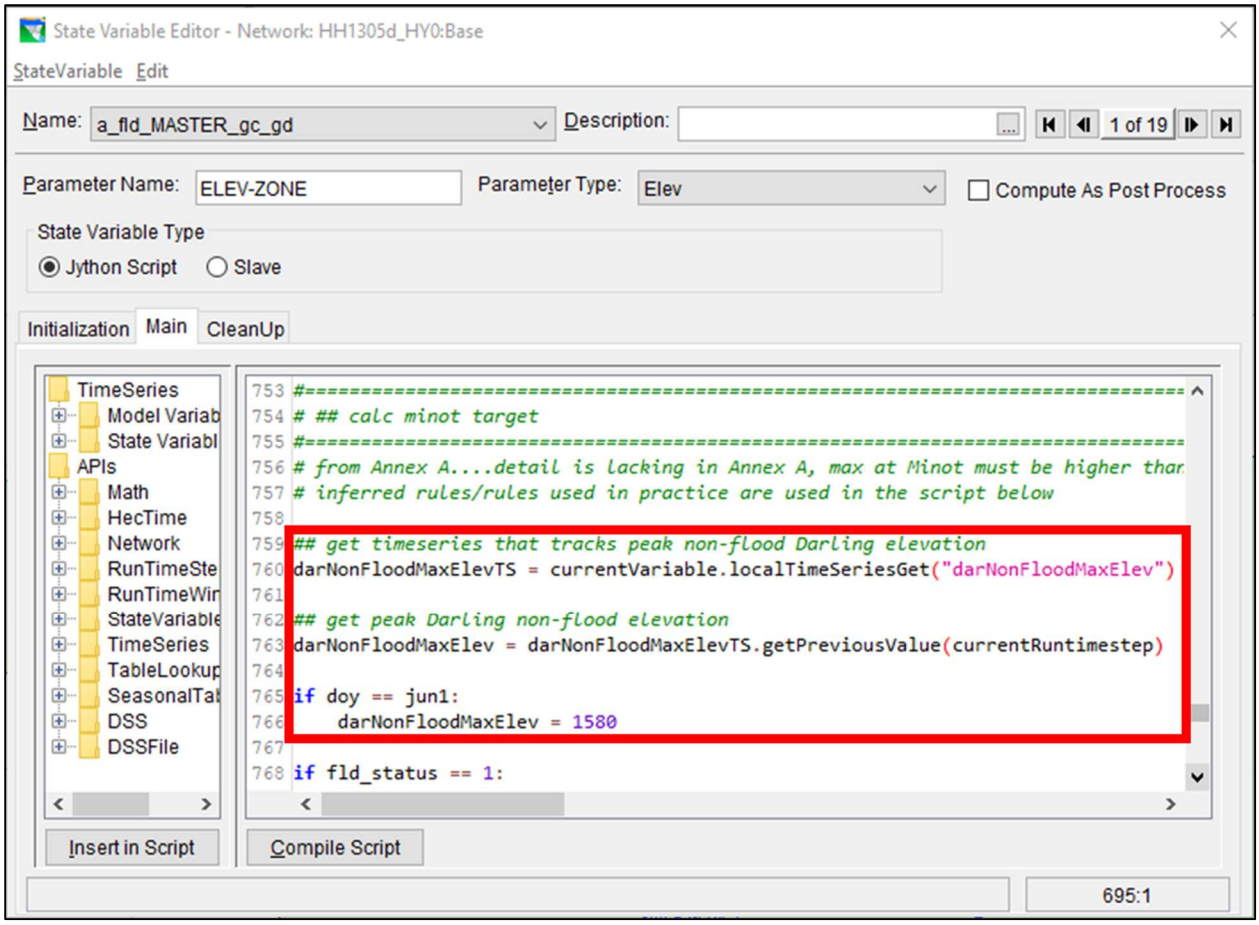


Figure 5. Additions to the "Main" portion of the "a_fld_MASTER_gc_gd" script

**Note: This same addition was made to the scripts for all six iterations of Alternative 305d. This portion of the script tracks the "peak non-flood elevation" at Lake Darling. This is necessary for summer operations and for starting these operations on June 1st every year.*

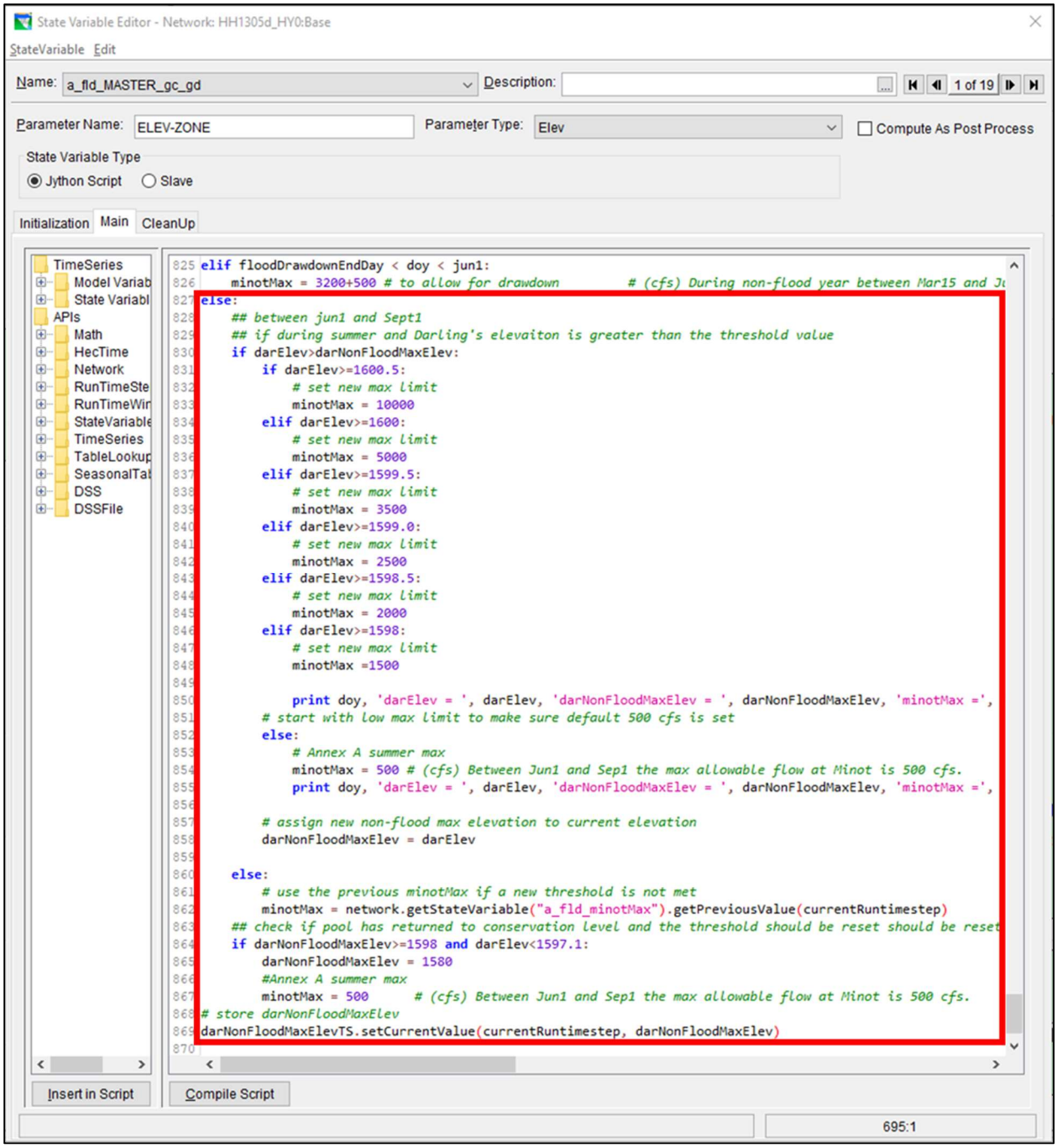


Figure 6. Additions to the "Main" portion of the "a_fld_MASTER_gc_gd" script

**Note: The example shown is for iteration "HH1305d_HY", but essentially the same addition was made to the scripts for all six iterations of Alternative 305d, with the only difference being the values following each of the "minotMax = " elements. This portion of the script sets the elevation thresholds, and corresponding maximum flow constraints at Minot, for Lake Darling. It also sets the start date of these operations to be June 1st. (Only the left half of the screen is shown for legibility).*

2.2 Changes to Operating Rules at Rafferty

At Rafferty Reservoir, for iterations “HH1305d_HN”, “HH1305d_MN”, and “HH1305d_LN”, the rule setting the maximum downstream flow constraint at Estevan was changed to essentially eliminate the constraint during the summer months when Rafferty’s pool elevation is within its flood control zone. Figure 7 shows how this operational rule change appears in ResSim’s “Reservoir Editor” window.

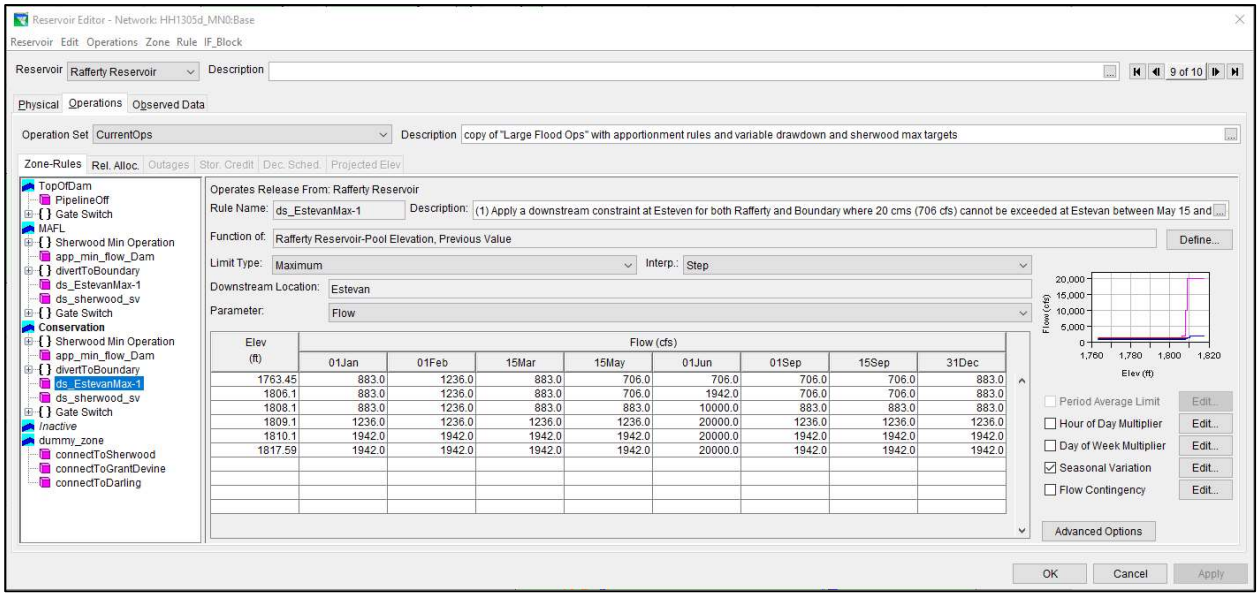


Figure 7. Rafferty Reservoir’s operation set

The operation set shown above includes changes made to the operating rule “ds_EstevanMax-1” for iterations “HH1305d_HN”, “HH1305d_MN”, and “HH1305d_LN”. To create this rule change, two columns were added to the table dictating releases from Rafferty, one for June 1 and another for September 1. The column for June 1 essentially eliminates the flow constraint at Estevan, SK when Rafferty Reservoir’s pool elevation rises above FSL. The column for September 1 reinstates the original flow constraints to continue after the summer months. This change was not made for the other three 305d iterations.

2.3 Changes to Operating Rules at Grant Devine

Similar to the changes made to Rafferty's operations set, for iterations "HH1305d_HN", "HH1305d_MN", and "HH1305d_LN," the rule setting the maximum downstream flow constraint at Grant Devine was changed to essentially eliminate the constraint during the summer months when Grant Devine's pool elevation is within its flood control zone. Figure 8 shows how this operational rule change appears in ResSim's "Reservoir Editor" window.

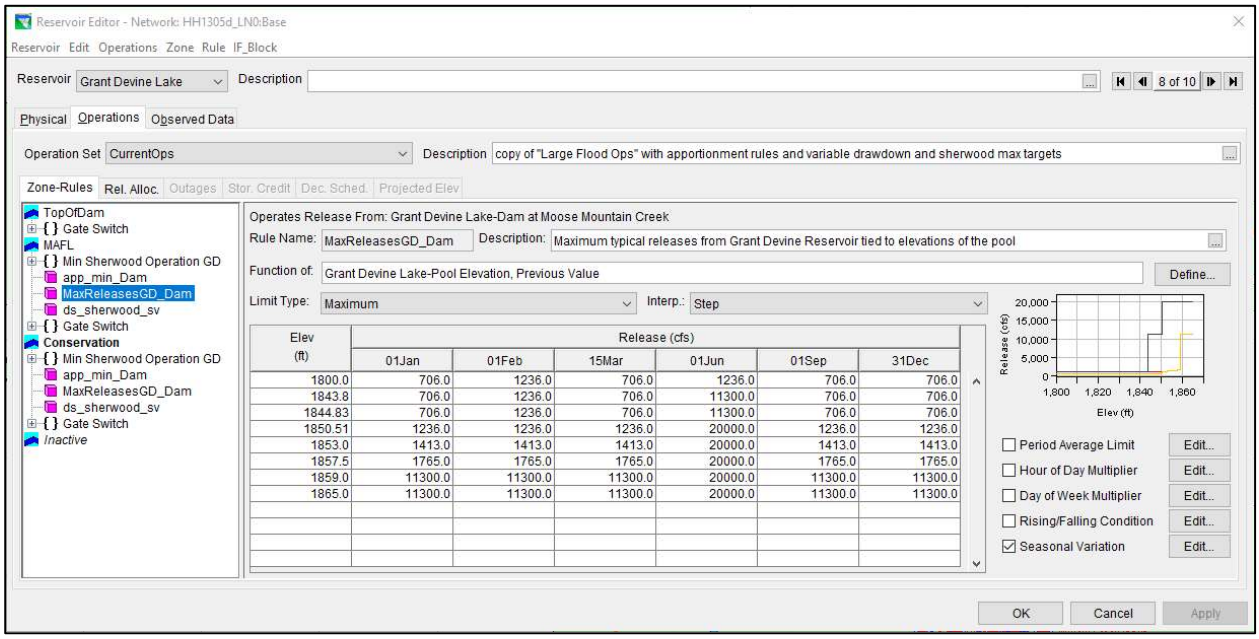


Figure 8. Grant Devine Reservoir's operation set

The operation set shown above includes changes made to the operating rule "MaxReleasesGD_Dam" for iterations "HH1305d_HN", "HH1305d_MN", and "HH1305d_LN". To create this rule change, two columns were added to the table dictating releases from Grant Devine, one for June 1st and another for September 1. Additionally, a row was added for Grant Devine's FSL elevation. The column for June 1 essentially eliminates the flow constraint downstream from Grant Devine when its pool elevation rises above FSL. The column for September 1 reinstates the original flow constraints to continue after the summer months. These changes were not made to the other three alternative 305d iterations.

2.4 Changes to Operating Rules at Lake Darling

In the baseline's operation set, Lake Darling's "Flood Control" zone is lowered from 1600.999 ft to 1598 ft from June 1 through December 31. Under this operation set, Lake Darling's summer flood control operations, as defined in alternative 305d, would never go into effect. To change this, the "MAFL" zone was eliminated from Lake Darling's operation set and the top elevation for the "Flood Control" zone was set to be 1601 ft year round. Figure 9 shows how this operational rule change appears in ResSim's "Reservoir Editor" window.

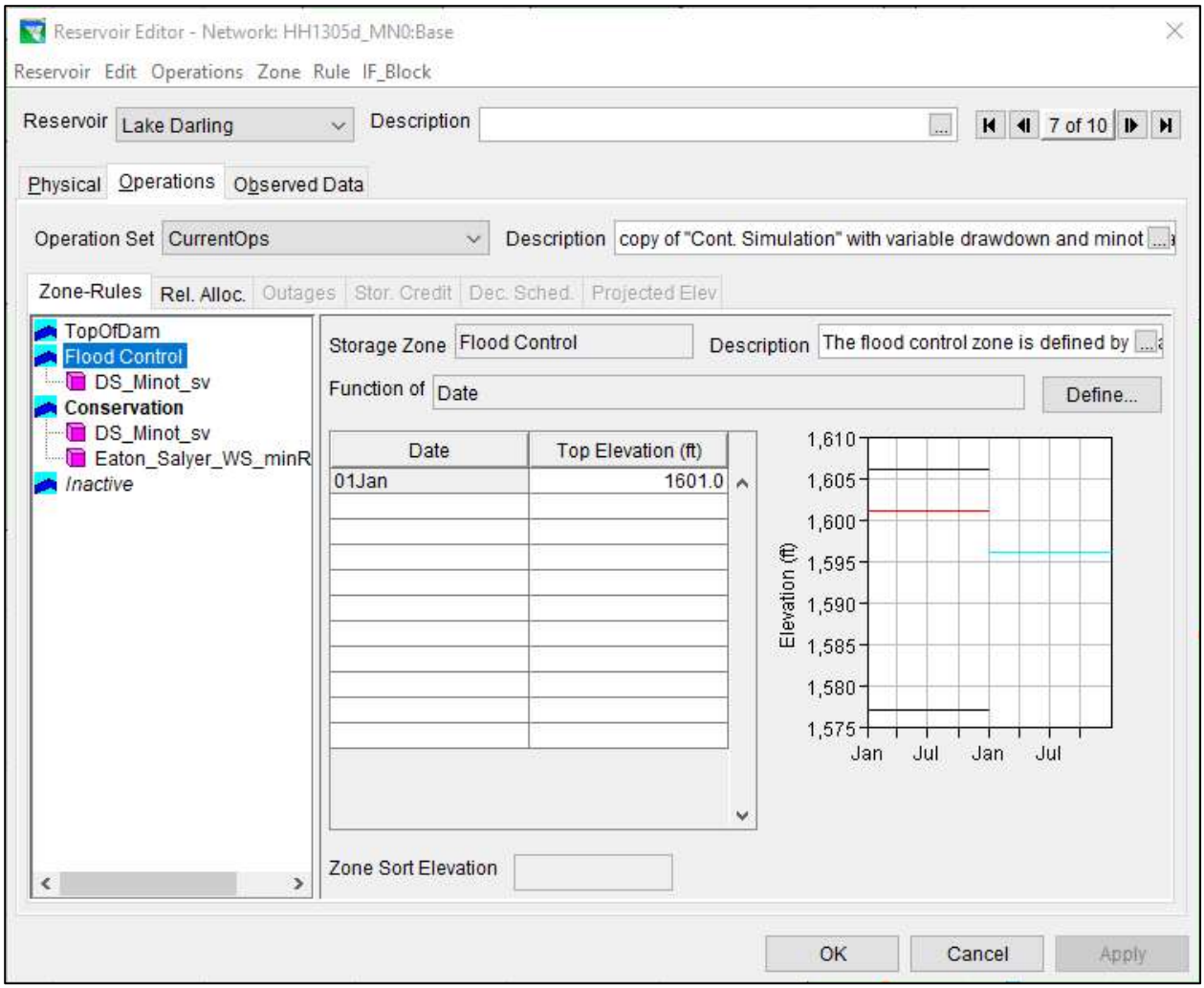


Figure 9. Lake Darling's operation set for all iterations of Alternative 305d

3. Alternative vs Baseline Condition Results

Plates 01-08 show hydrographs detailing the results of Alternative 305d relative to the baseline scenario at Rafferty, Boundary, Grant Devine, and Lake Darling reservoirs, as well as seven critical mainstem flow locations, for 1976, 2011, 2013, and 2014. Since this alternative is concerned with summer operations, the plots only show the months of May through September.

For scenario 305d, although 6 different runs were completed, only 2 are plotted, the least aggressive release scenario and most aggressive release scenario in which the flow constraints at Estevan and Grant Devine remain unchanged (HH1305d_LY and HH1305d_HY). The two simulations, when compared to the baseline, show the range of results for the alternative. Since removing the Estevan and Grant Devine flow constraints was experimental, results for those simulations are not plotted.

Plate 09 displays performance indicator results for all study reaches over the entire simulation (1930-2017) for simulations HH1305d_LY and HH1305d_HY. More information regarding performance indicator (PI) results and PI development can be found in the Data Collection for the Analysis of Alternatives Report (DW4) and Appendix A-5.

4. Summary of Results

4.1 Iterations HH1305d_HY, HH1305d_MY, and HH1305d_LY

Operations at Rafferty and Grant Devine remain unchanged, relative to the baseline, in all years aside from 1974, 1975, 1976, 2013 and 2014. In 2014, the pool at Grant Devine is able to return to FSL faster in all three iterations without increasing peak outflow, but while increasing the duration of peak flows. No other event appears to be large enough to see significant benefits or drawbacks from the summer operations set at either reservoir. Reducing the flow at Sherwood to below 400 cfs (11 cms) at the lowest threshold may offer greater benefits for these events, and should be looked at in future phases.

Operations at Lake Darling differ from the baseline in 1953 and 2011, in addition to the same years operations differ at the Canadian reservoirs. Peak flows during the 2011 event remain unchanged, as Lake Darling's pool still reaches MAFL in all three iterations, but the pool is able to drop back below MAFL sooner as well. Peak flows are reduced significantly at Minot in 2014 in all three iterations, by at least 1,500 cfs (42 cms). Results for the late spring events in 1974, 1975, and 1976 are mixed, with reduced peak outflows with longer durations in some years, and higher peak outflows with reduced durations in others. Similarly to the Rafferty and Grant Devine, greater benefits may be seen if outflows at the lower thresholds are reduced to below 500 cfs (14 cms); this will be explored in phase 3.5.

4.2 Iterations HH1305d_HN, HH1305d_MN, and HH1305d_LN

Contrary to the initial results from variants 305a, 305b, and 305c, completely lifting the flow constraints at Estevan and below Grant Devine does not appear to give beneficial results when summer operations are implemented at all three major reservoirs, as in variant 305d. The 2011 event is the only summer storm in the period of record where this change appears especially significant.

Contradictory to what was initially expected when including these three iterations in the model, peak flows from Rafferty and Grant Devine increased compared the baseline and the three iterations that kept the downstream flow constraints as they were. The modeler's initial thoughts were that, by allowing each reservoir to make larger releases over a longer period of time, it would be less likely that

pool elevations would approach MAFL. As mentioned earlier, when a reservoir's pool elevation exceeds MAFL, the reservoir is required to release inflow. Reducing the likelihood of a pool elevation approaching MAFL may be beneficial for this reason, but this strategy was not effective in doing so.

Due to the larger releases from Rafferty and Grant Devine, higher peak flows at Sherwood and into Lake Darling are seen for the 2011 event. Interestingly though, peak flows at Minot are decreased by approximately 1000 cfs (28 cms). Perhaps a less extreme lifting of the Estevan and Grant Devine flow constraints would be beneficial, but completely lifting them does not appear to be.

4.3 Performance Indicators

Inspection of the HEC-ResSim results indicate the modeled alternative only results in significant changes to reservoir pool elevations or river flows during large, summer flood events, which are rare in the historic record (1930-2017). The performance indicator (PI) plots, which show PI results for the period 1930-2017, validate this by showing change in a very limited number of years.

To understand how the operational changes implemented in this alternative impact PIs during summer flood events, the technical team analyzed PI results on a yearly basis for each reach. The following sections describe the trends observed while carrying out this analysis. While plots showing PI results on a yearly basis are not shown in this report, they may be supplied upon request.

4.3.1 Reservoirs

PIs do not show significant change from baseline at Rafferty or Grant Devine. At Boundary, the reservoir's pool stays at MAFL for slightly longer in some years, resulting in a slight increase in the Permitted Water Use indicator and a slight decrease in the MAFL indicator under both the least aggressive (305dLY) and most aggressive (305dHY) flow regime.

At Lake Darling, the reservoir generally stays above FSL for a longer period of time relative to the baseline during years with late spring or summer flood events under both the least aggressive (305dLY) and most aggressive (305dHY) flow regime. This leads to more frequent flood operations at Mouse River Park, which occurs when Lake Darling is above 1597.5 ft (486.9 m). This is expected, since Lake Darling is programmed to let its pool rise during the summer months, using storage to attenuate summer rain events. The Lake Darling hydrograph in 2013 clearly demonstrates this operation. For the same reason, the Historic Site Preservation PI shows more archaeological sites being inundated in the alternative, and the Boating & Fishing Access PI shows boating access points being inundated for longer periods.

4.3.2 Riverine Reaches

Since Rafferty and Boundary reservoirs were not impacted by the 2014 summer rain event, the PIs for the riverine reaches upstream of the confluence with Moose Mountain Creek show very limited change from baseline. The only PI showing noticeable change is the Fish Habitat PI at Estevan, which shows positive change. This indicates Rafferty Reservoir stays slightly higher for a longer period of time throughout the summer, prolonging releases that support fish habitat through the city. Downstream of Moose Mountain Creek, slightly reduced peak flows during the summer lead to slightly improvements to the Agricultural Damages PI.

In North Dakota, the alternative summer operation results in slight reductions in structural and agricultural damages due to reduced peak flow during large, summer flood events. An example of this peak reduction can be seen in 2014. Other environmental, recreational, and water quality PIs also show improvement due to prolonged, low magnitude releases from the reservoirs following summer flood events.

In Manitoba, impacts to PIs are generally less due to the province's distance from the upstream, flood control reservoirs. One change of note is the negative impact to the Bankfull Exceedances PI in the 305dLY variant. This means flows are out of bank at Westhope, ND (above 600 cfs) for longer periods during the summer than they are in the baseline simulation. This is not the case in the 305dHY simulation, indicating the duration of flooding at Westhope is somewhat less during summer flood events when the 305dHY operations are implemented relative to the 305dLY operations.

5. Path Forward

At the August face-to-face meeting in Bismarck, ND, the Plan Formulation Committee decided to carry alternative 305 forward into Phases 3.5, 4, and 5. Phase 3.5 was proposed at the August meeting to conduct additional research on several alternatives prior to Phase 4. In Phase 3.5, Alternative 305 will be combined with Alternative 303, which examined potential summer operations with the goal of reduced agricultural damages. The current strategy for this combination being proposed by the PFC is to carry forward Alternative 305's summer operations strategy, but to limit flows to below 400 cfs (11 cms) at Sherwood and 500 fcs (14 cms) at Minot at the lower elevation thresholds within the 3 major reservoirs.

5.1 Additional Fine-Tuning Recommendations

Due to the short time window in between the July modeling workshop and the August face-to-face meeting, there are still some gaps in the model that should be worked out in future phases. Eliminating these gaps may improve the effectiveness of the summer operations plan.

5.1.1 Dampen Outflow Oscillations

Occasionally, the model will oscillate between two different reservoir outflows over several time steps. This does not happen frequently, nor does this appear to impact results significantly. In particular, this does not appear to happen during summer rainfall events, which this alternative is concerned with. Figure 10 shows an example of this behavior occurring. One potential solution may be increasing the number of computation iterations that ResSim cycles through when performing its calculations. Other solutions may include adding rate of increase and rate of decrease rules, smoothing calculated inflows, and decreasing the model's time step. However, many of these solutions would increase the model's run time significantly.

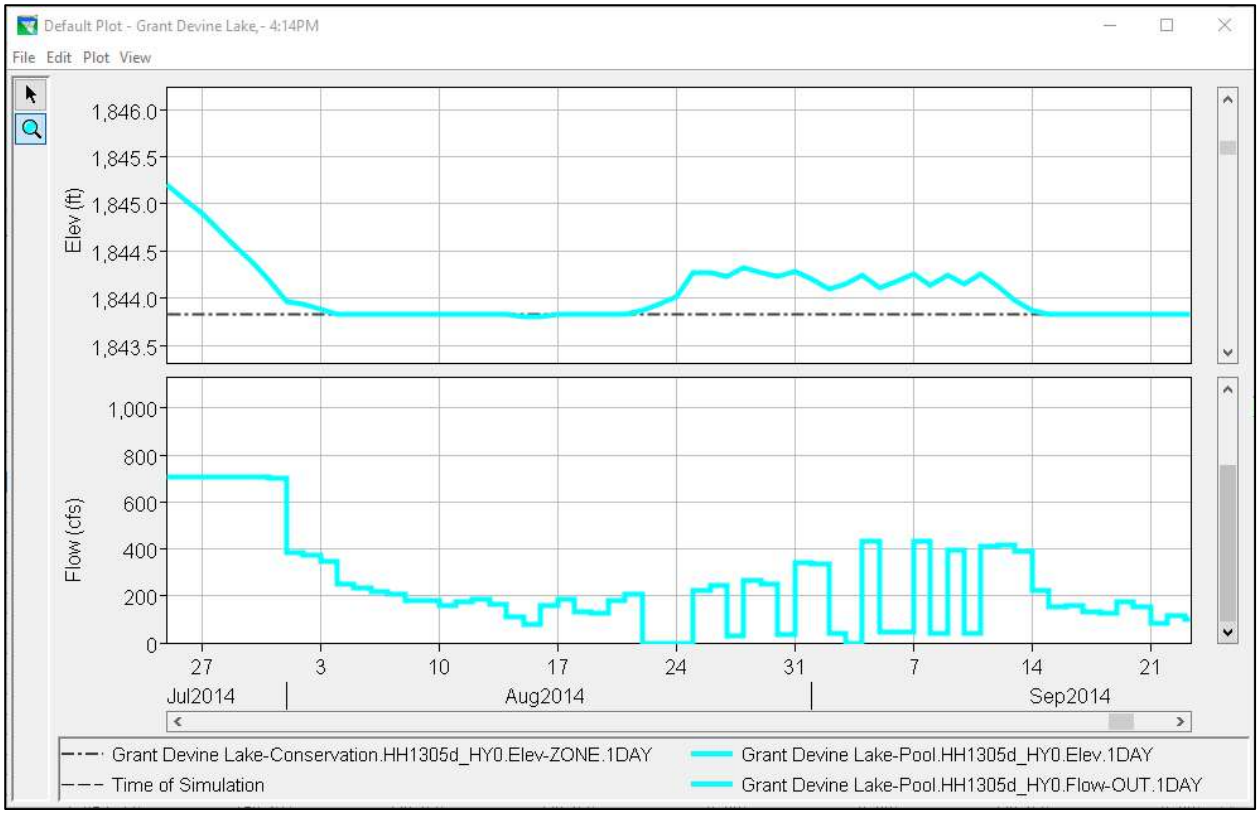


Figure 10. An example of outflows from Grant Devine oscillating

5.1.2 Dampen Drastic Changes in Reservoir Outflows and Max Flow Constraints

The current strategy for summer operations that is programmed into 305d is not particularly well suited for handling extended periods of high inflows. The 2011 event is one event where the summer ops strategy may need to be altered slightly to perform optimally. For example, in iterations "HH1305d_HY" and "HH1305d_HN", the maximum flow constraint is reset to 500 cfs (14 cms) several times when Lake Darling's pool elevation returns to approximately FSL. However, this occurs when Lake Darling is still receiving relatively high inflows. Lake Darling is behaving exactly how it is programmed to in 305d, but the reservoir's elevation and outflow vary wildly in this scenario. Figure 11 shows an example of this behavior occurring in iterations "…HY" and "…HN".

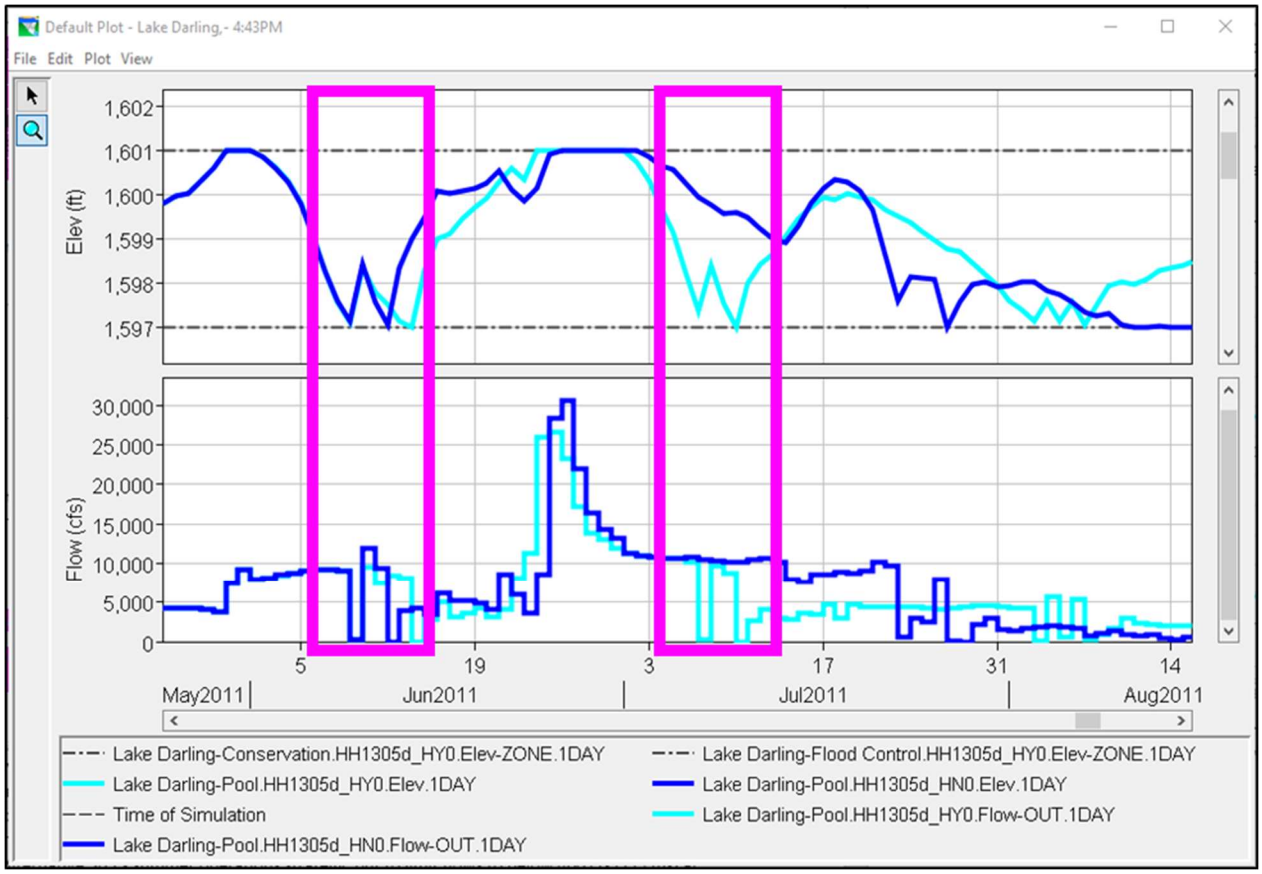


Figure 11. An example of large fluctuations in outflows from Lake Darling

One potential solution for this behavior may involve including rate of increase and rate of decrease rules in each reservoirs' operation set. Another solution may be taking inflow into account, not just the reservoir's pool elevation, when resetting its downstream flow constraint. Resetting the downstream flow constraint to a more moderate flow for a period, not immediately 500 cfs (14 cms), may be another solution. All of these strategies, and others, will be included in the modeling of summer operations in Phases 3.5 and 4.

5.2 Recommendations for Future Phases

The modeler for 305d has several recommendations for future Plan of Study work that examines summer operations.

5.2.1 Examine Potential for Other Triggers besides Pool Elevations

Determining the downstream flow constraints at Minot and Sherwood based on the pool elevations in Rafferty, Grant Devine, and Lake Darling certainly isn't the only possible summer operations strategy that could be modeled and implemented. It may be worthwhile to examine other strategies that mimic this one, but use another variable to base flow constraints on. Potential variables may include reservoir storage, the percentage of storage remaining, inflow to each reservoir, forecasted inflow, some combination of these with elevation, and others.

5.2.2 Examine Range of Potential Flow Constraints at Estevan and Below Grant Devine

As seen in a few events, not all, the downstream flow constraints at Estevan and below Grant Devine may be limiting the effectiveness of this summer operations strategy. This is particularly apparent at Rafferty Reservoir during the 2011 event, when iterations "…HY", "…MY", and "…LY" all gave the same results as the baseline simulation. At the August face-to-face meeting, the PFC asked the Saskatchewan Water Security Agency to examine the current flow constraints and to determine if they could be loosened to allow greater flows. The updated flow constraints have been provided to the Plan of Study team and will be included in the summer operations modeling conducted in Phases 3.5 and 4. The original flow constraints should also be included for comparison.

5.2.3 Test Summer Operations against Significant Stochastic Events

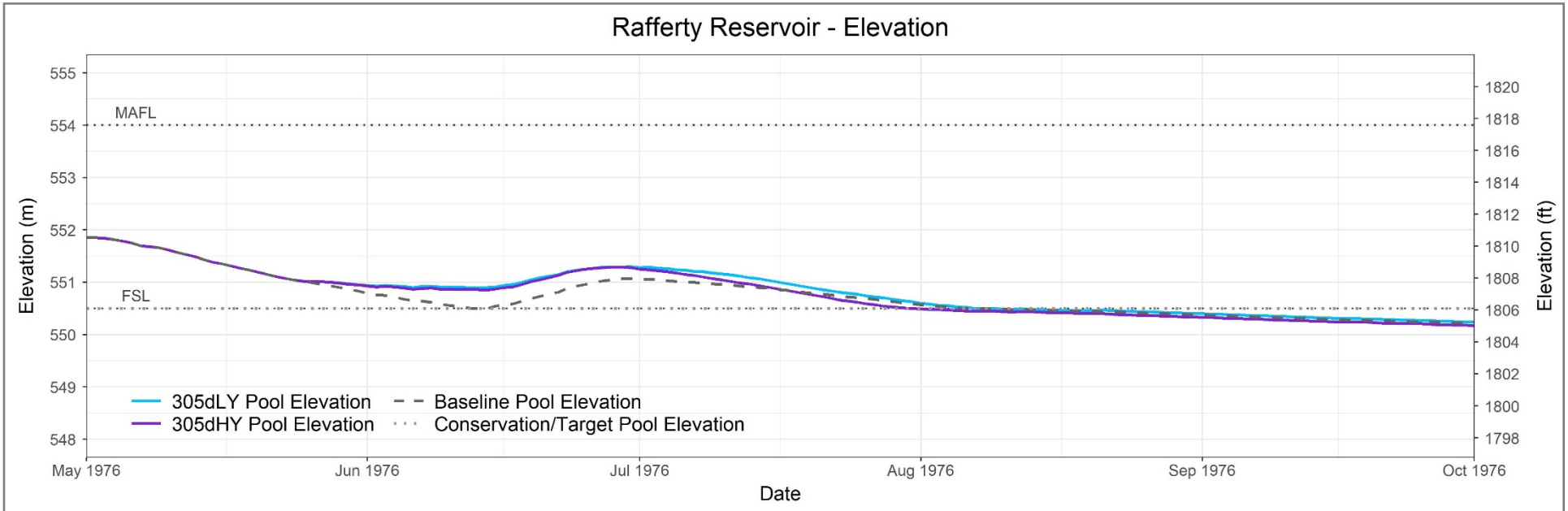
A key limitation to the modeling of Alternative 305 is the lack of intense, basin-wide summer rainfall events within the historic record. Currently, only the 2011, 2013, and 2014 summer events appear to fit this criteria. The 2011 event though occurred when the reservoir system was already stressed from a large spring snowmelt, making it difficult to judge how effective the summer operations would have been if the summer rain happened isolated from the spring snowmelt. The 2014 event too is limited in showing how effective the proposed summer operations are, as Rafferty was mostly unaffected by this event. The stochastic traces generated by the USGS may provide additional storms that the summer operations strategy could be tested against.

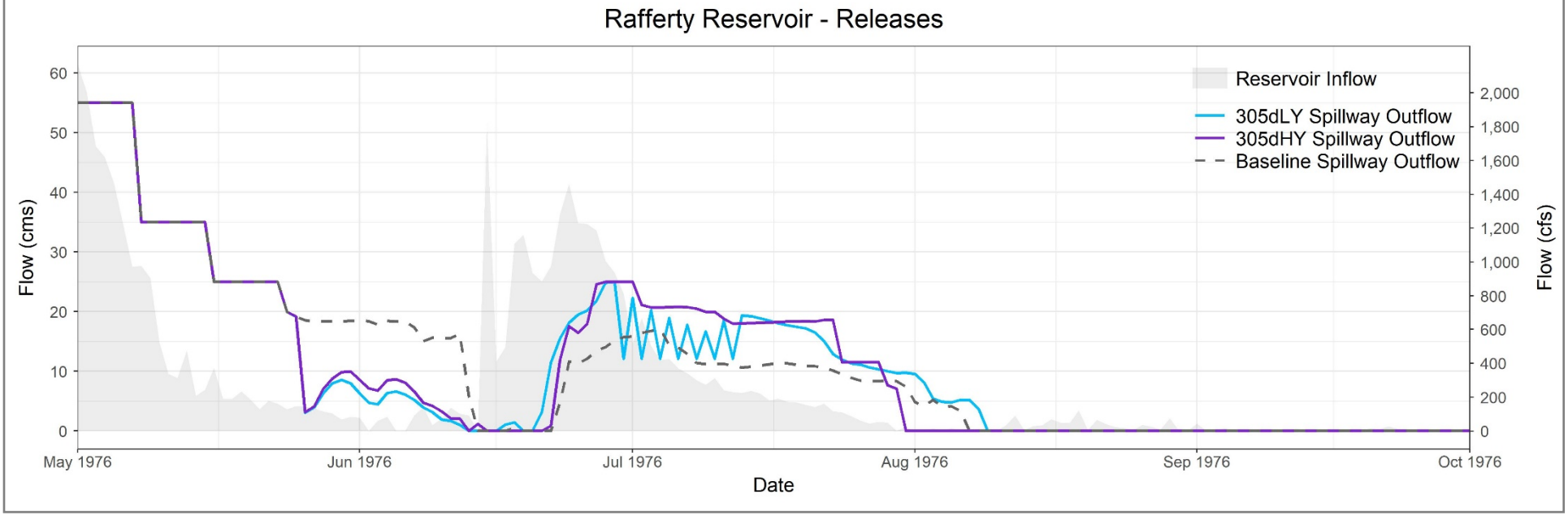
At the time the modeling for Alternative 305 was conducted, there were no summer storms within the currently available stochastic traces that were intense enough to test the summer operations strategy. Following the August face-to-face meeting, the USGS was asked to generate additional stochastic traces and to search those traces for storms that fall over the watersheds of all three major reservoirs and vary in intensity between the 2014 and 2011 storms. These new events will be tested in either Phases 3.5 or 4, depending on when they become available.

6. References

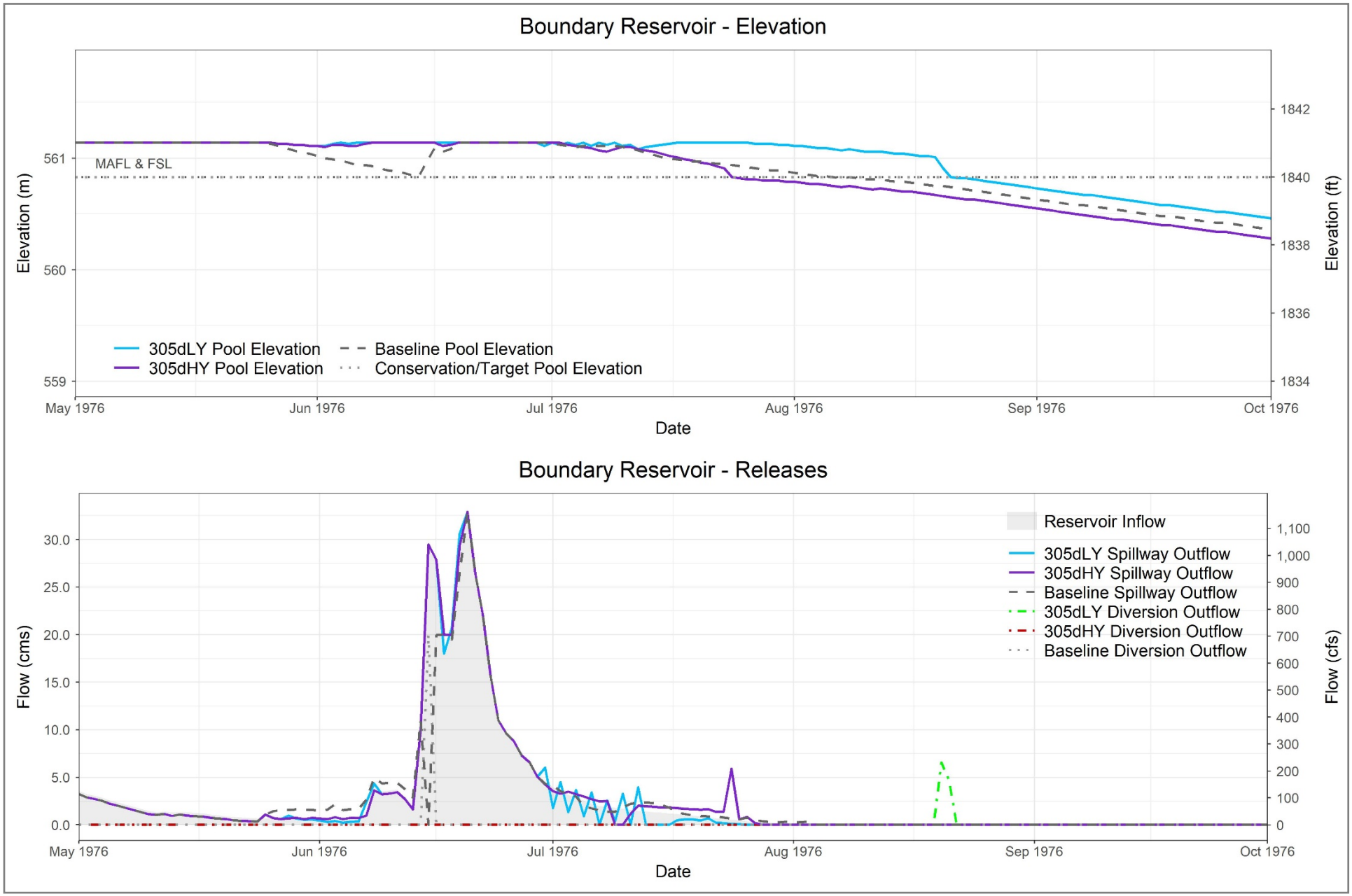
1. “HEC-DSSVue,” U.S Army Corps of Engineers, Hydraulic Engineering Center, February 2010.
2. “HEC-ResSim, Reservoir System Simulation, Version 3.3”, U.S Army Corps of Engineers, Hydraulic Engineering Center, December 2018.
3. Canada and USA, 1989. Agreement between the Government of Canada and the United States for Water Supply and Flood Control in the Souris River Basin.
4. Canada and USA, 2000. Interim Measures As Modified For Apportionment of the Souris River.

Plate 01	Reservoirs – 1976	Alternative 305 (Phase 3) Souris River Plan of Study



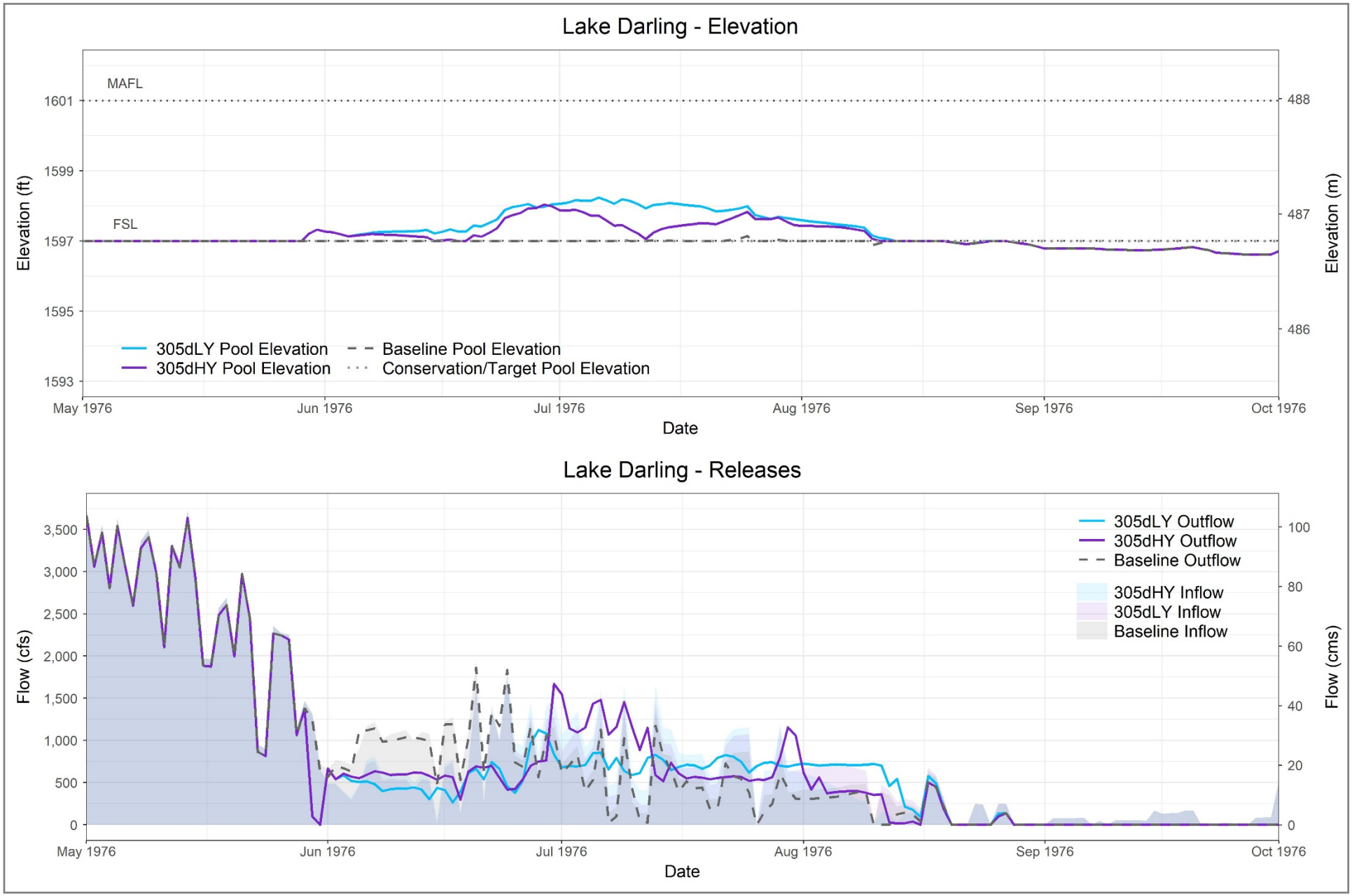


***305dLY** = Least aggressive releases (all flow constraints in place), **305dHY** = Most aggressive releases (all flow constraints in place)*



***305dLY** = Least aggressive releases (all flow constraints in place), **305dHY** = Most aggressive releases (all flow constraints in place)*

***305dLY** = Least aggressive releases (all flow constraints in place), **305dHY** = Most aggressive releases (all flow constraints in place)*



***305dLY** = Least aggressive releases (all flow constraints in place), **305dHY** = Most aggressive releases (all flow constraints in place)*

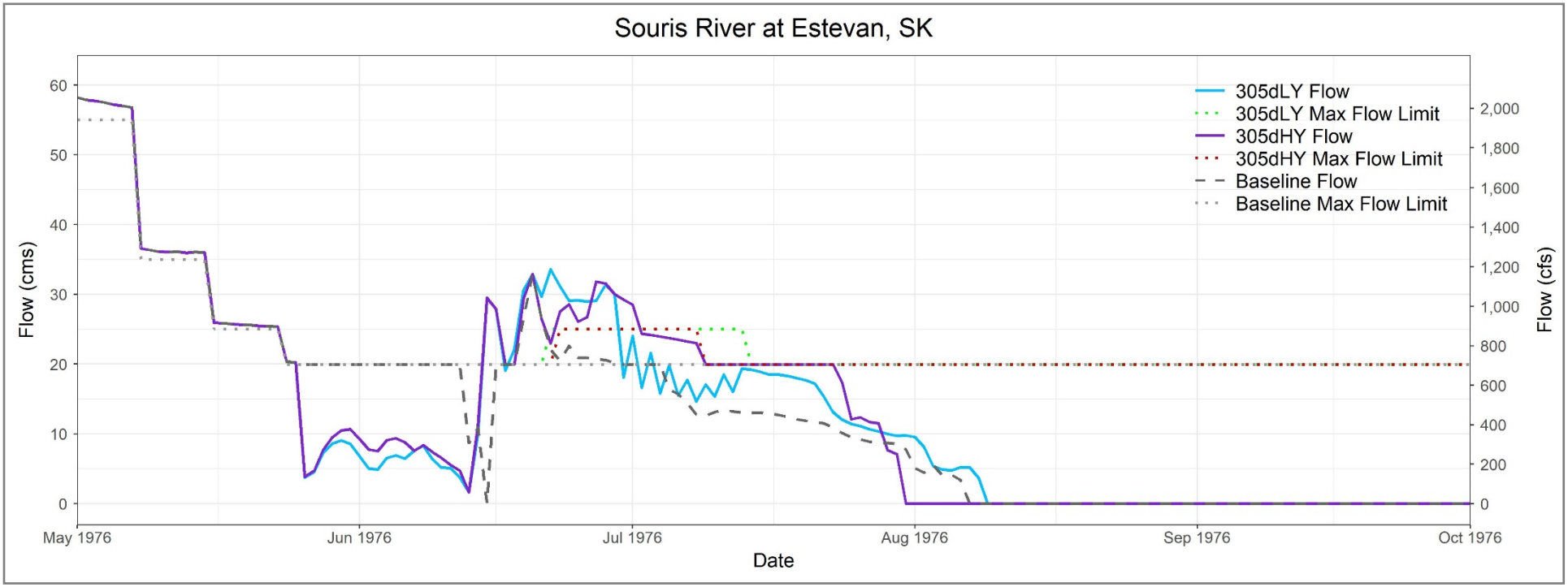
Plate 02

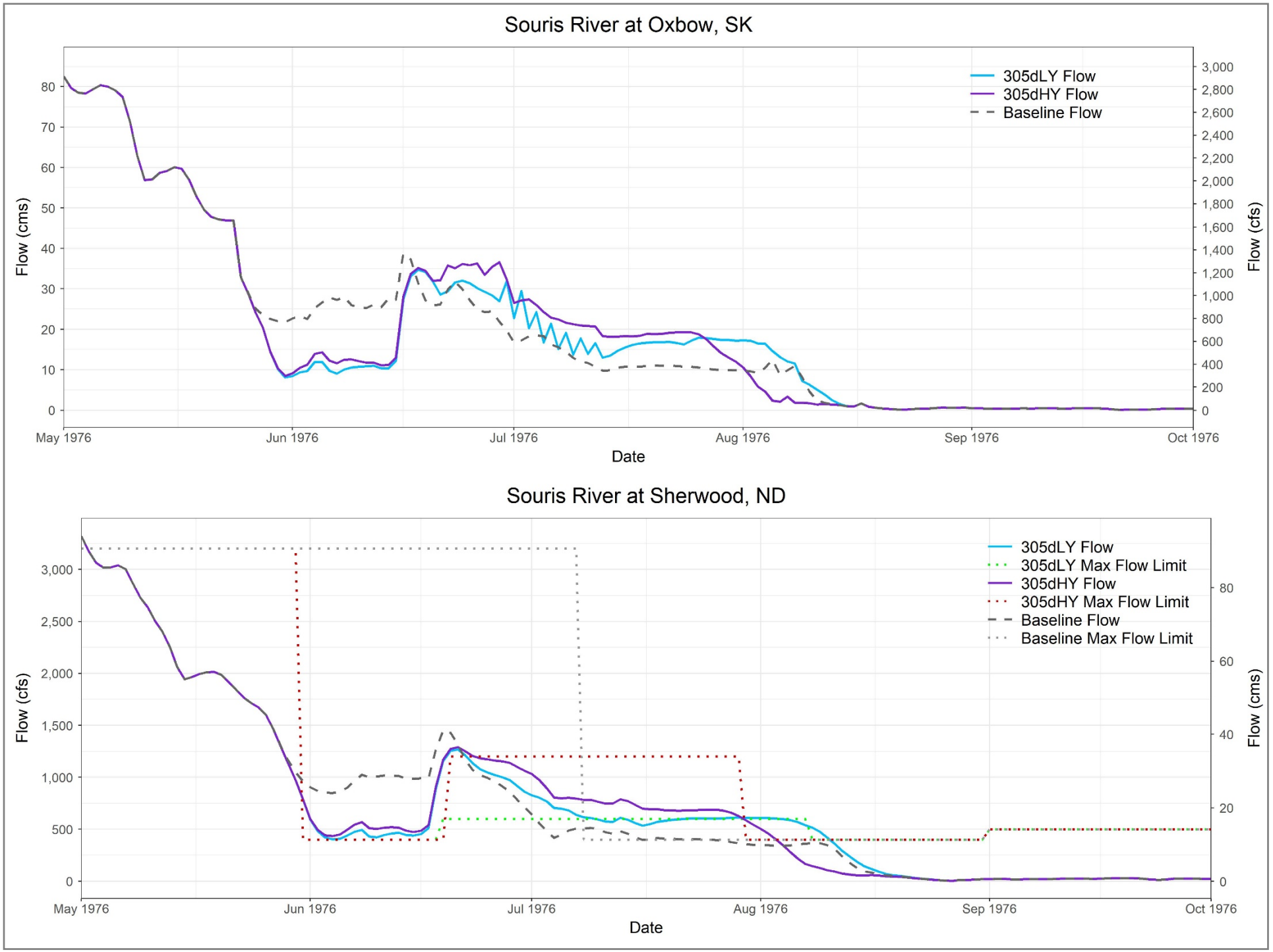
Critical Flow Locations – 1976

Alternative 305 (Phase 3)

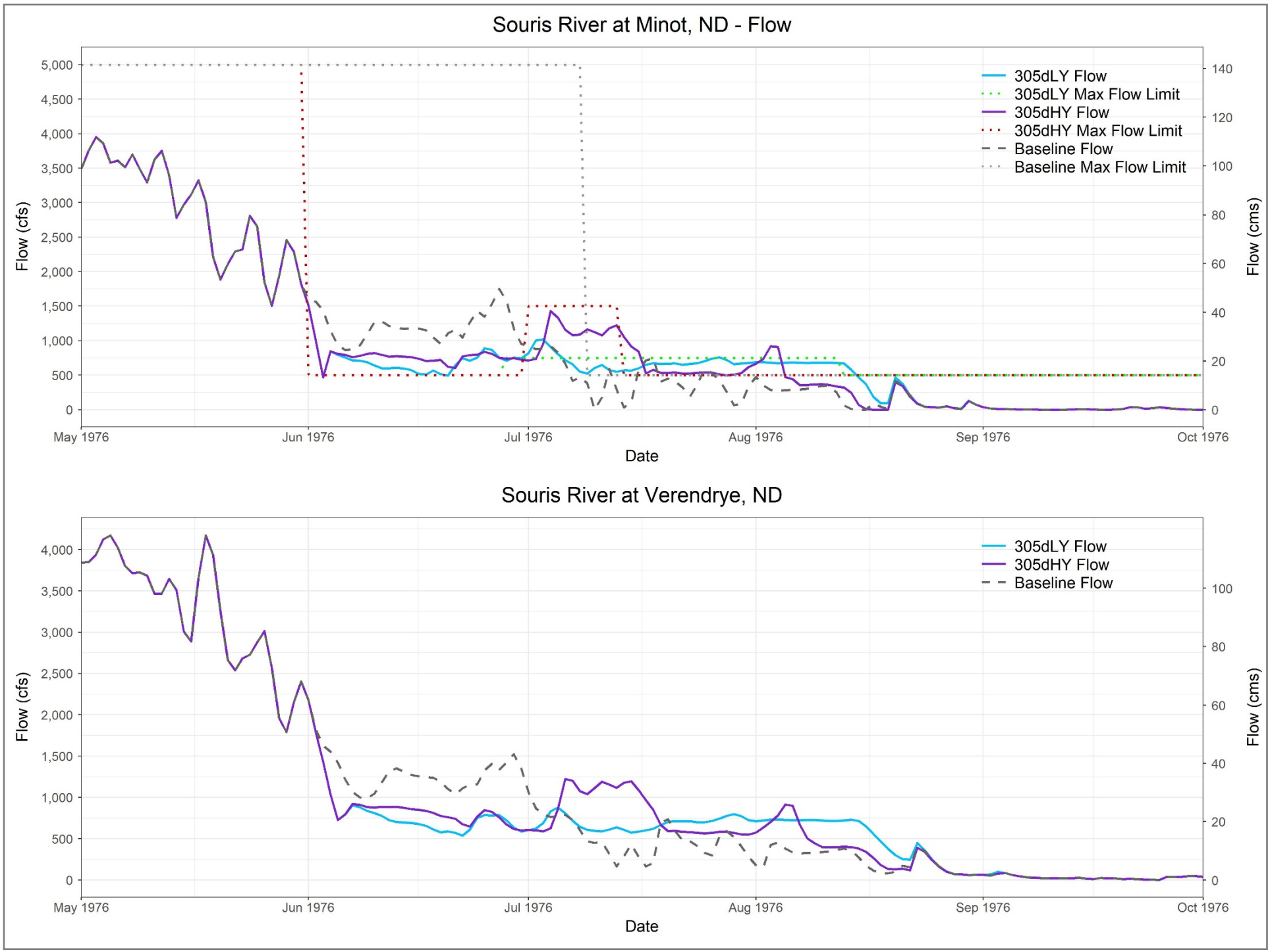
Souris River Plan of Study

305dLY *= Least aggressive releases (all flow constraints in place)*
305dHY *= Most aggressive releases (all flow constraints in place)*

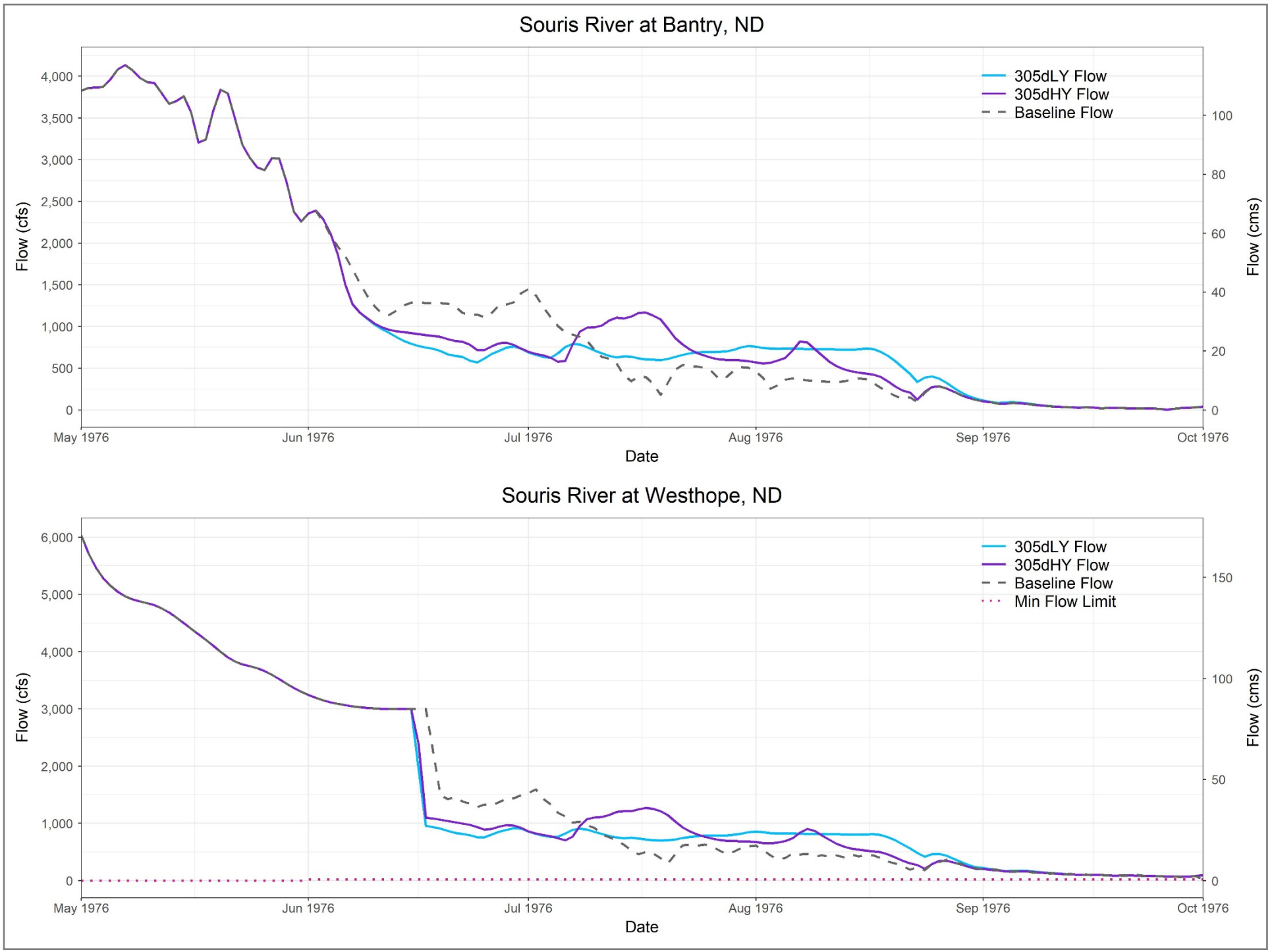




***305dLY** = Least aggressive releases (all flow constraints in place), **305dHY** = Most aggressive releases (all flow constraints in place)*

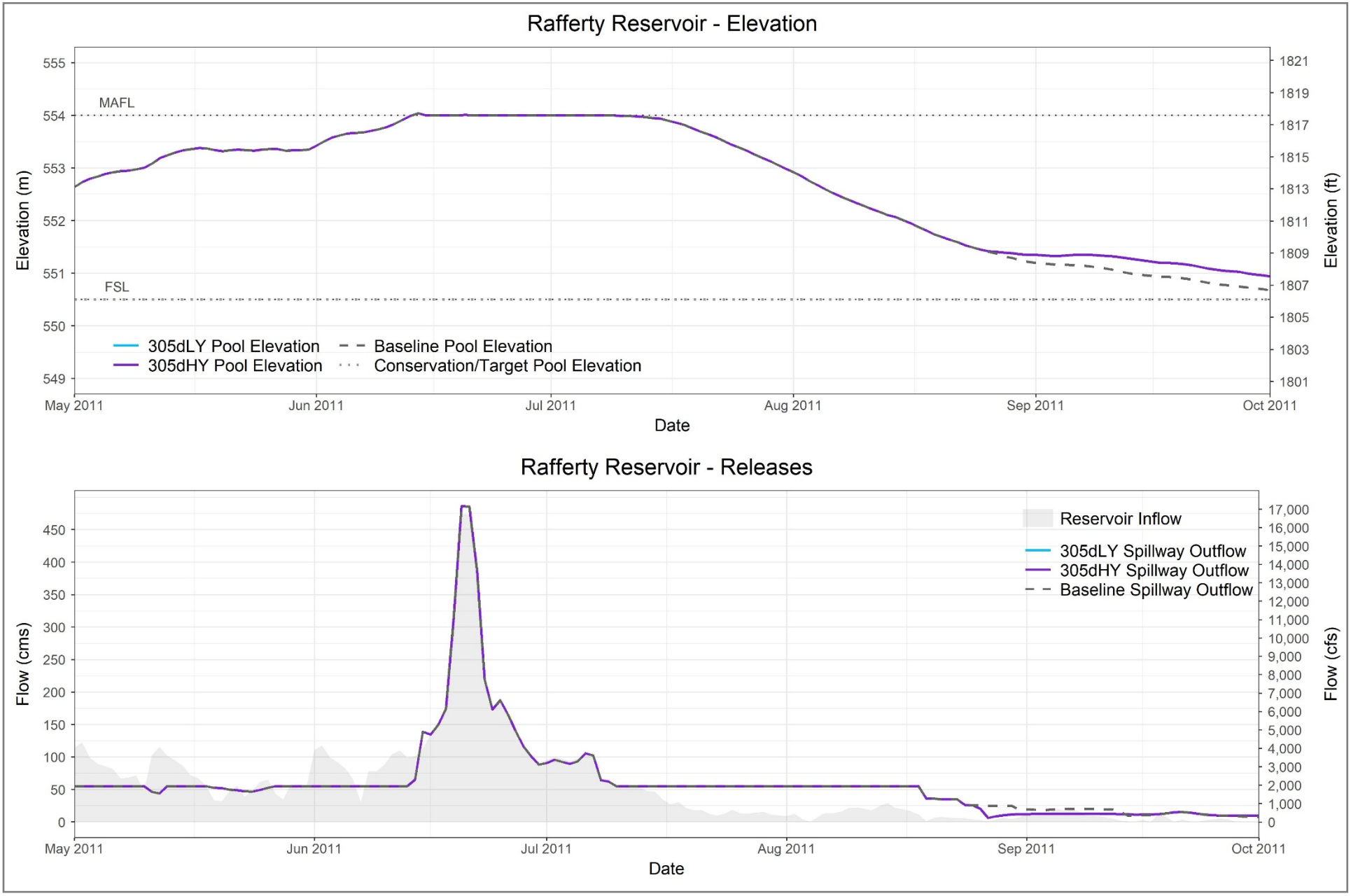


***305dLY** = Least aggressive releases (all flow constraints in place), **305dHY** = Most aggressive releases (all flow constraints in place)*

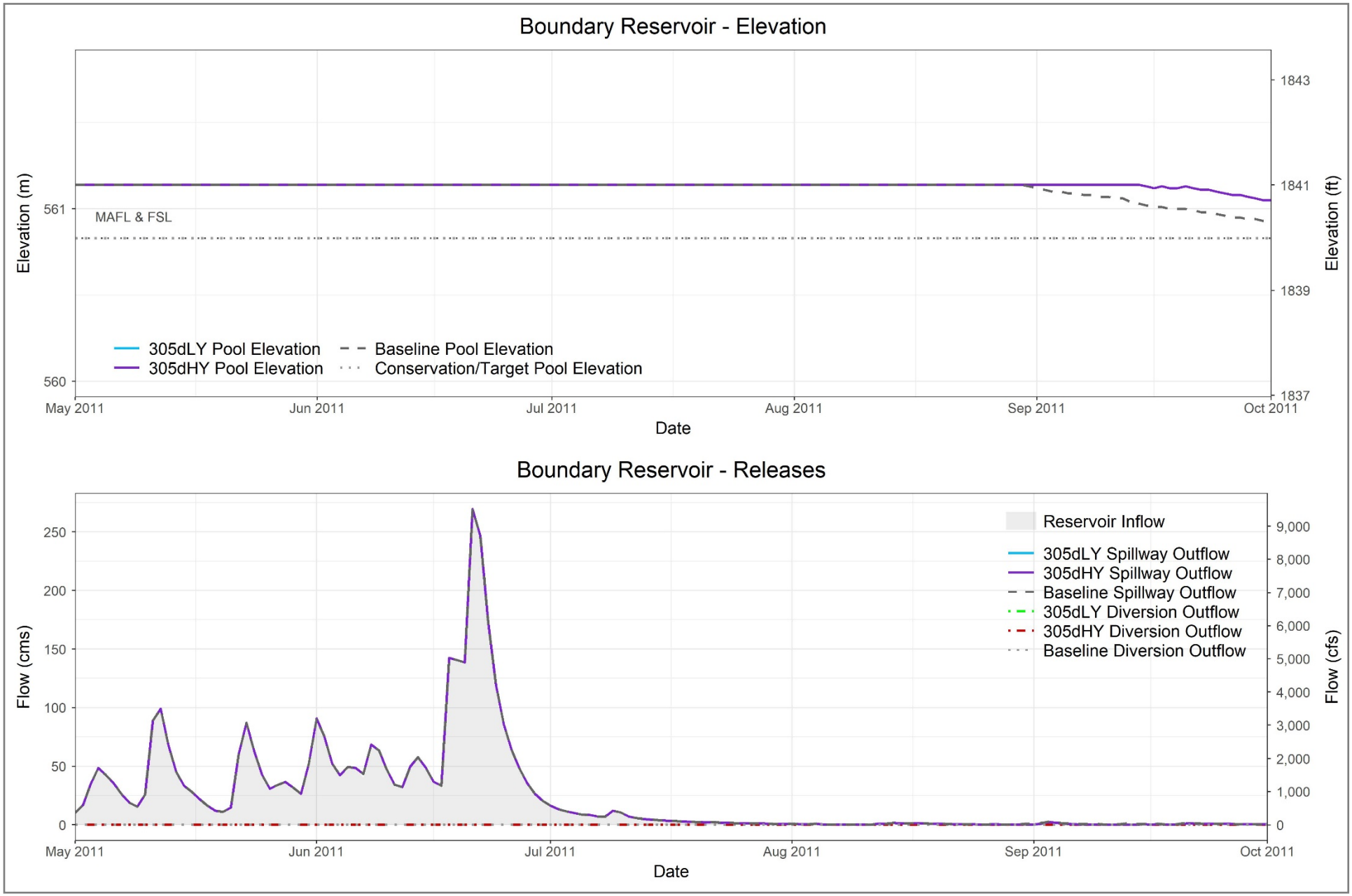


***305dLY** = Least aggressive releases (all flow constraints in place), **305dHY** = Most aggressive releases (all flow constraints in place)*

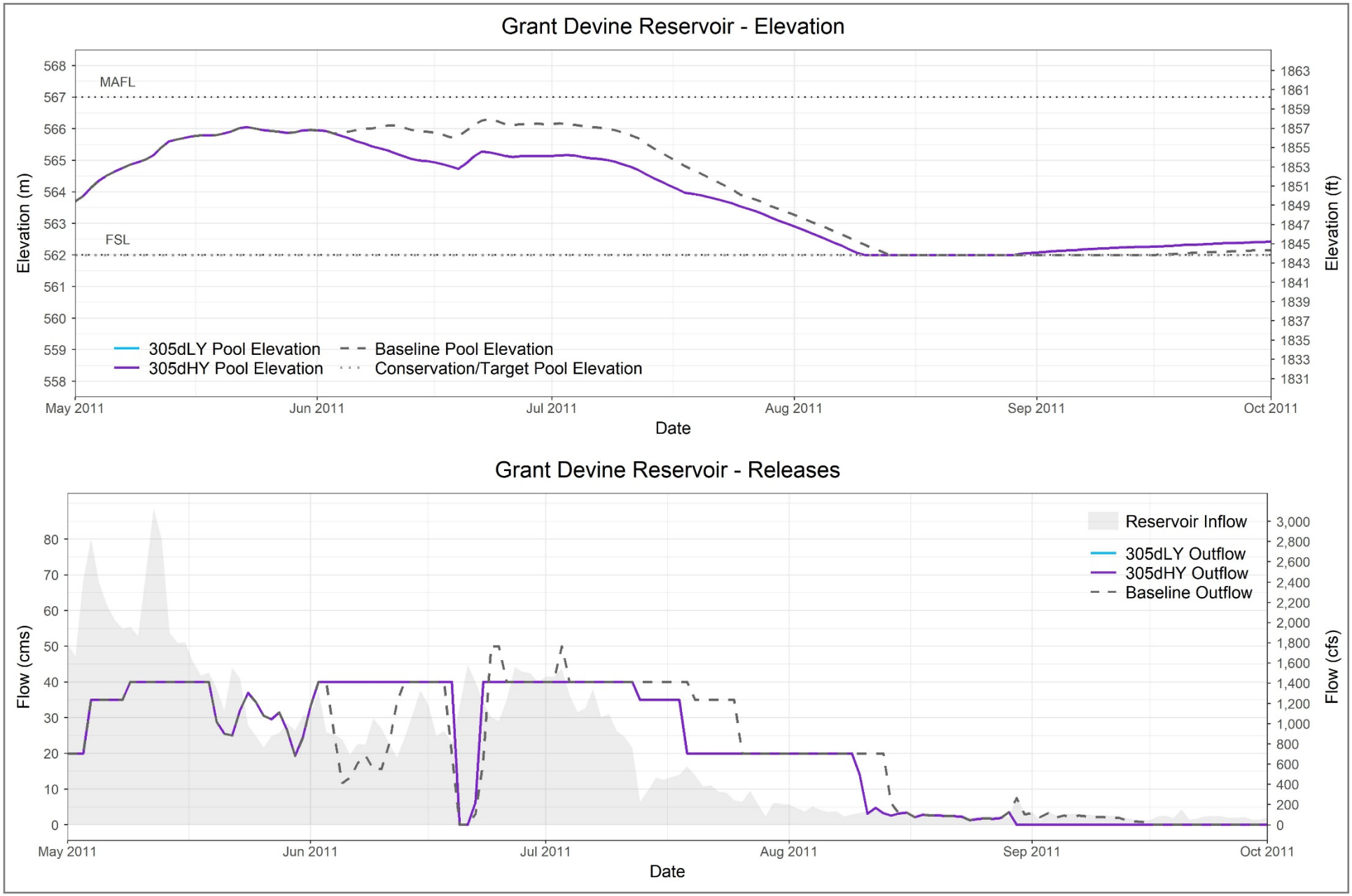
Plate 03	Reservoirs – 2011	Alternative 305 (Phase 3) Souris River Plan of Study



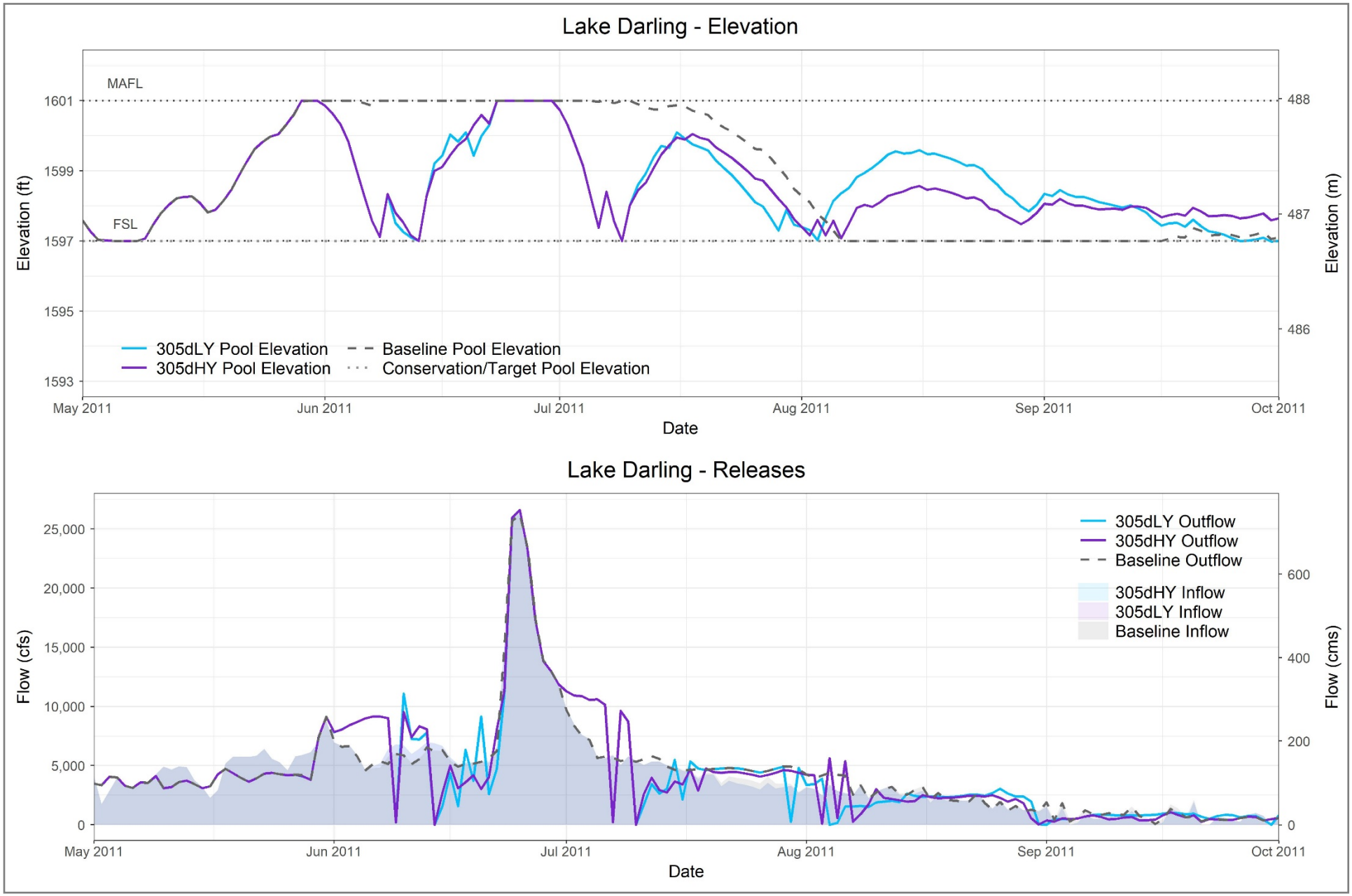
***305dLY** = Least aggressive releases (all flow constraints in place), **305dHY** = Most aggressive releases (all flow constraints in place)*



***305dLY** = Least aggressive releases (all flow constraints in place), **305dHY** = Most aggressive releases (all flow constraints in place)*



***305dLY** = Least aggressive releases (all flow constraints in place), **305dHY** = Most aggressive releases (all flow constraints in place)*



***305dLY** = Least aggressive releases (all flow constraints in place), **305dHY** = Most aggressive releases (all flow constraints in place)*

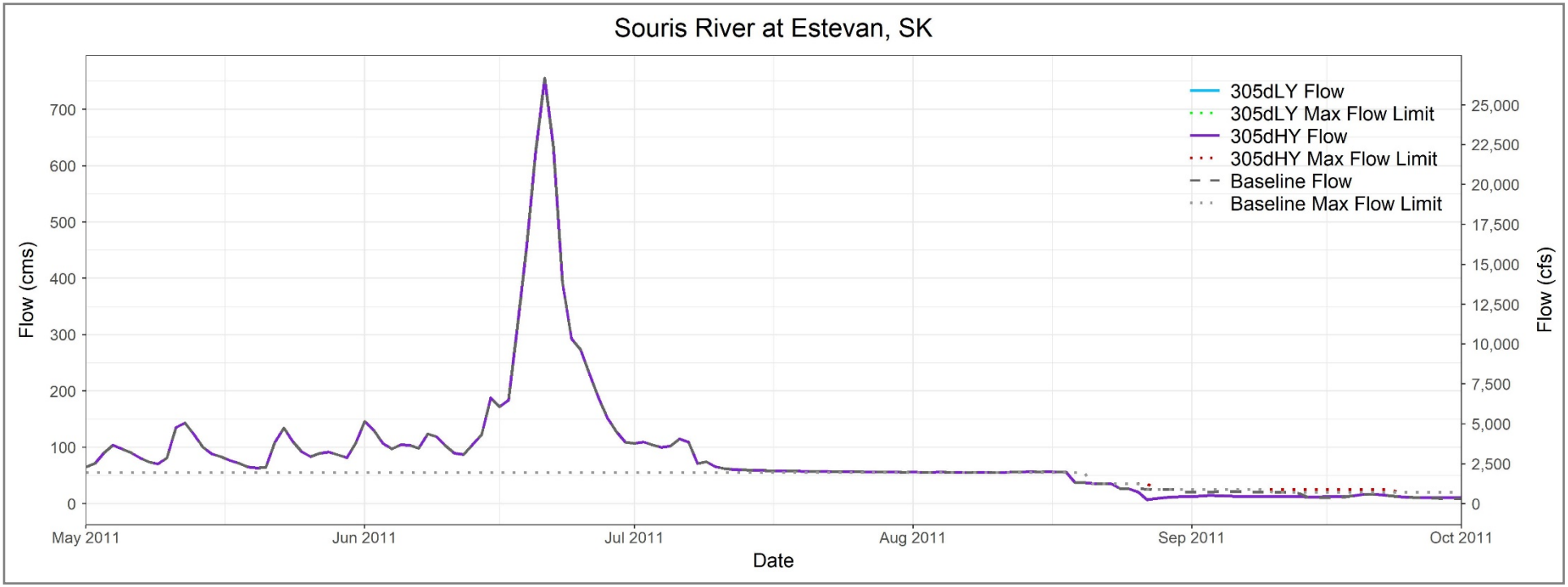
Plate 04

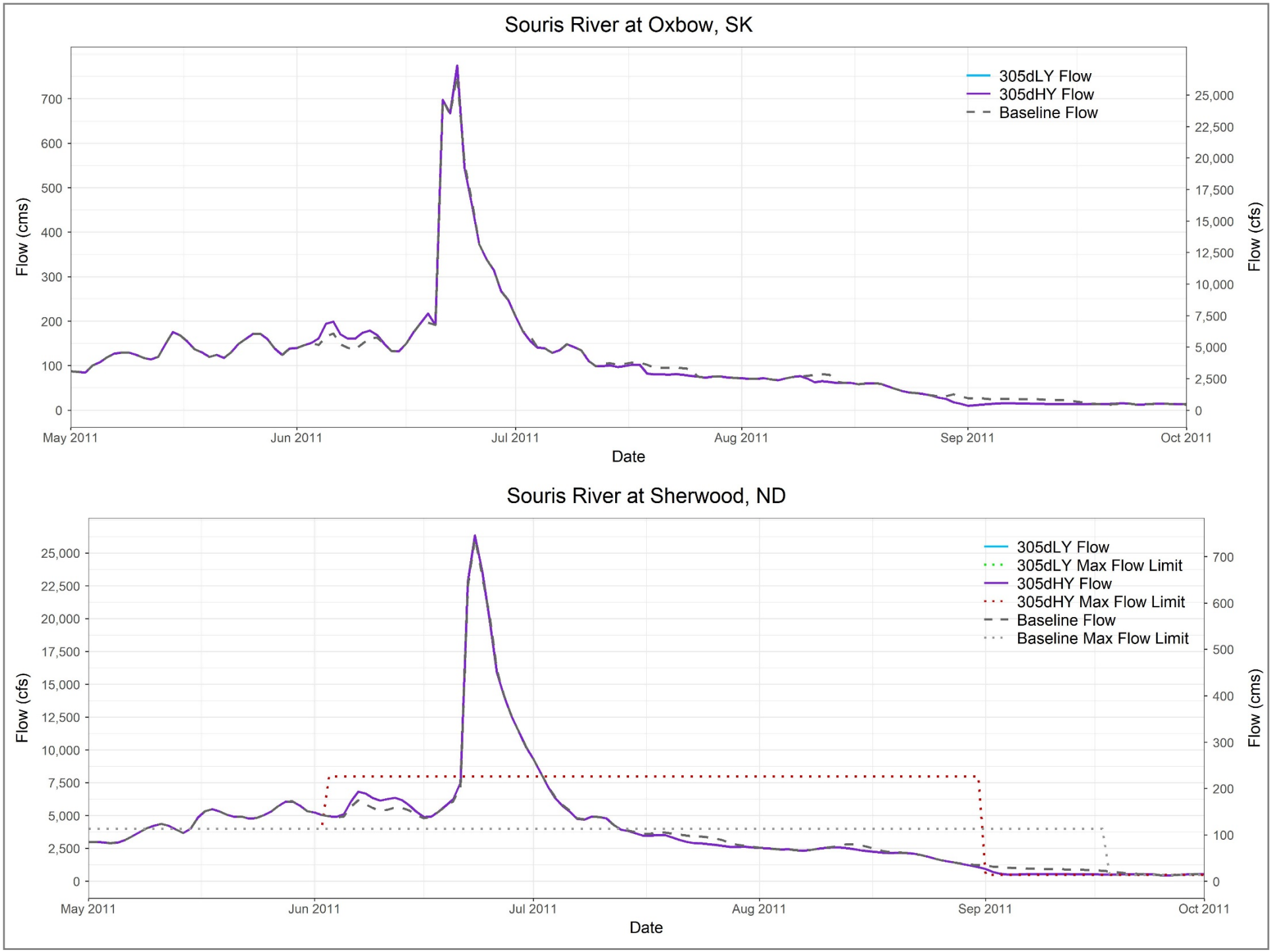
Critical Flow Locations – 2011

Alternative 305 (Phase 3)

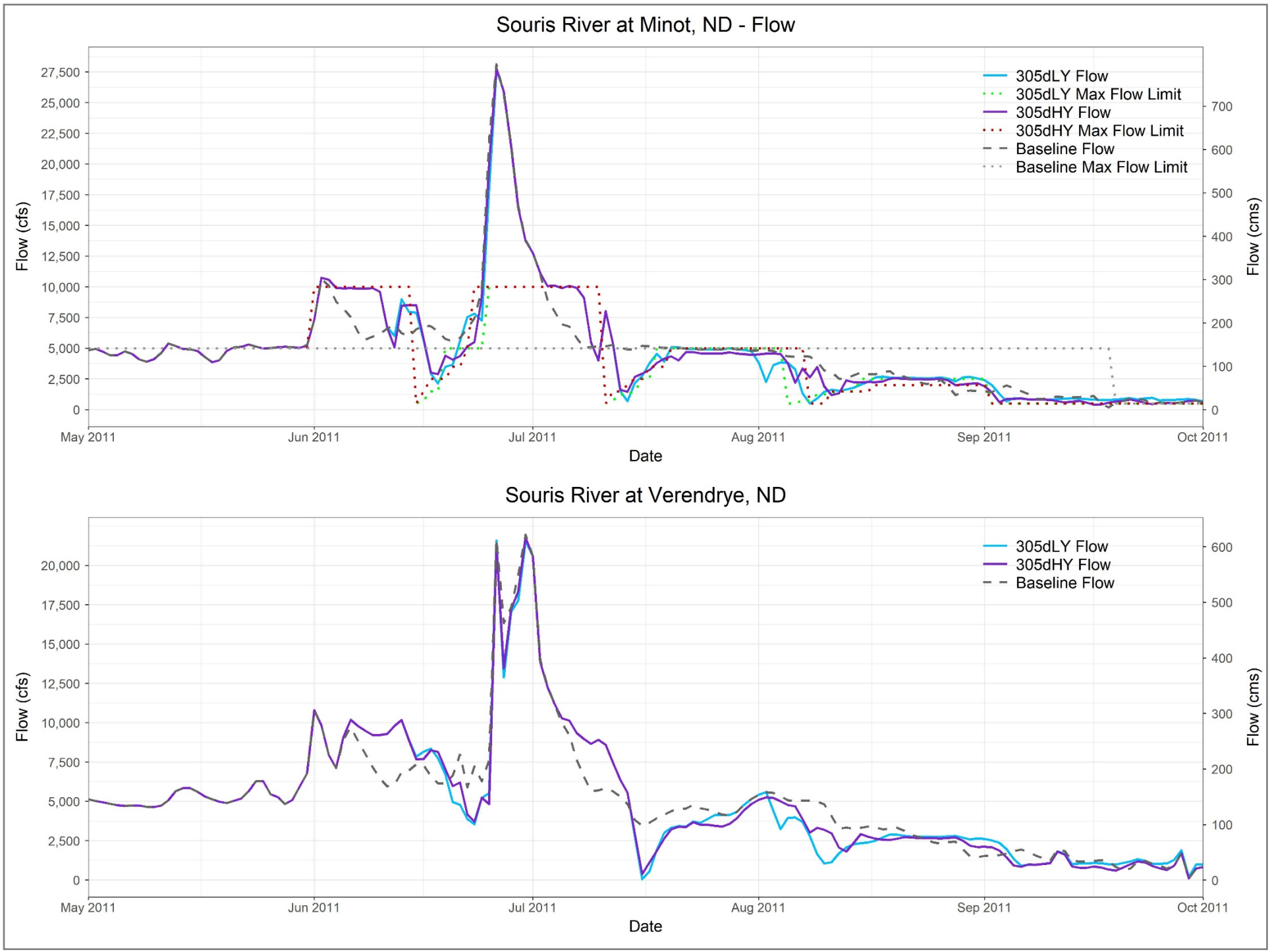
Souris River Plan of Study

305dLY *= Least aggressive releases (all flow constraints in place)*
305dHY *= Most aggressive releases (all flow constraints in place)*

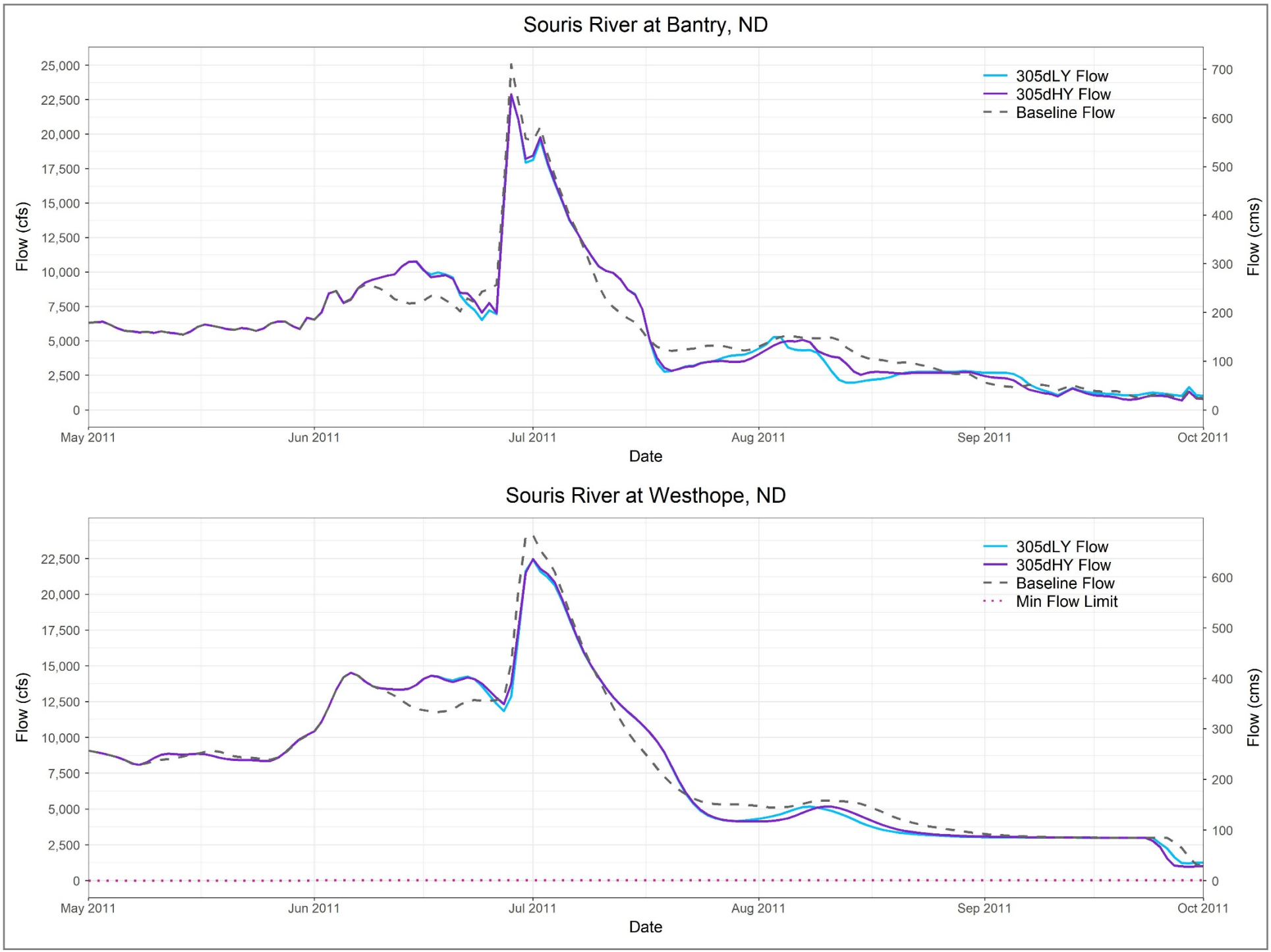




***305dLY** = Least aggressive releases (all flow constraints in place), **305dHY** = Most aggressive releases (all flow constraints in place)*

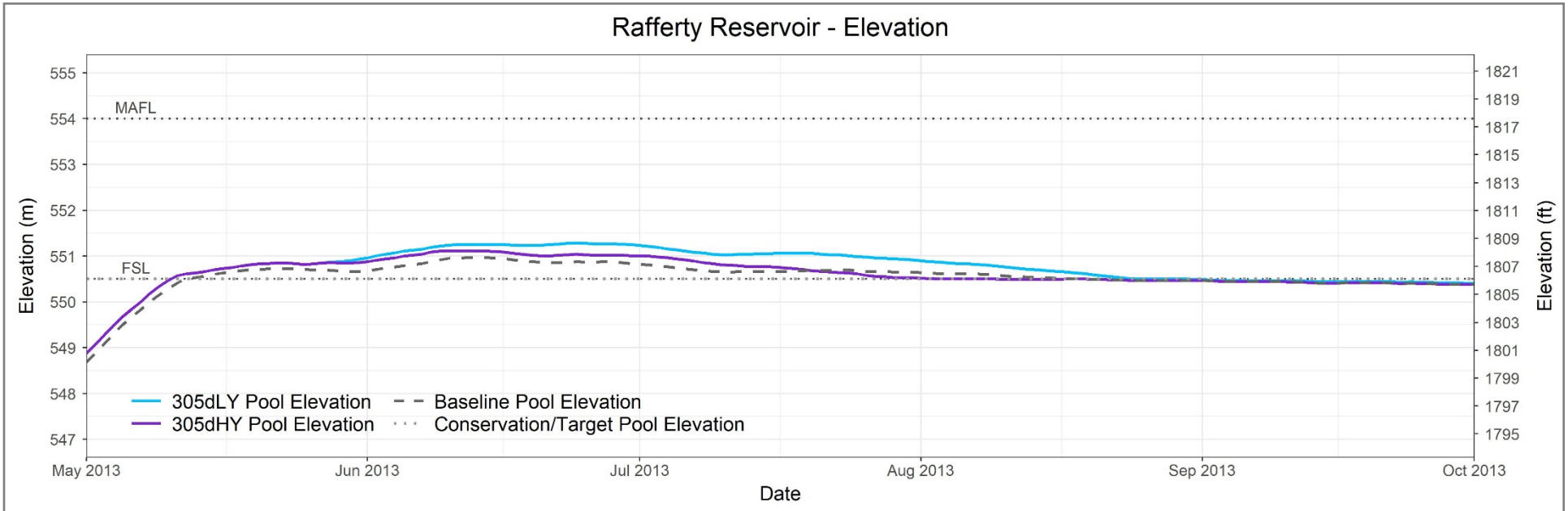


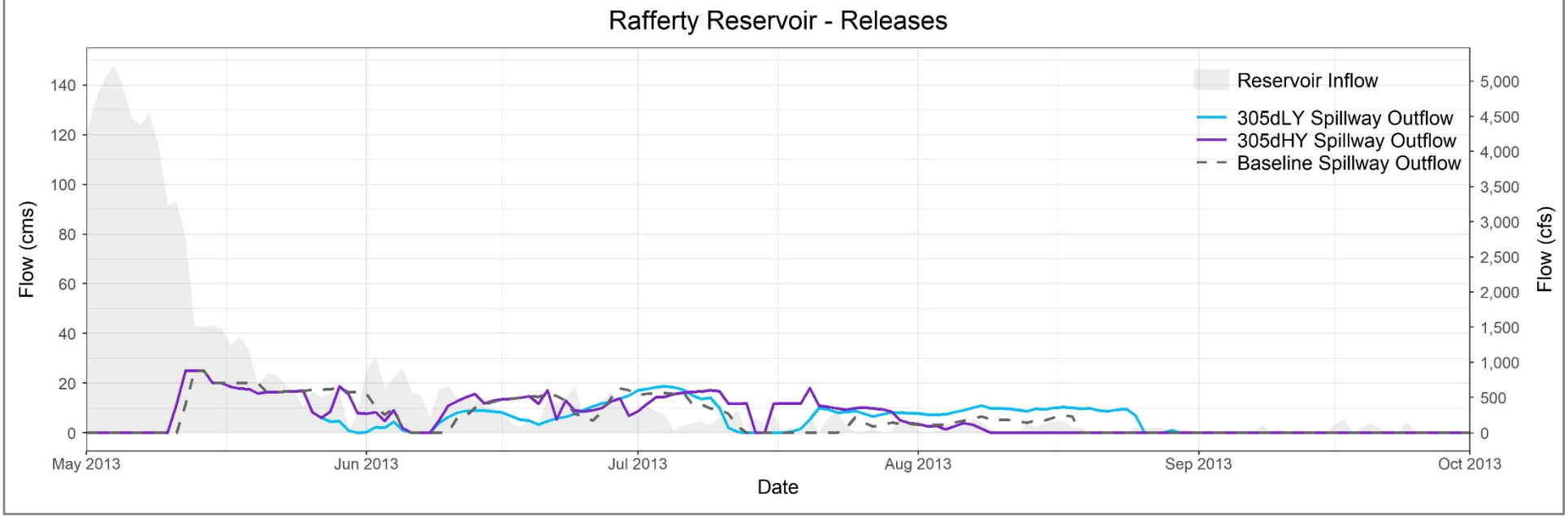
***305dLY** = Least aggressive releases (all flow constraints in place), **305dHY** = Most aggressive releases (all flow constraints in place)*



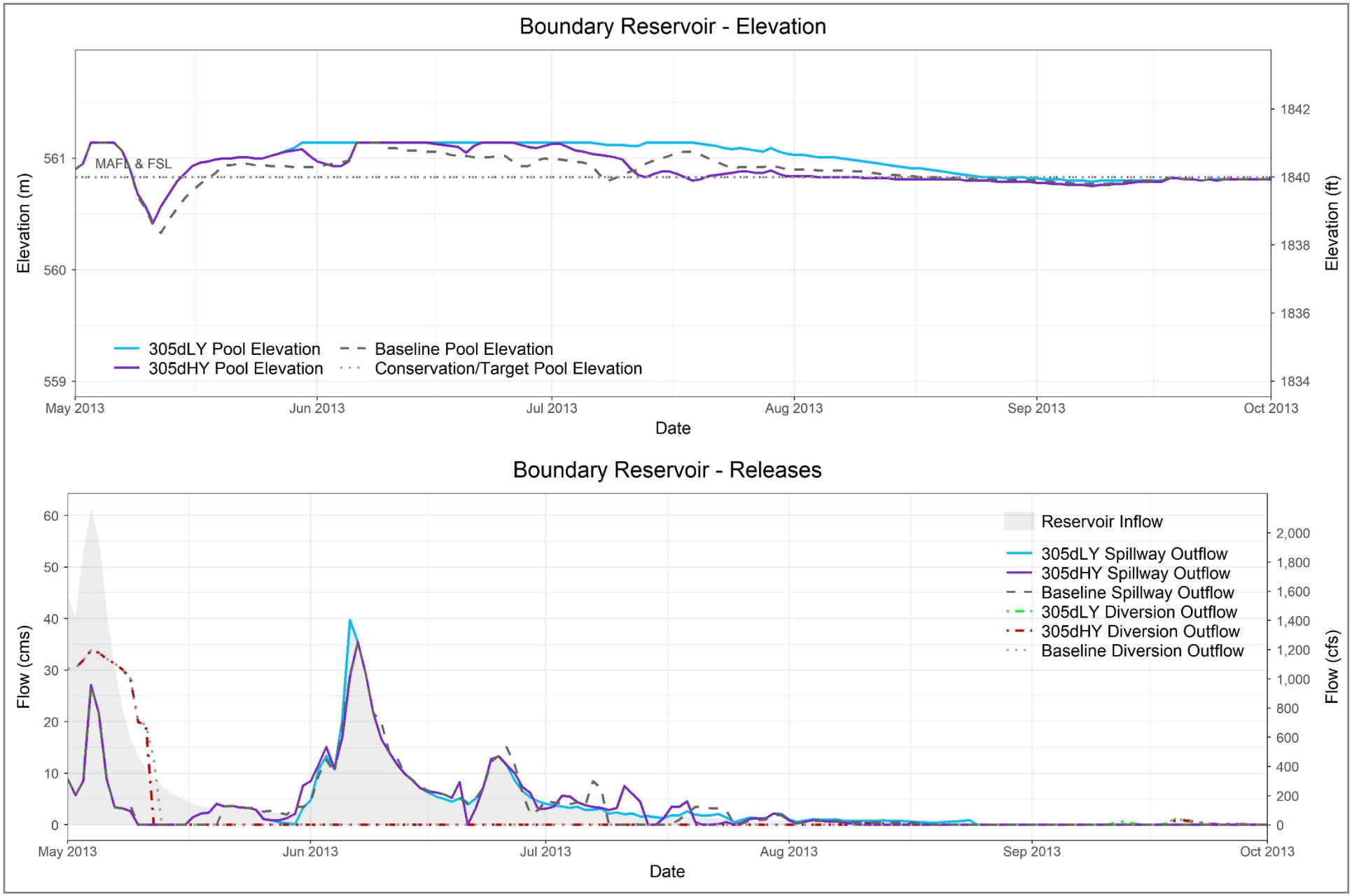
***305dLY** = Least aggressive releases (all flow constraints in place), **305dHY** = Most aggressive releases (all flow constraints in place)*

Plate 05	Reservoirs – 2013	Alternative 305 (Phase 3) Souris River Plan of Study

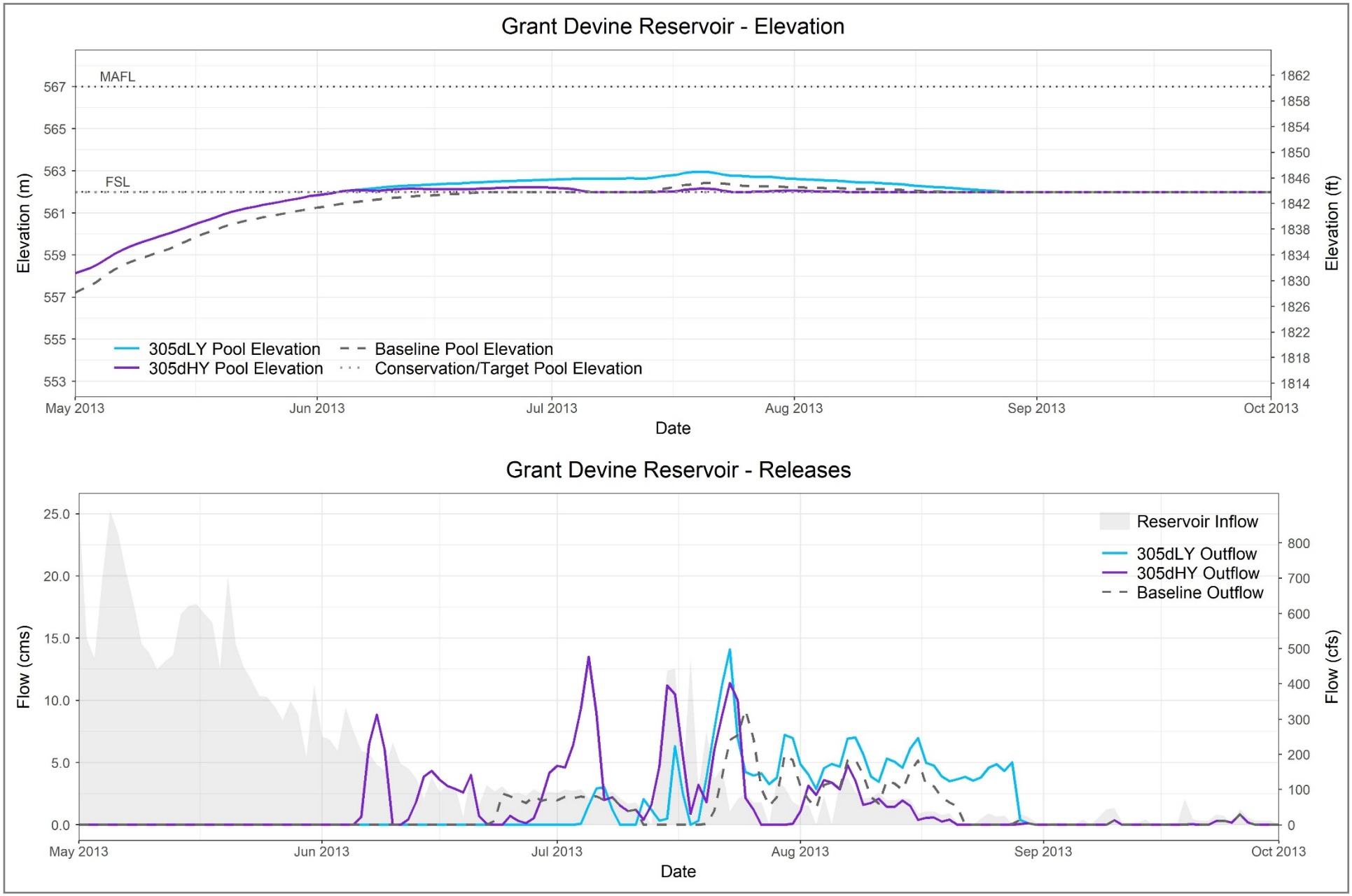




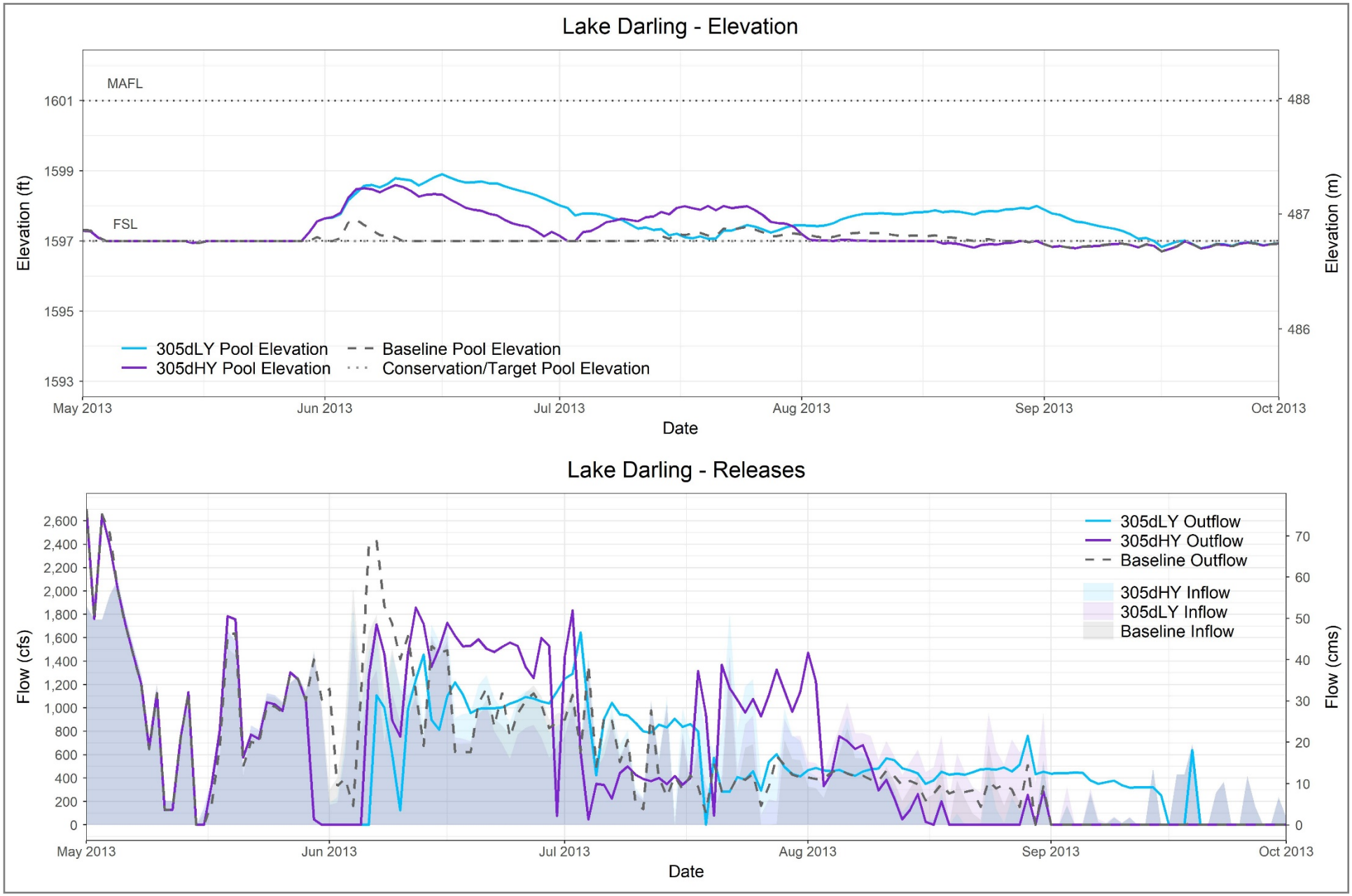
***305dLY** = Least aggressive releases (all flow constraints in place), **305dHY** = Most aggressive releases (all flow constraints in place)*



***305dLY** = Least aggressive releases (all flow constraints in place), **305dHY** = Most aggressive releases (all flow constraints in place)*



***305dLY** = Least aggressive releases (all flow constraints in place), **305dHY** = Most aggressive releases (all flow constraints in place)*



***305dLY** = Least aggressive releases (all flow constraints in place), **305dHY** = Most aggressive releases (all flow constraints in place)*

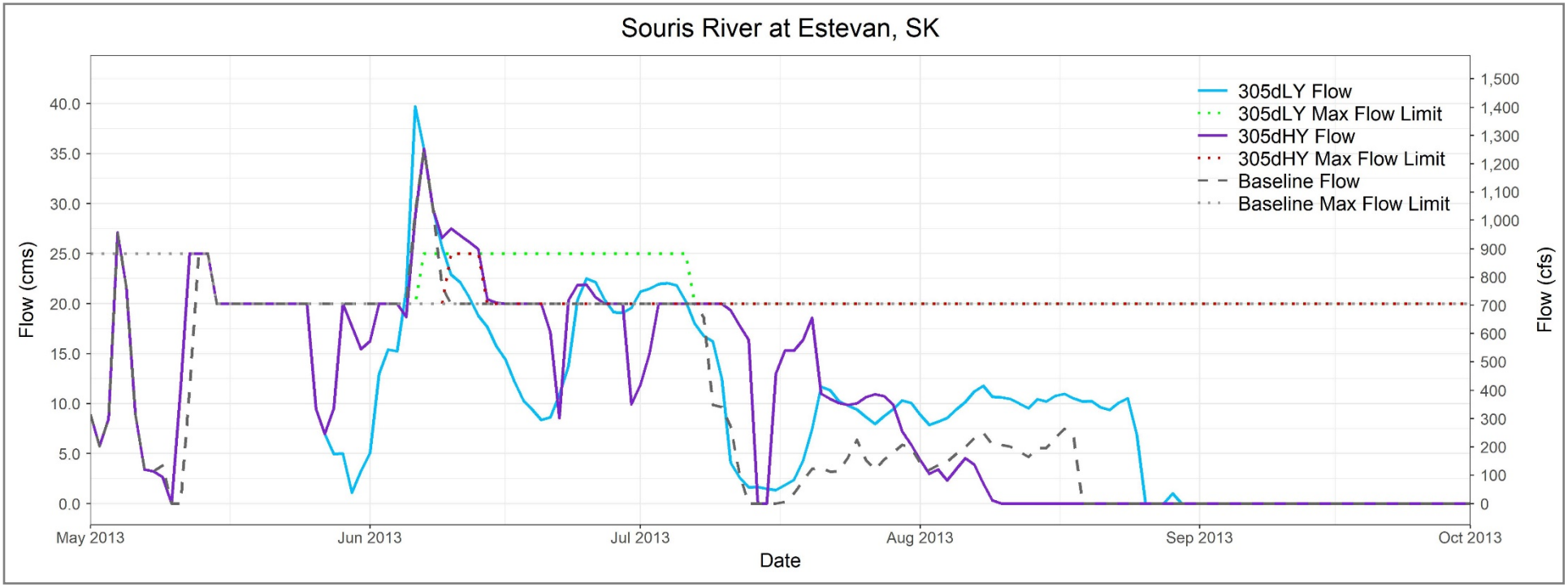
Plate 06

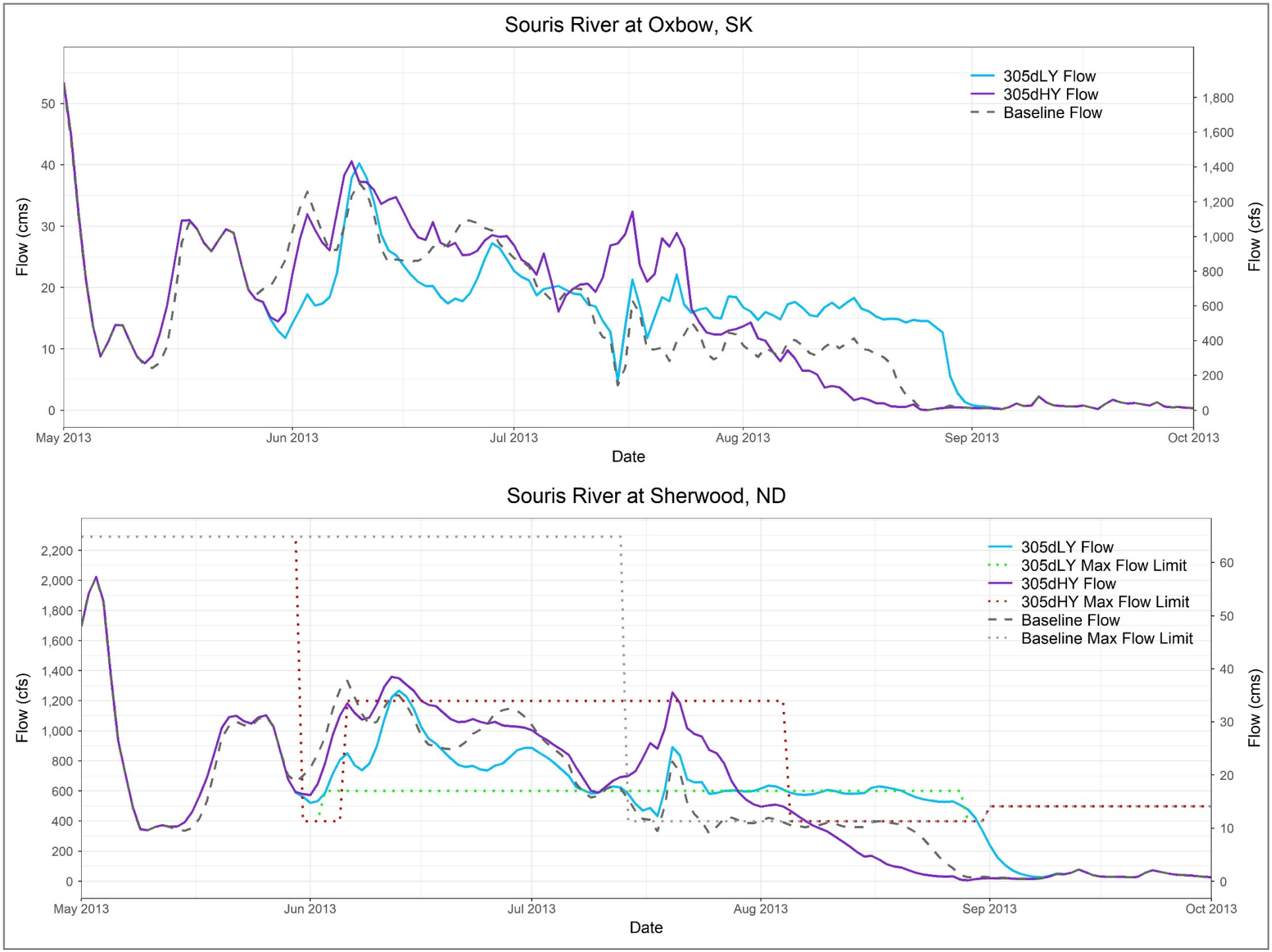
Critical Flow Locations – 2013

Alternative 305 (Phase 3)

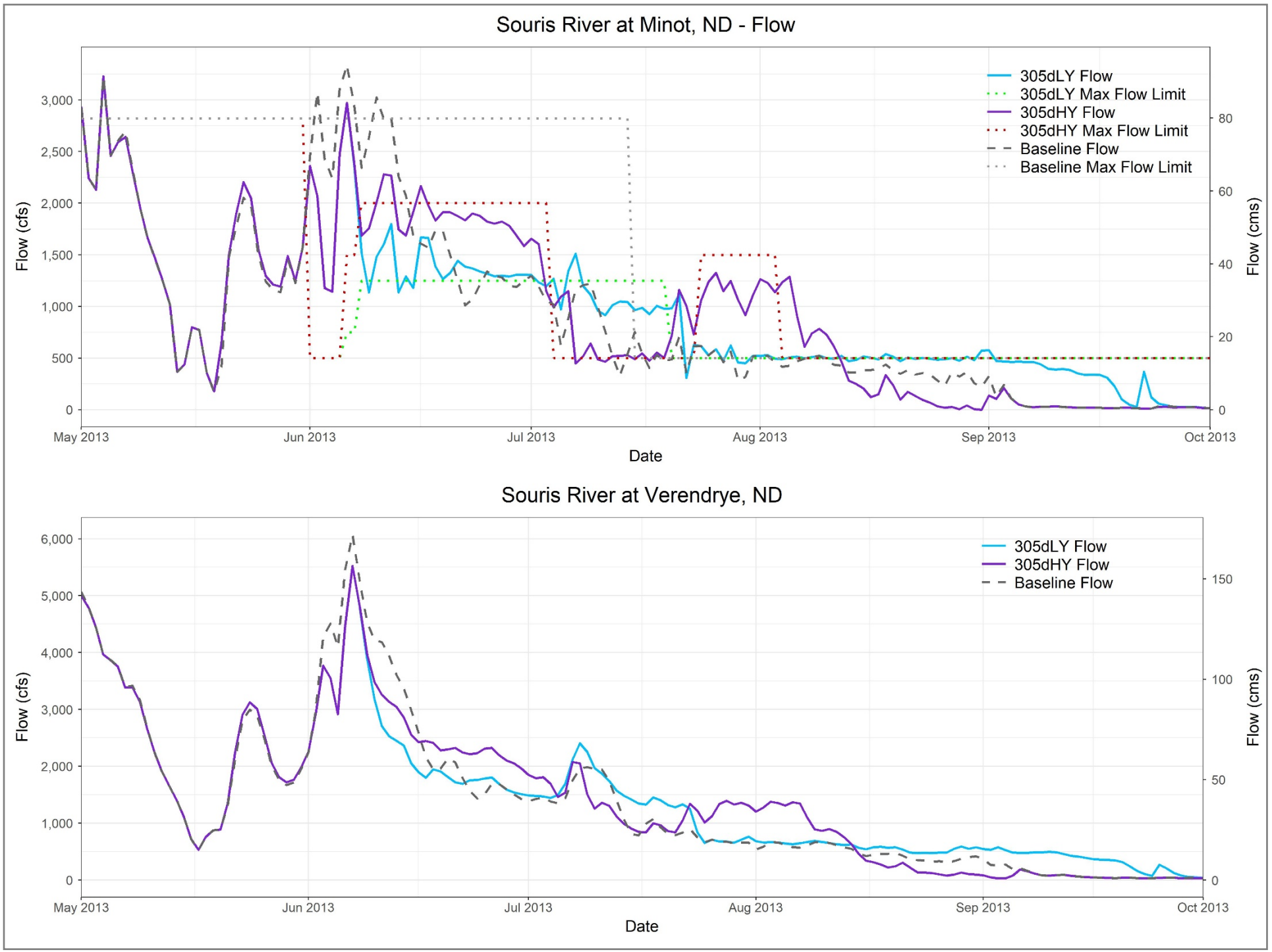
Souris River Plan of Study

305dLY *= Least aggressive releases (all flow constraints in place)*
305dHY *= Most aggressive releases (all flow constraints in place)*

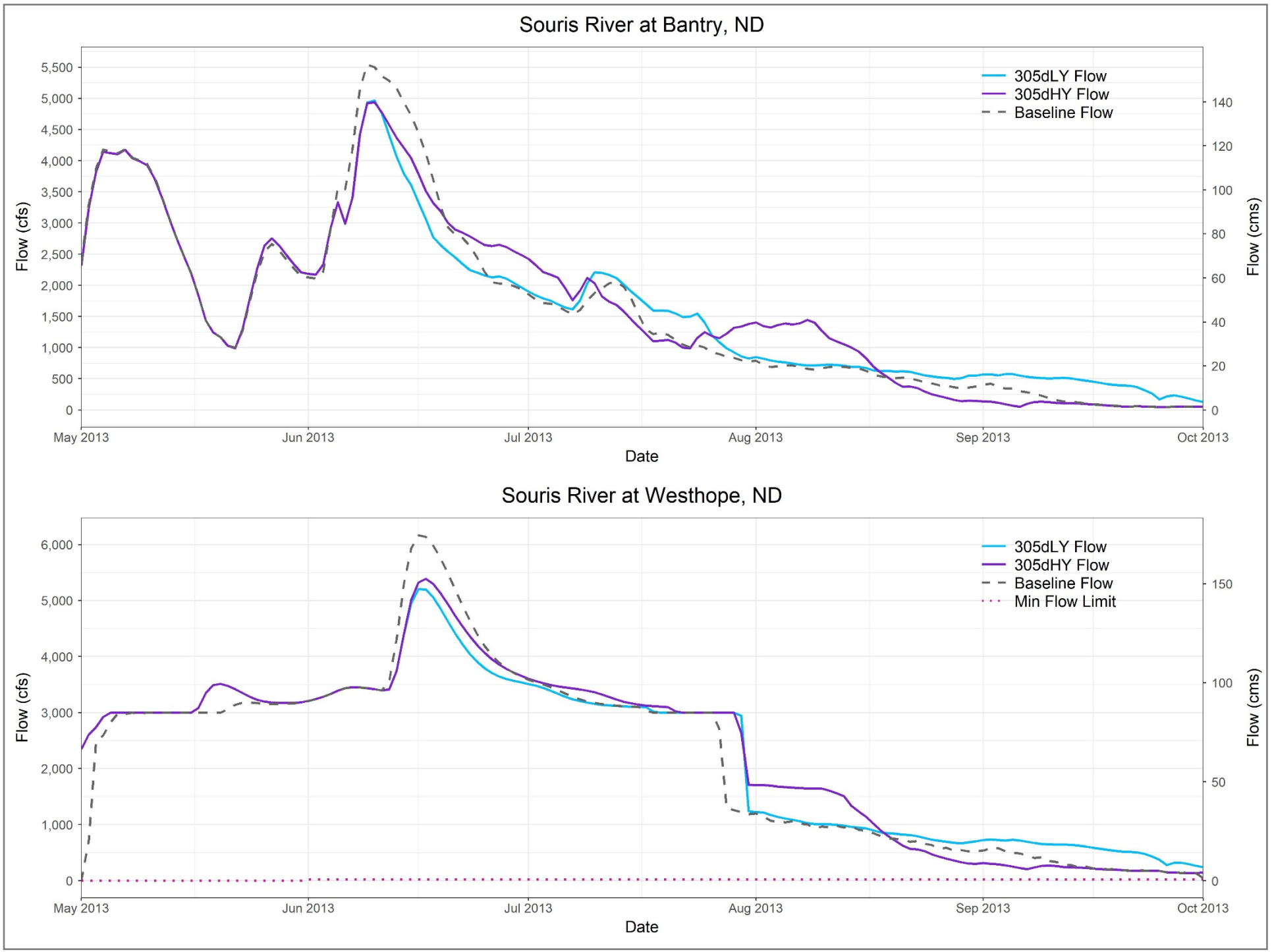




***305dLY** = Least aggressive releases (all flow constraints in place), **305dHY** = Most aggressive releases (all flow constraints in place)*

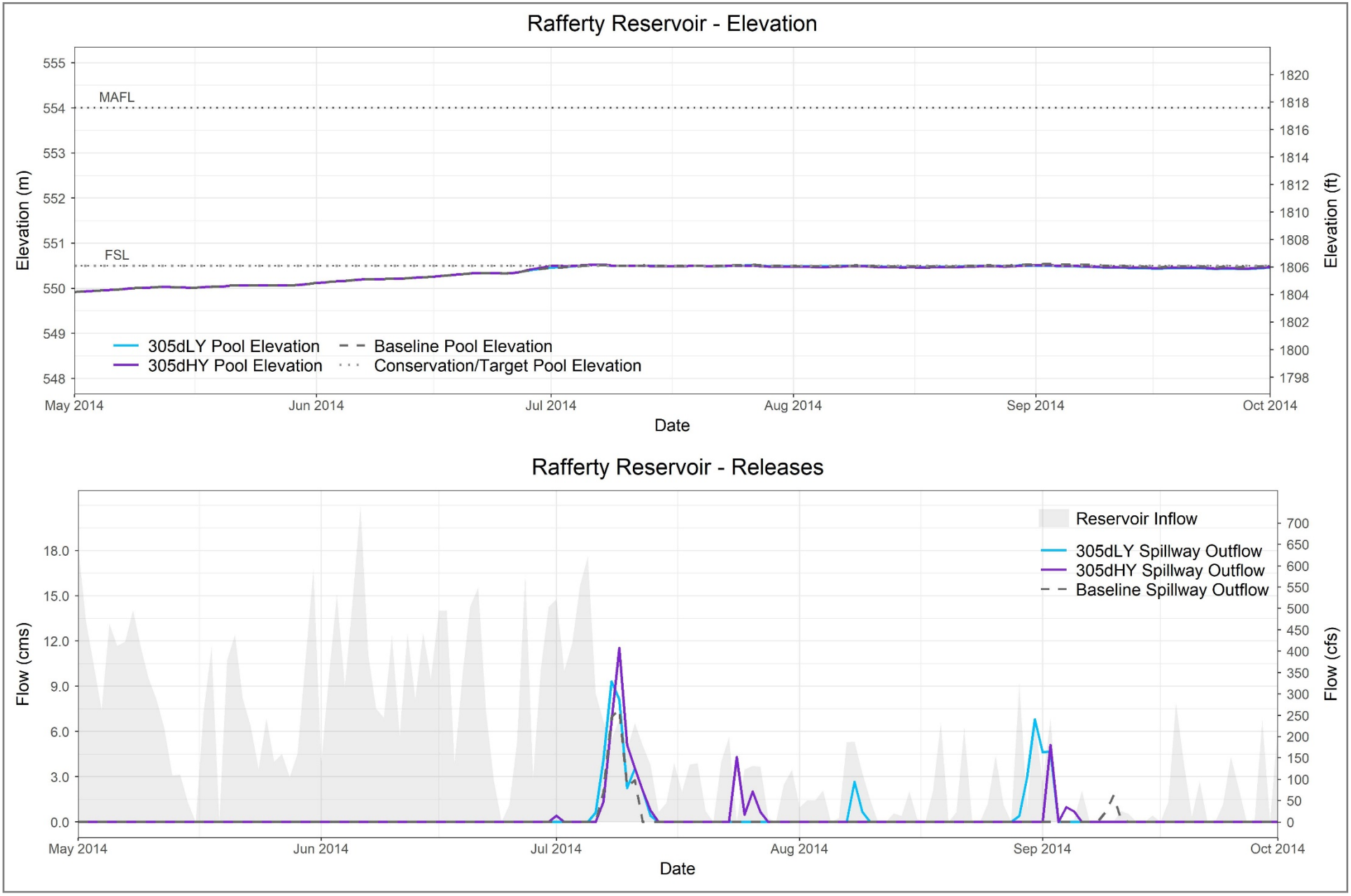


***305dLY** = Least aggressive releases (all flow constraints in place), **305dHY** = Most aggressive releases (all flow constraints in place)*



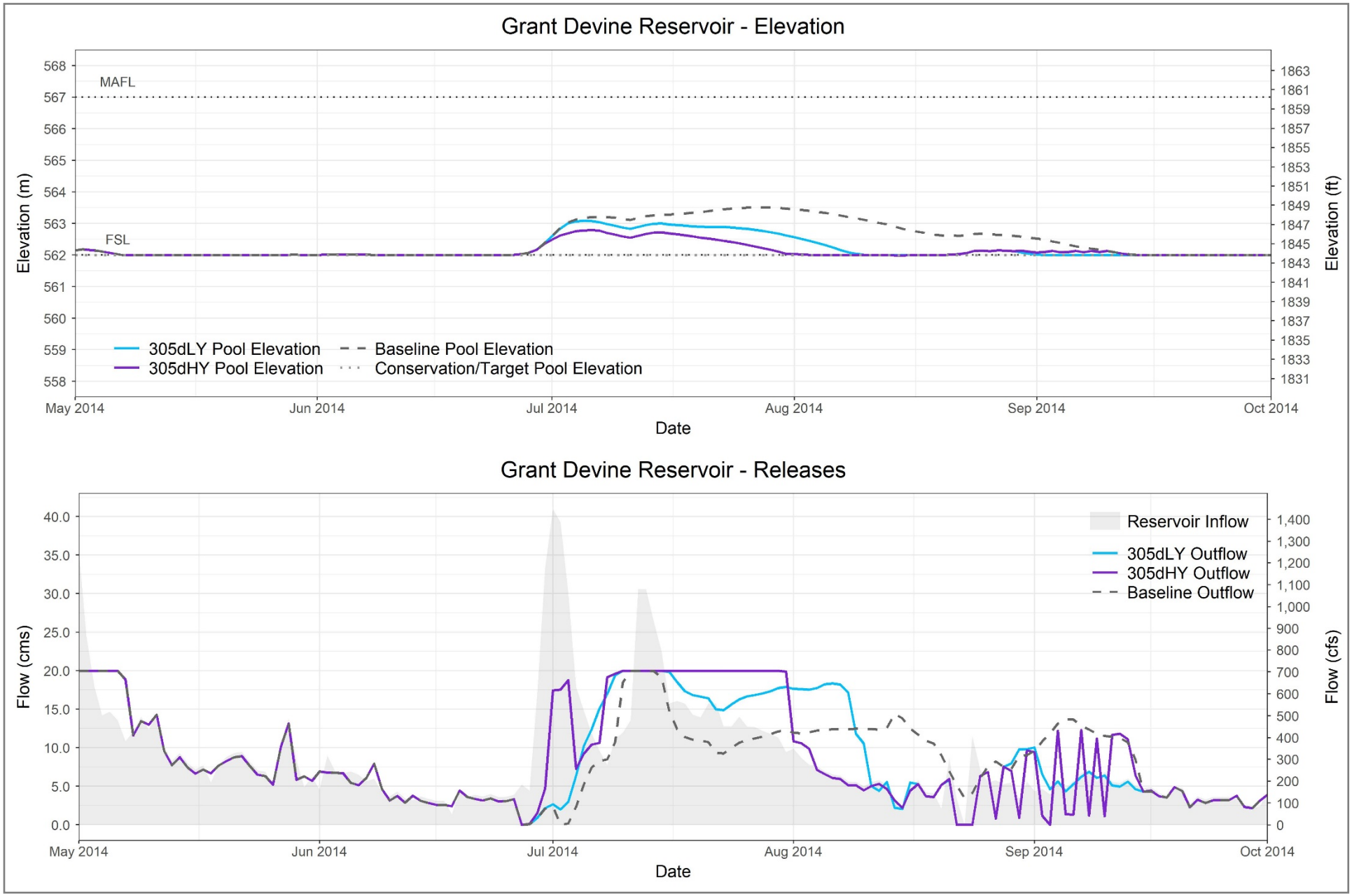
***305dLY** = Least aggressive releases (all flow constraints in place), **305dHY** = Most aggressive releases (all flow constraints in place)*

Plate 07	Reservoirs – 2014	Alternative 305 (Phase 3) Souris River Plan of Study

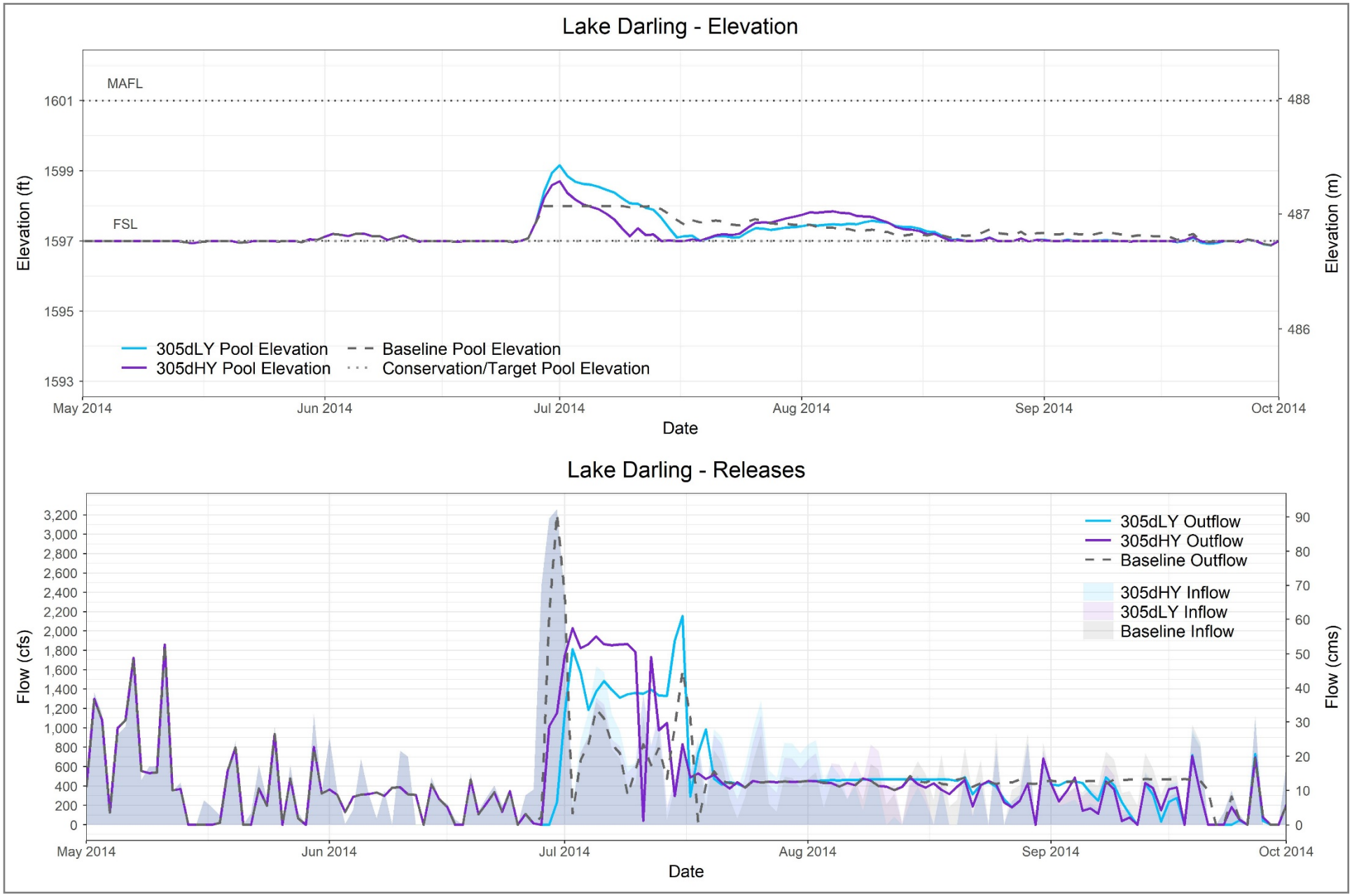


***305dLY** = Least aggressive releases (all flow constraints in place), **305dHY** = Most aggressive releases (all flow constraints in place)*

***305dLY** = Least aggressive releases (all flow constraints in place), **305dHY** = Most aggressive releases (all flow constraints in place)*



***305dLY** = Least aggressive releases (all flow constraints in place), **305dHY** = Most aggressive releases (all flow constraints in place)*



***305dLY** = Least aggressive releases (all flow constraints in place), **305dHY** = Most aggressive releases (all flow constraints in place)*

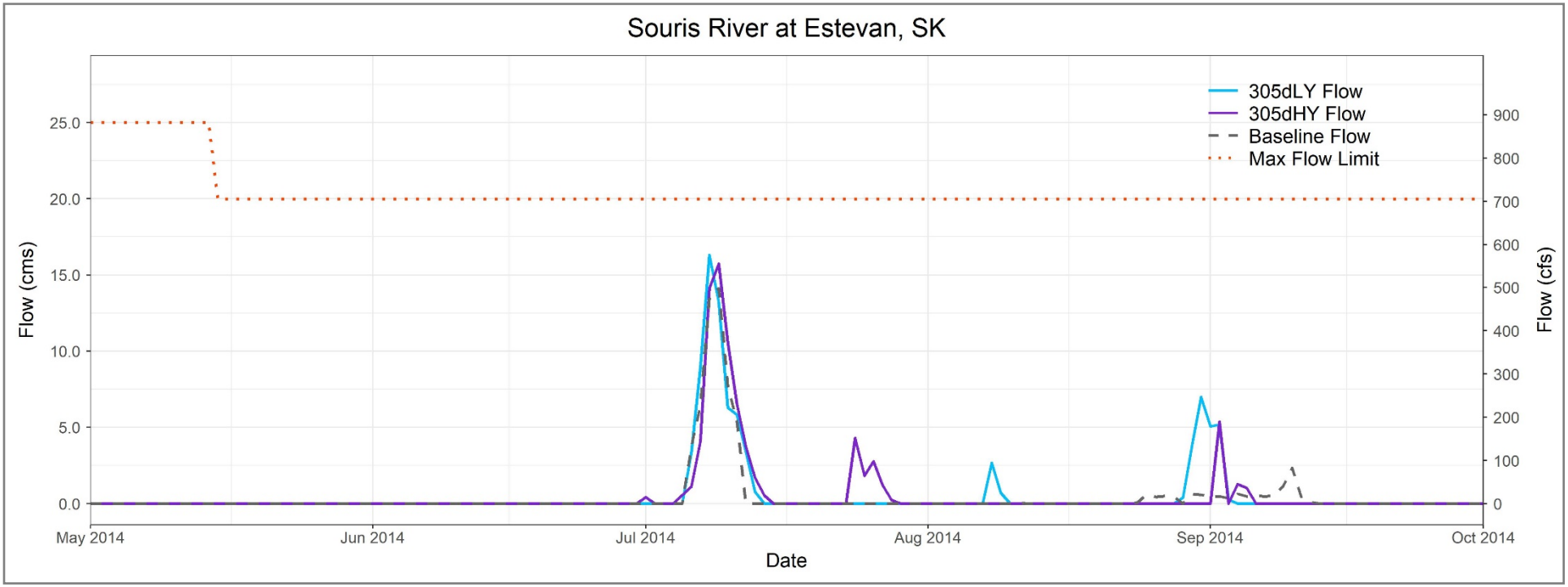
Plate 08

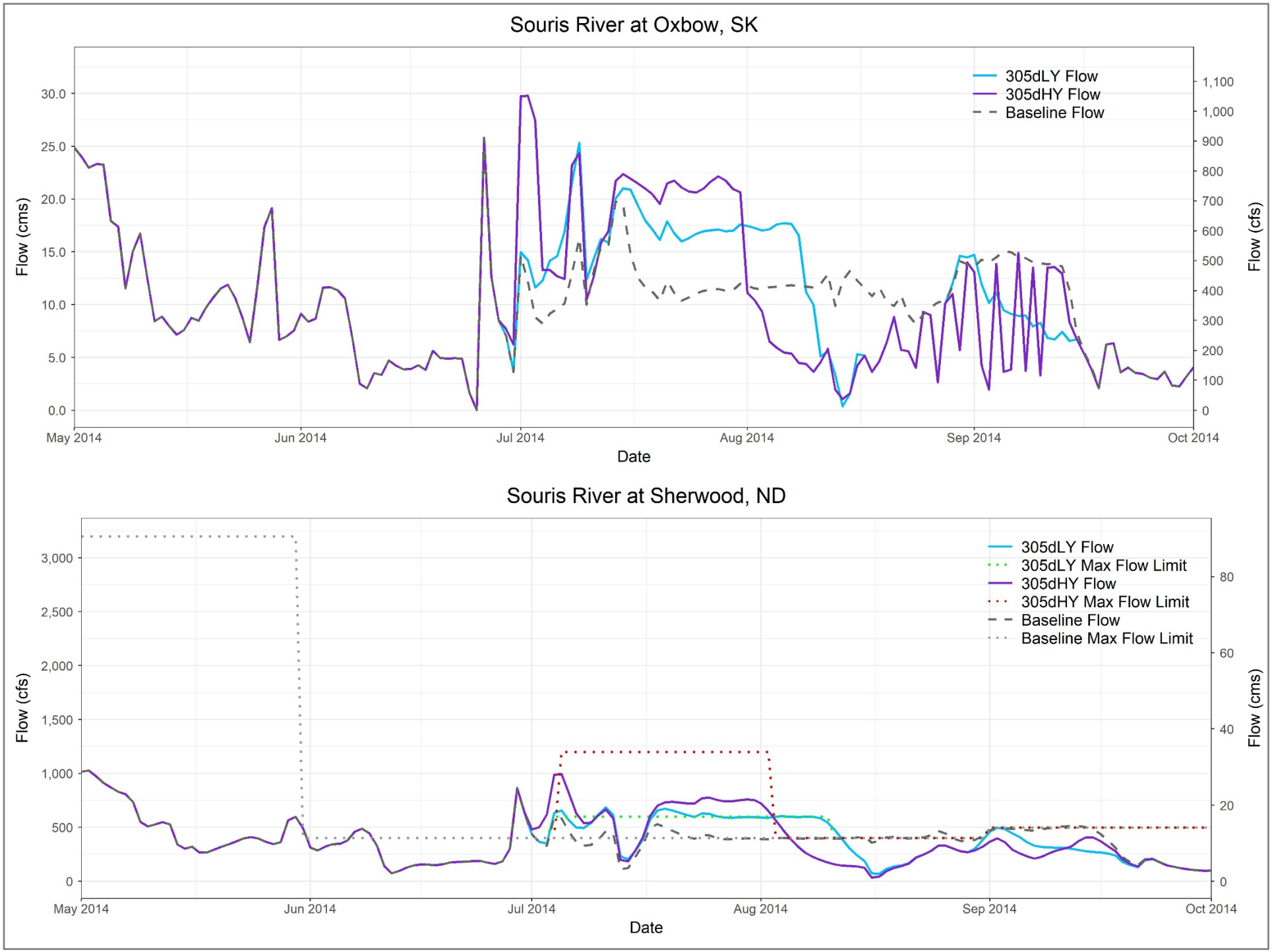
Critical Flow Locations – 2014

Alternative 305 (Phase 3)

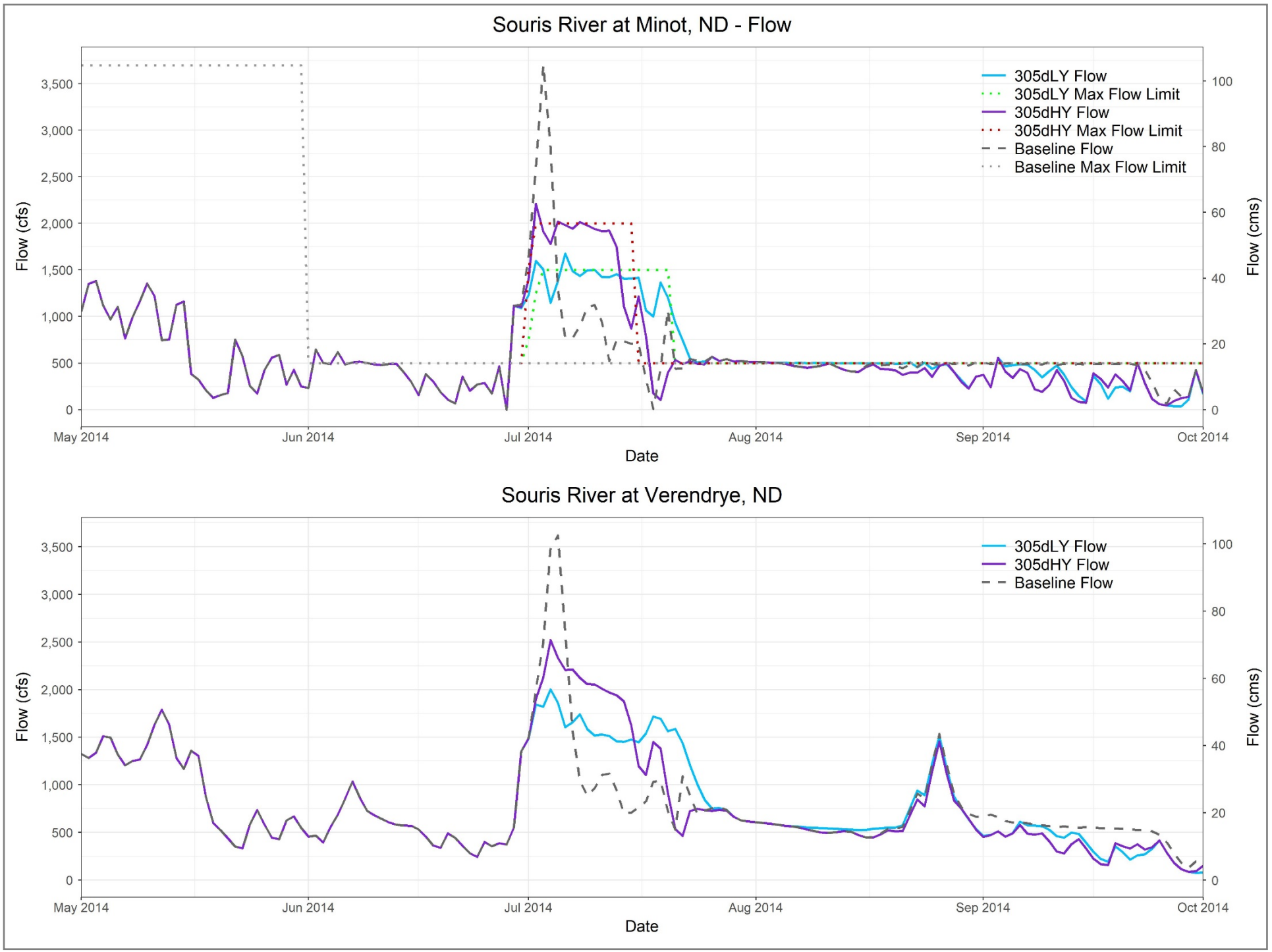
Souris River Plan of Study

***305dLY** = Least aggressive releases (all flow constraints in place)*
***305dHY** = Most aggressive releases (all flow constraints in place)*

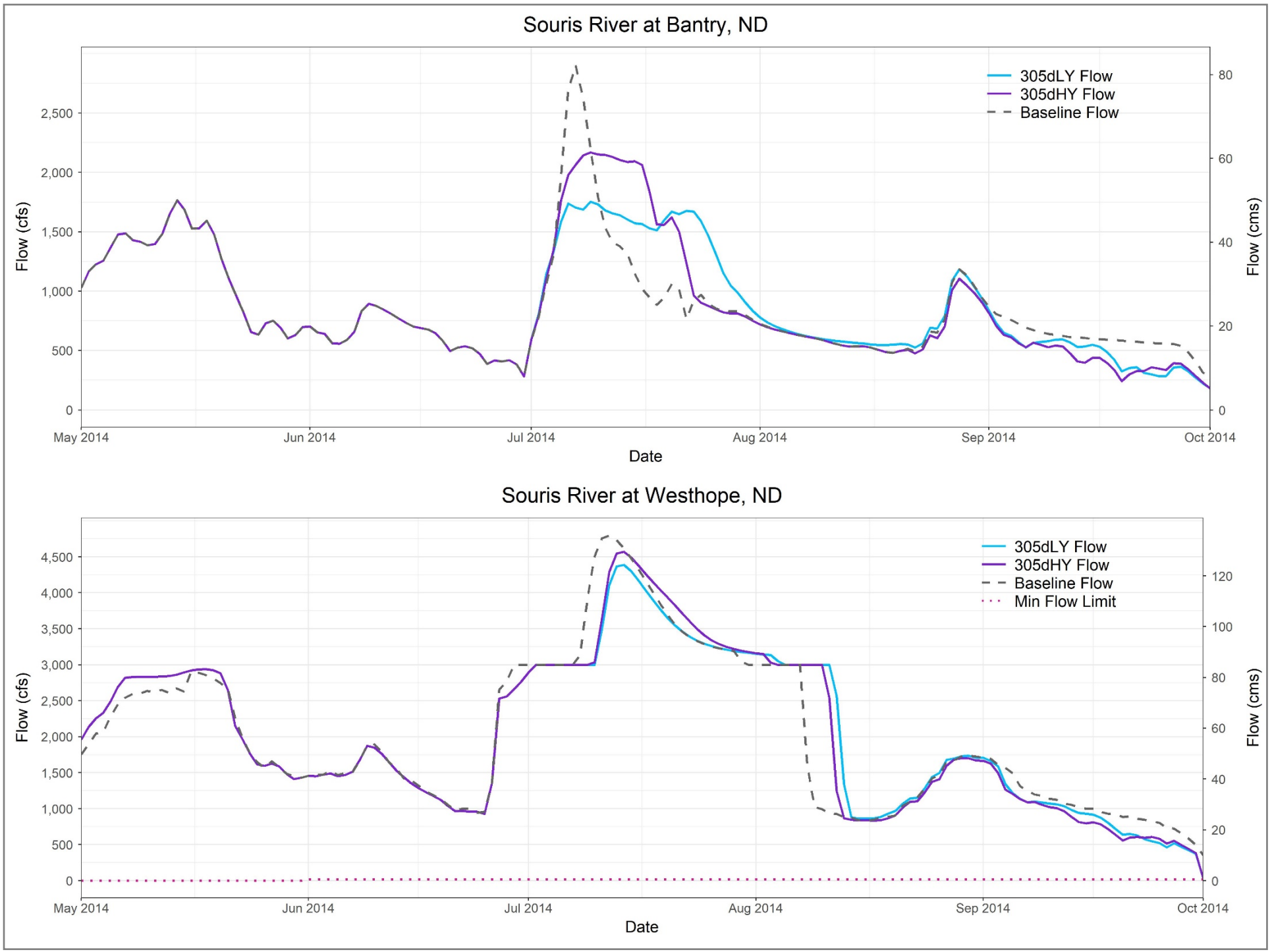




***305dLY** = Least aggressive releases (all flow constraints in place), **305dHY** = Most aggressive releases (all flow constraints in place)*

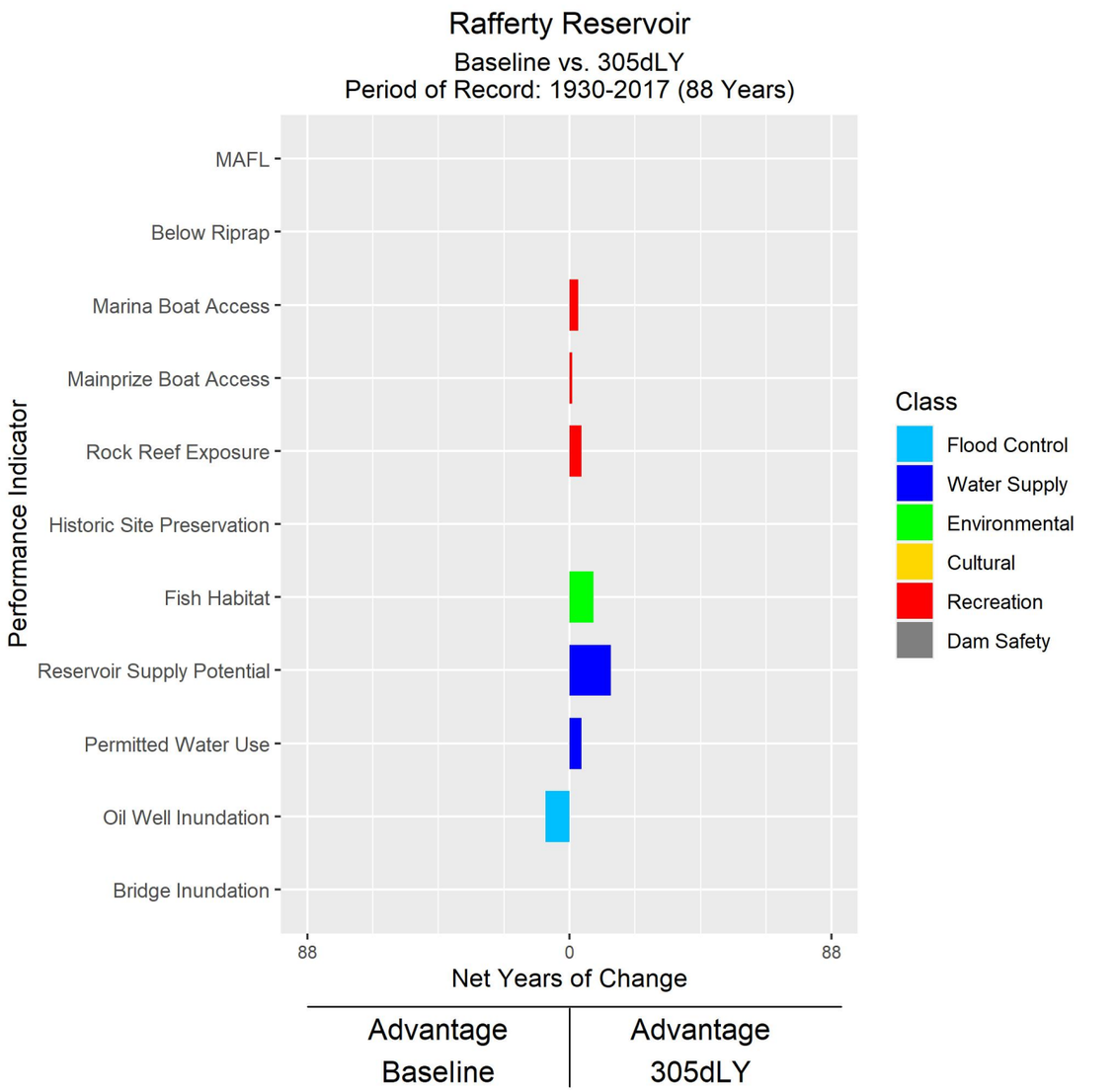


***305dLY** = Least aggressive releases (all flow constraints in place), **305dHY** = Most aggressive releases (all flow constraints in place)*



***305dLY** = Least aggressive releases (all flow constraints in place), **305dHY** = Most aggressive releases (all flow constraints in place)*

Plate 09	Performance Indicators – 1930-2017	Alternative 305 (Phase 3)

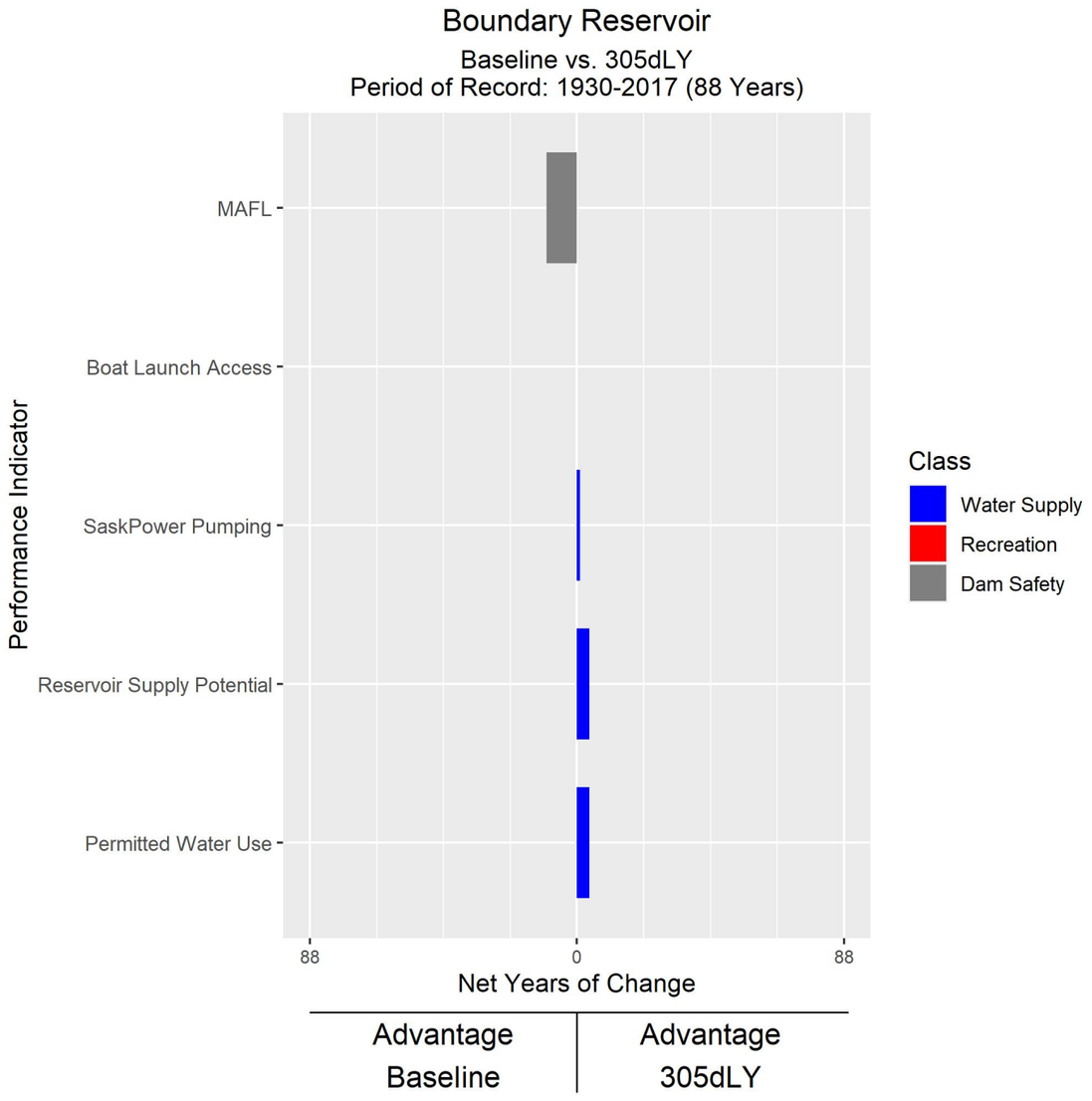


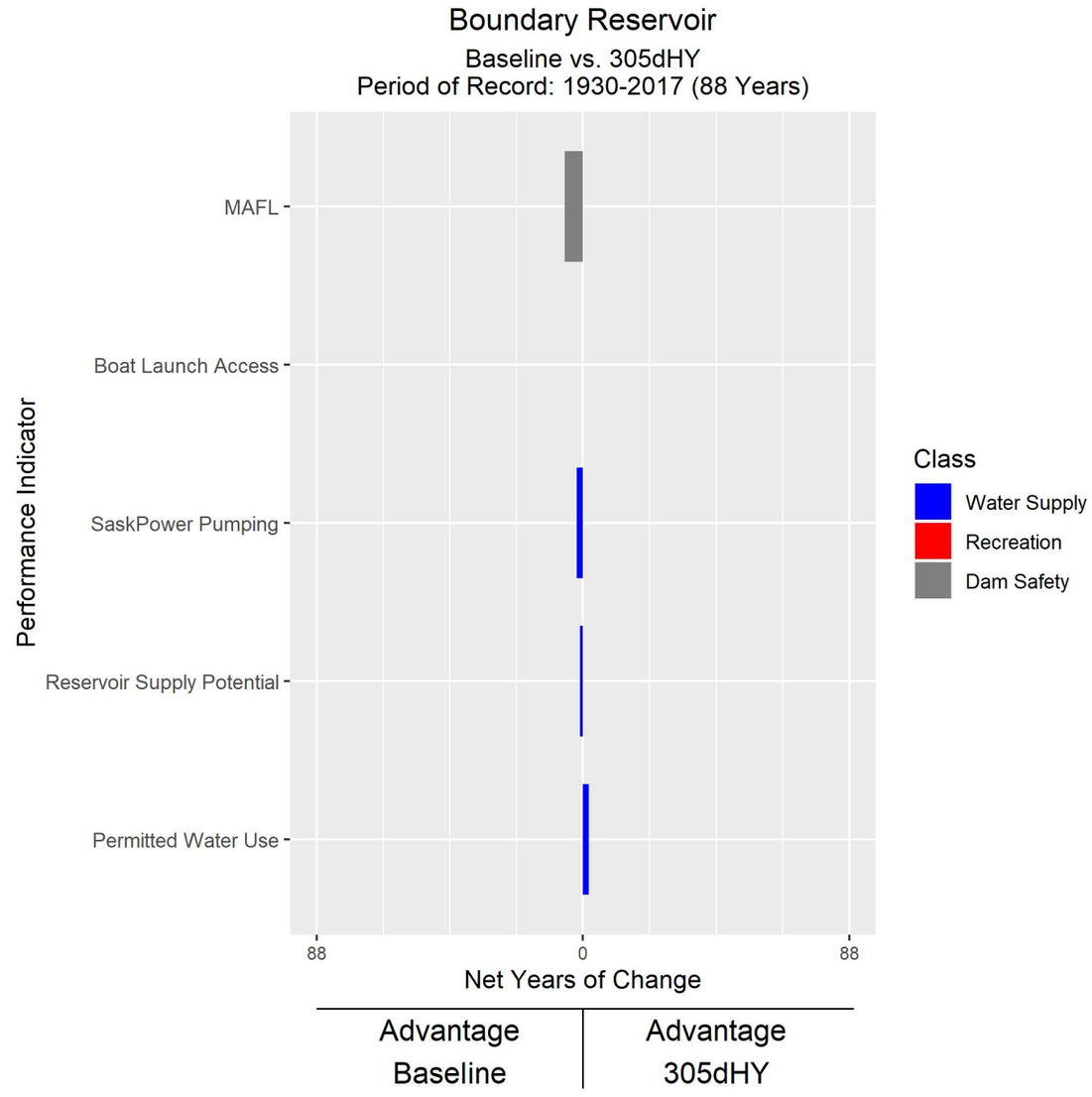
Alternative 305dLY

- Less aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months

Alternative 305dHY

- Highly aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months



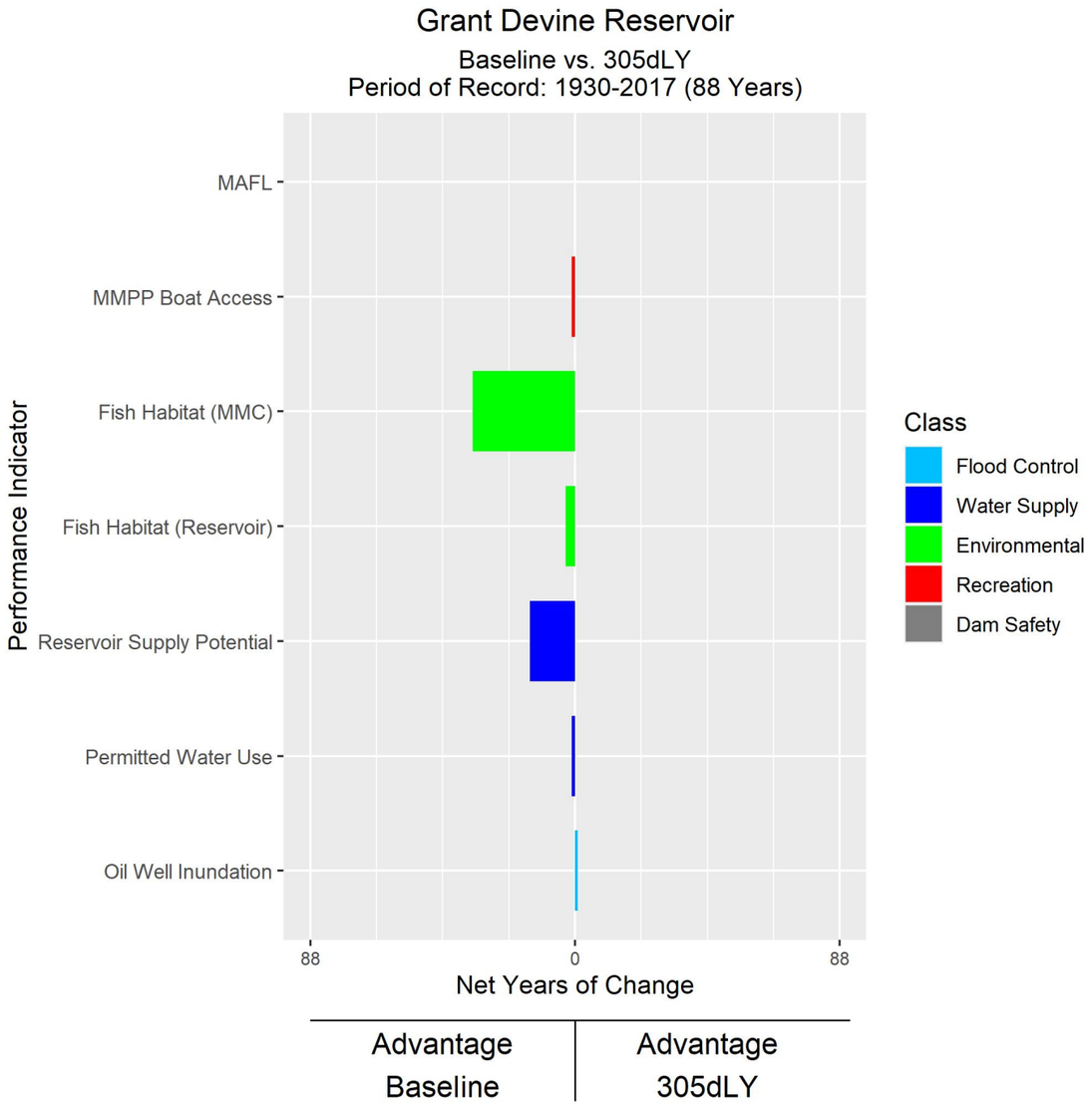


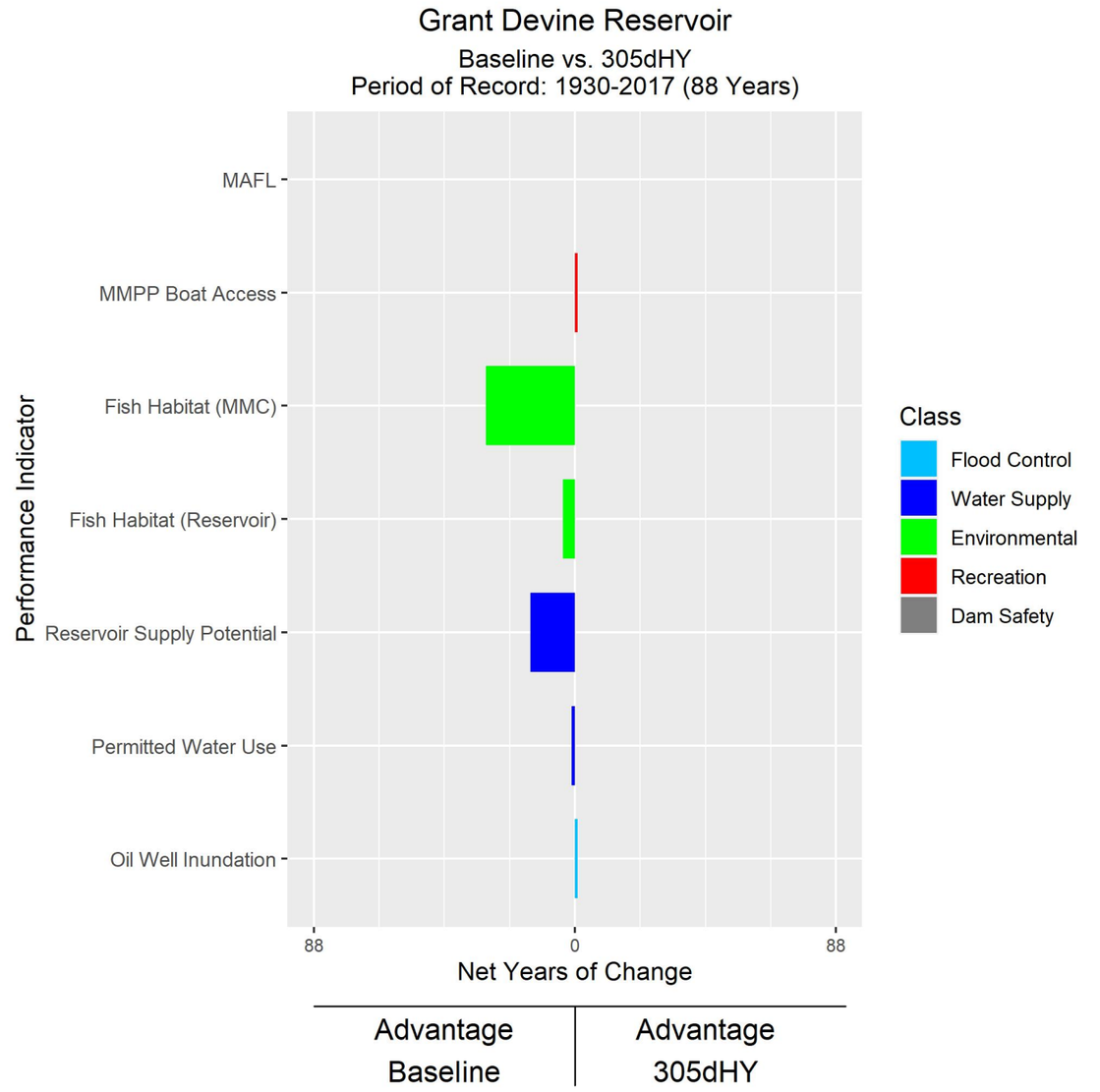
Alternative 305dLY

- Less aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months

Alternative 305dHY

- Highly aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months



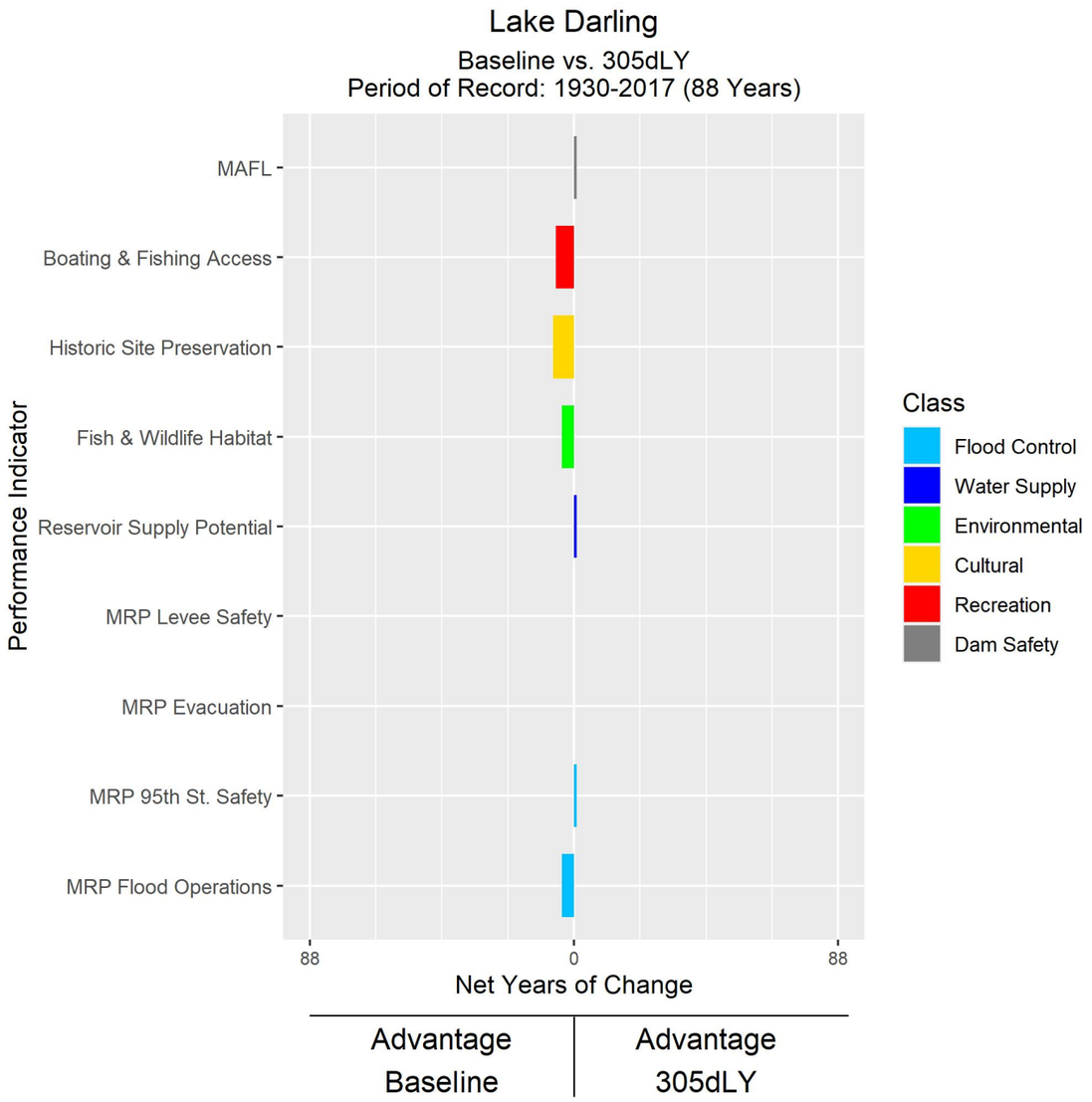


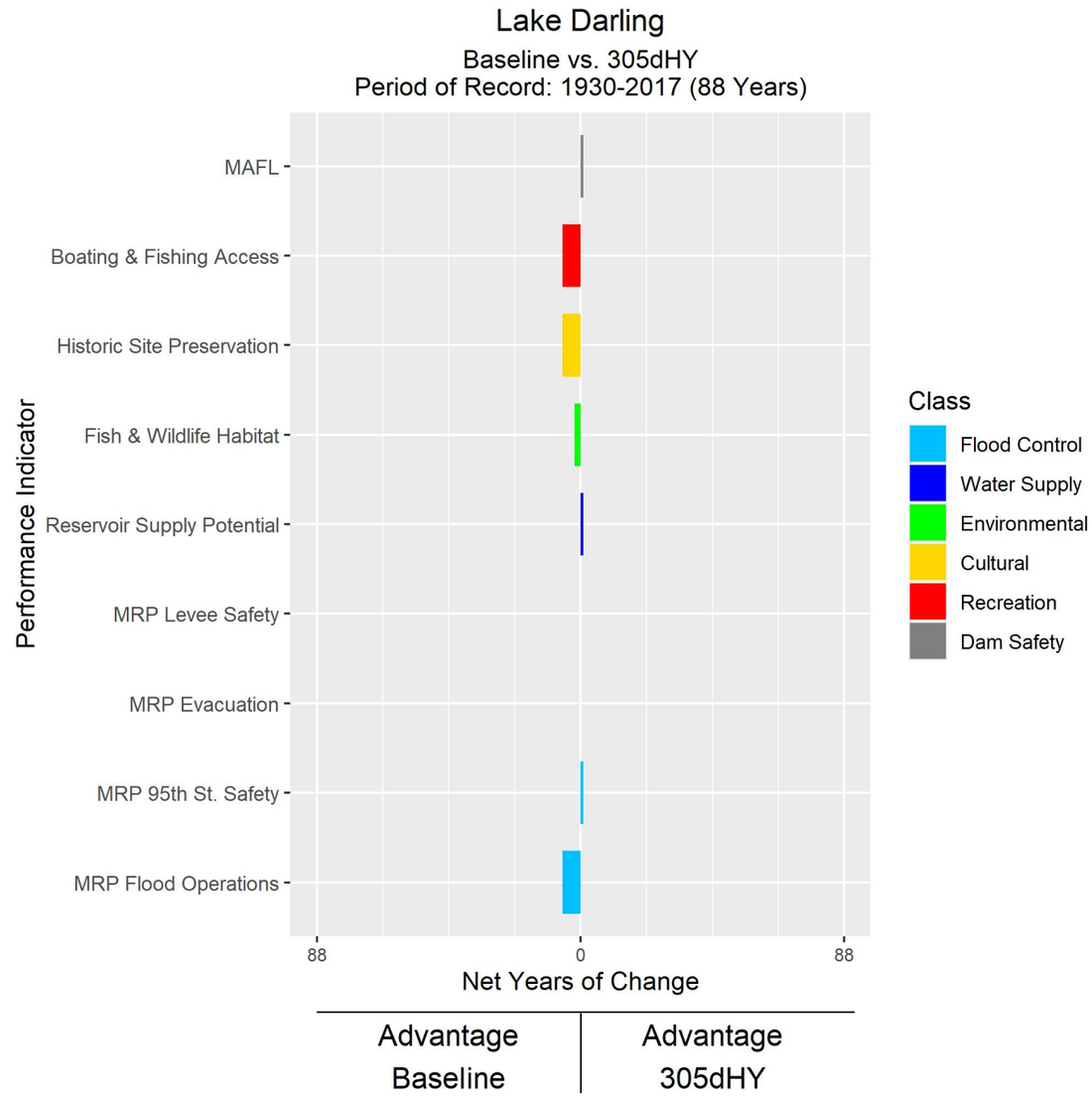
Alternative 305dLY

- Less aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months

Alternative 305dHY

- Highly aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months



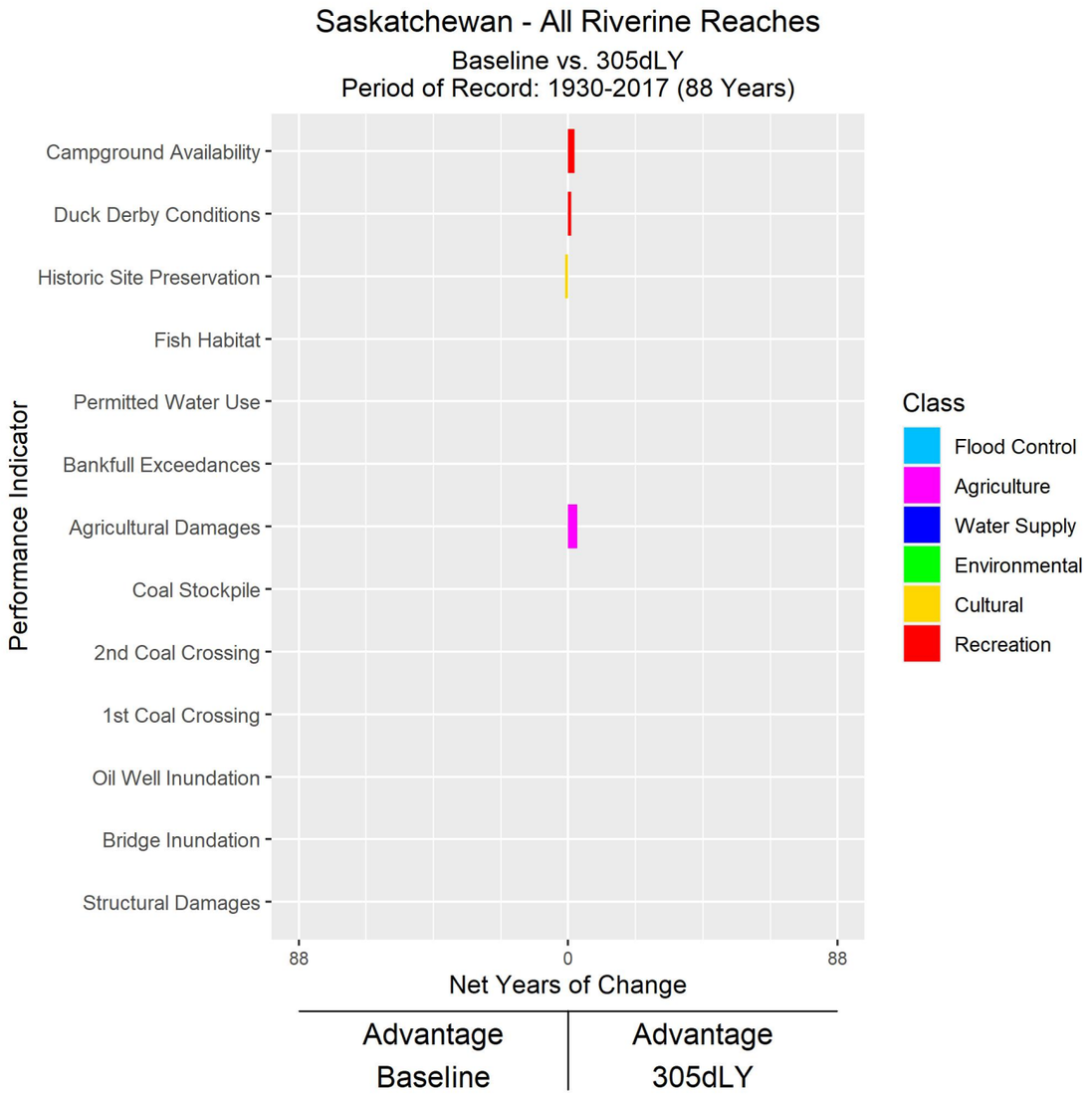


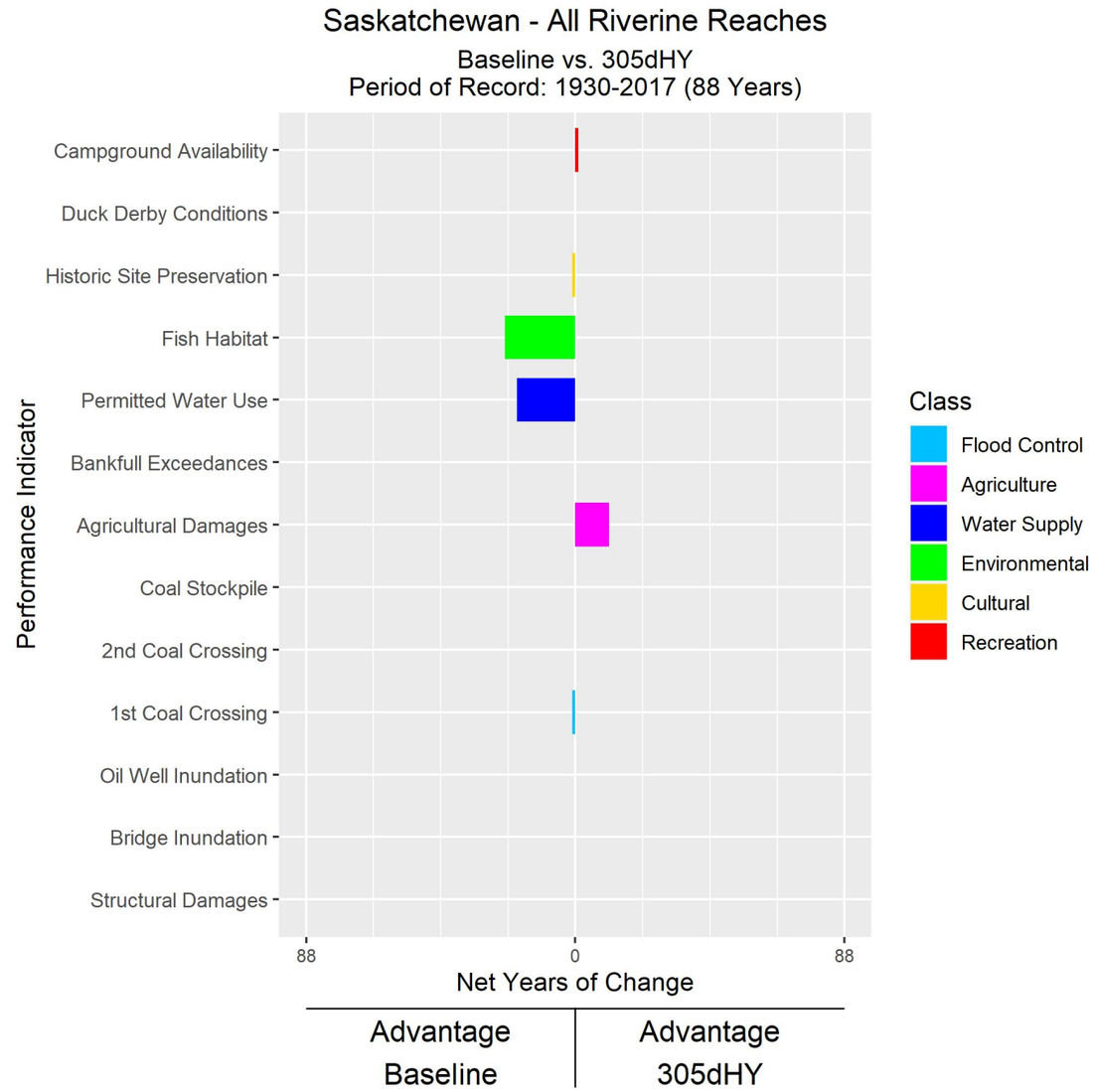
Alternative 305dLY

- Less aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months

Alternative 305dHY

- Highly aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months



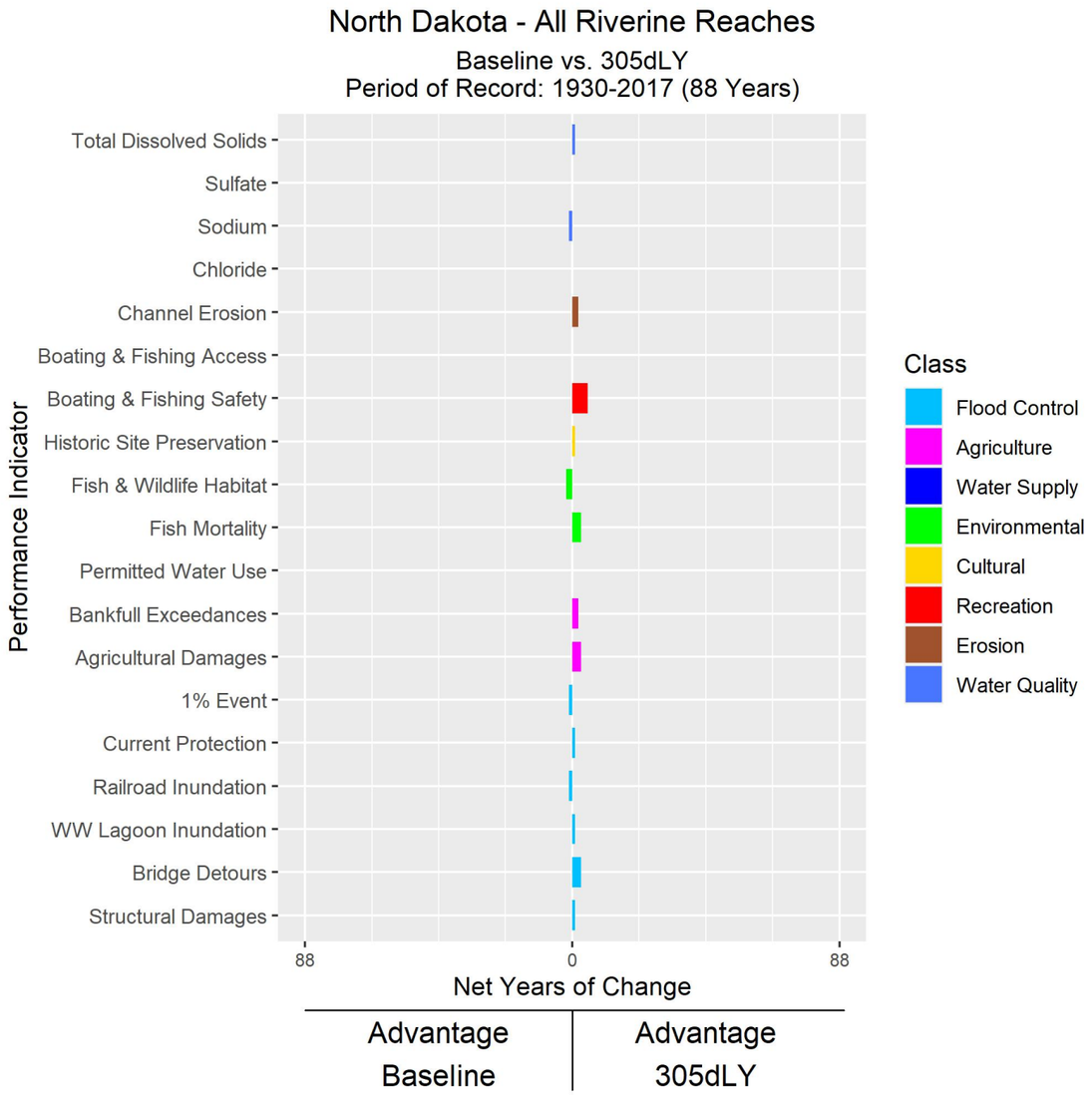


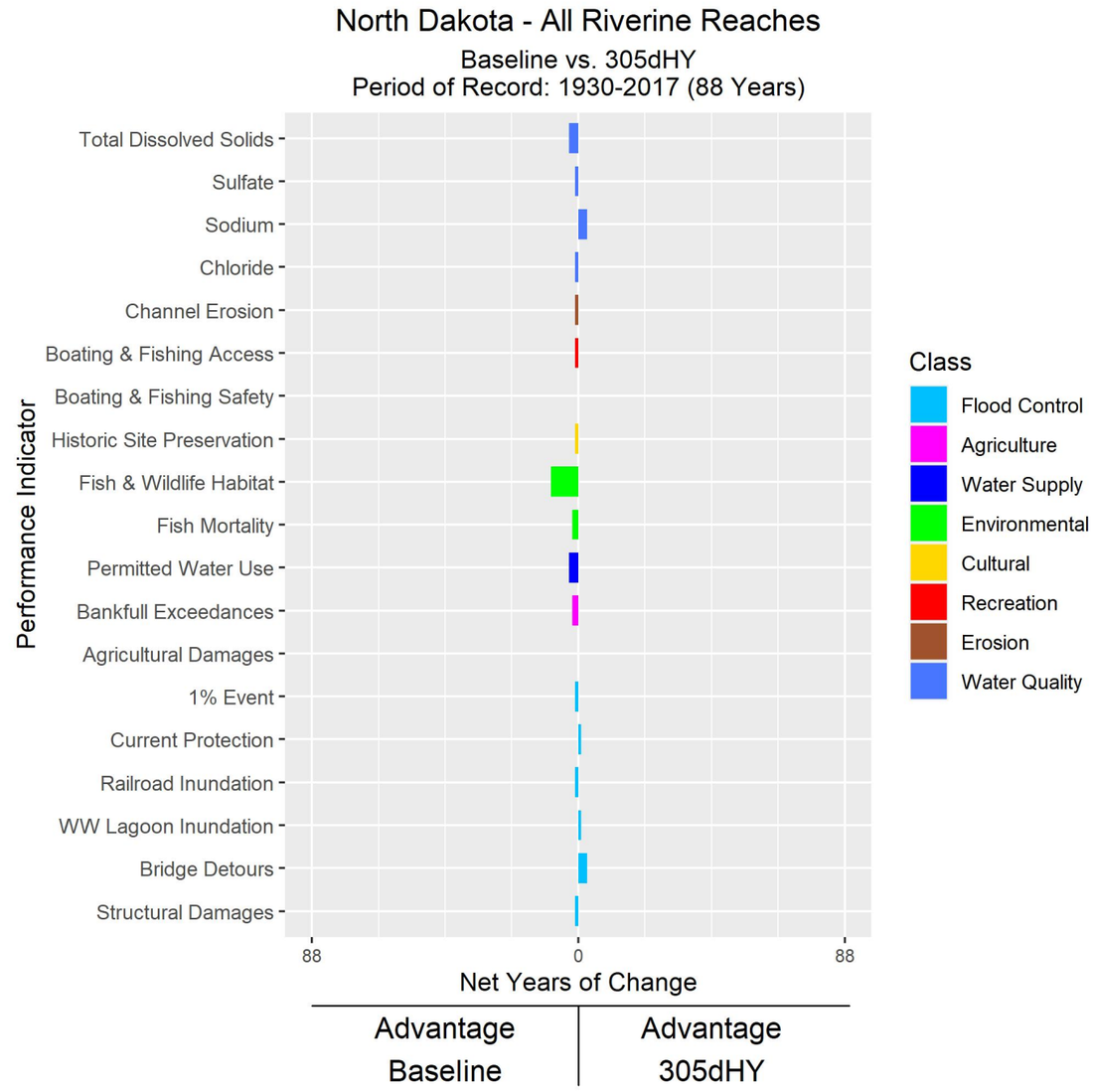
Alternative 305dLY

- Less aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months

Alternative 305dHY

- Highly aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months



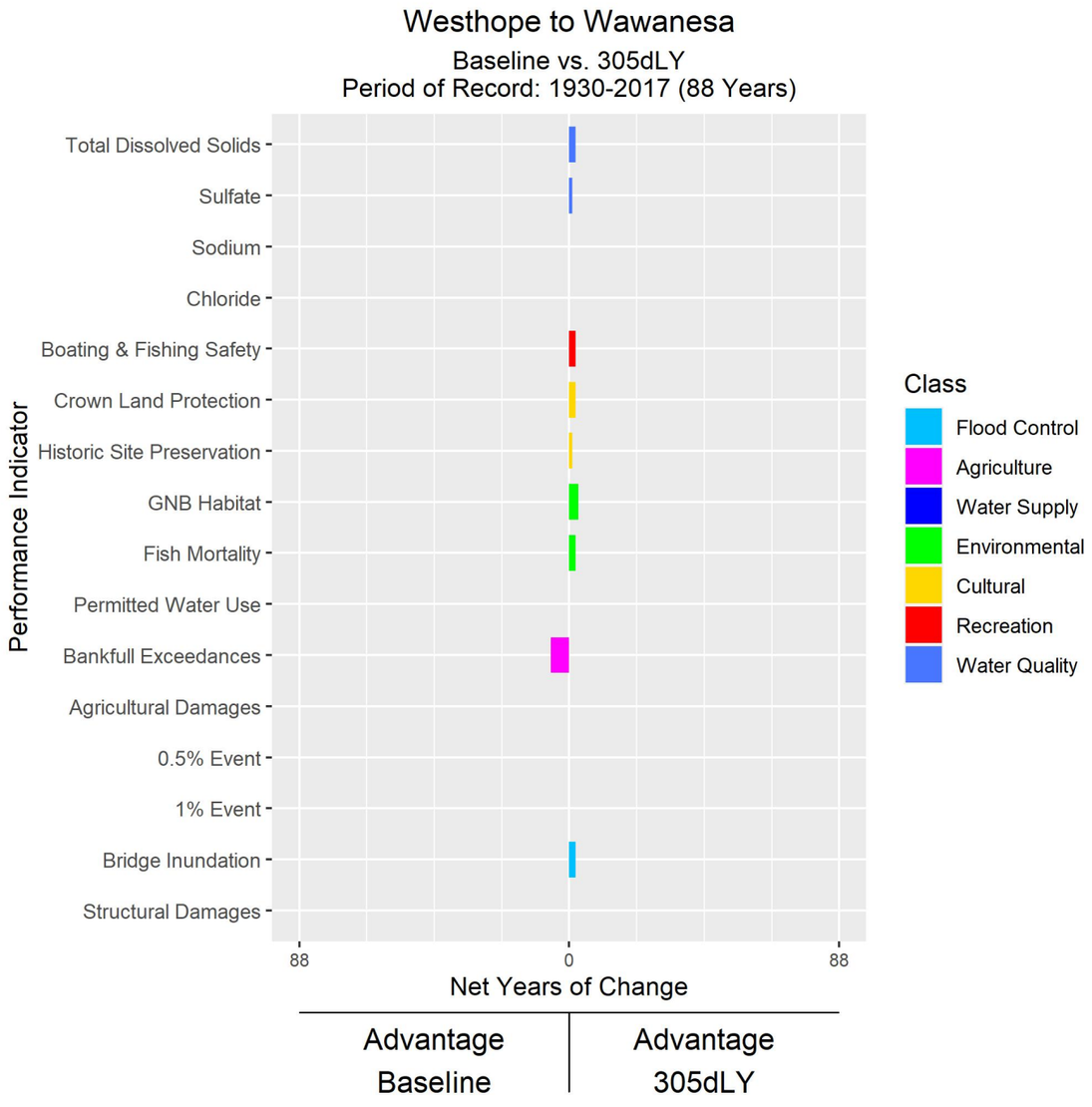


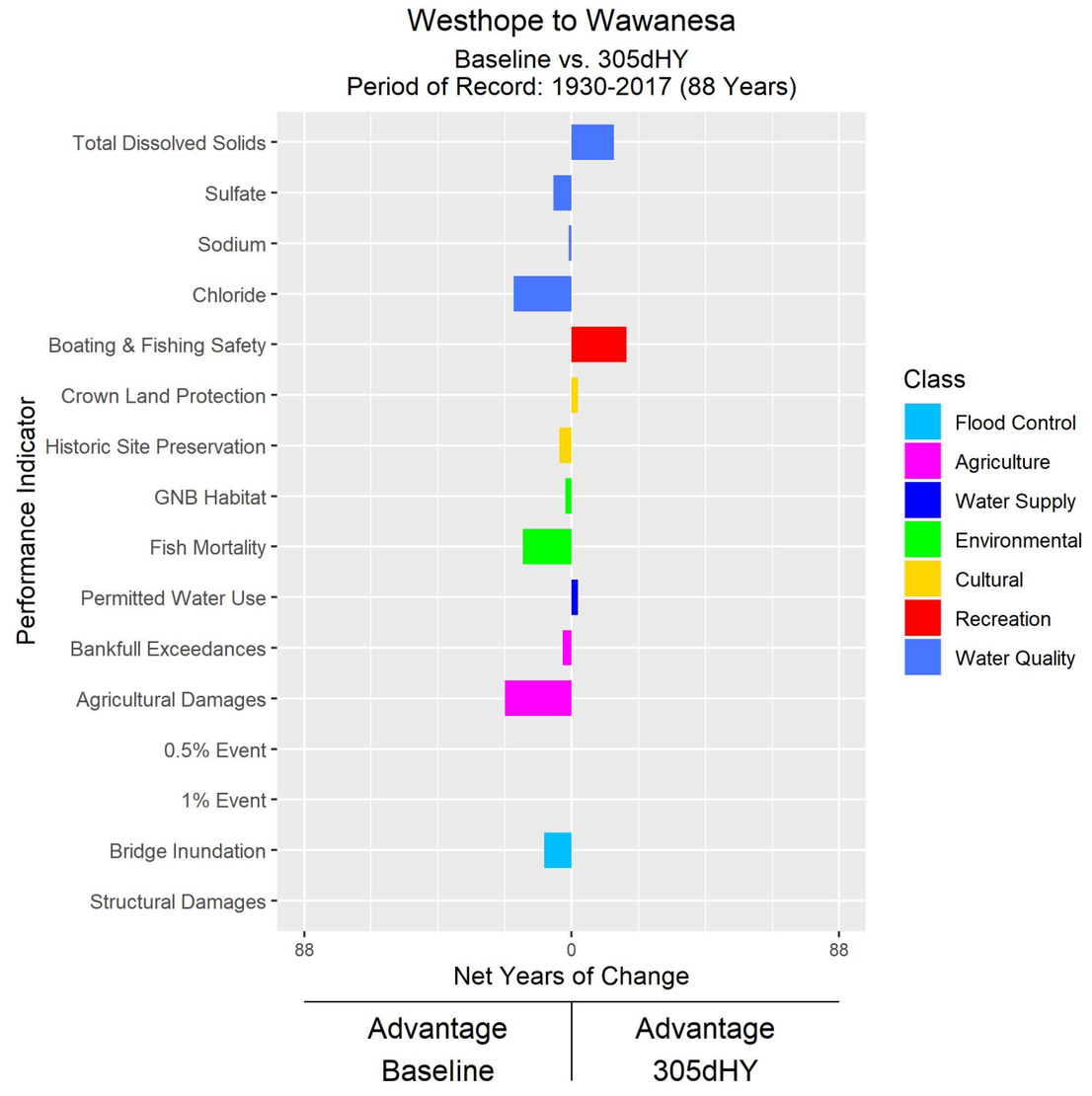
Alternative 305dLY

- Less aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months

Alternative 305dHY

- Highly aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months



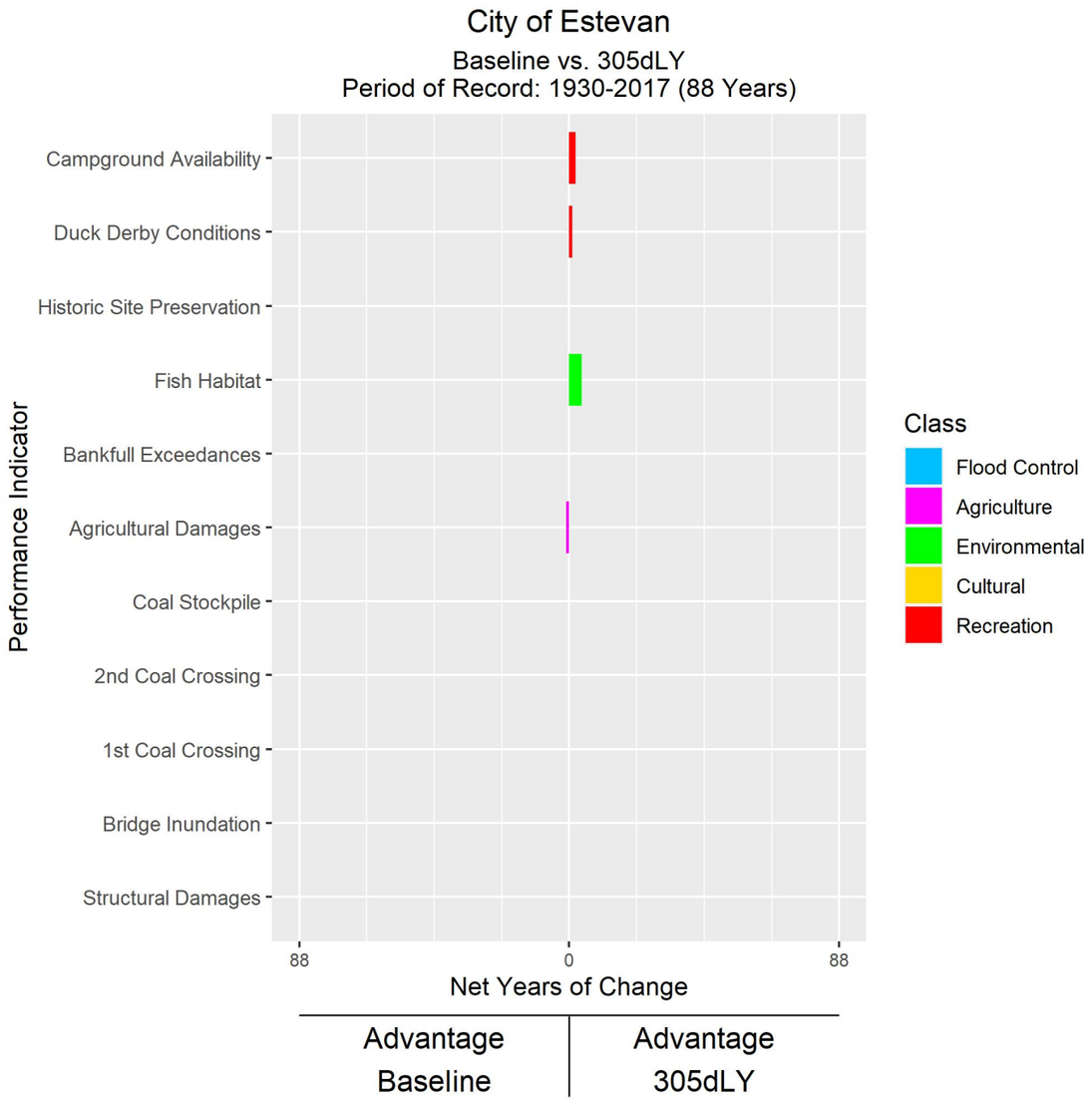


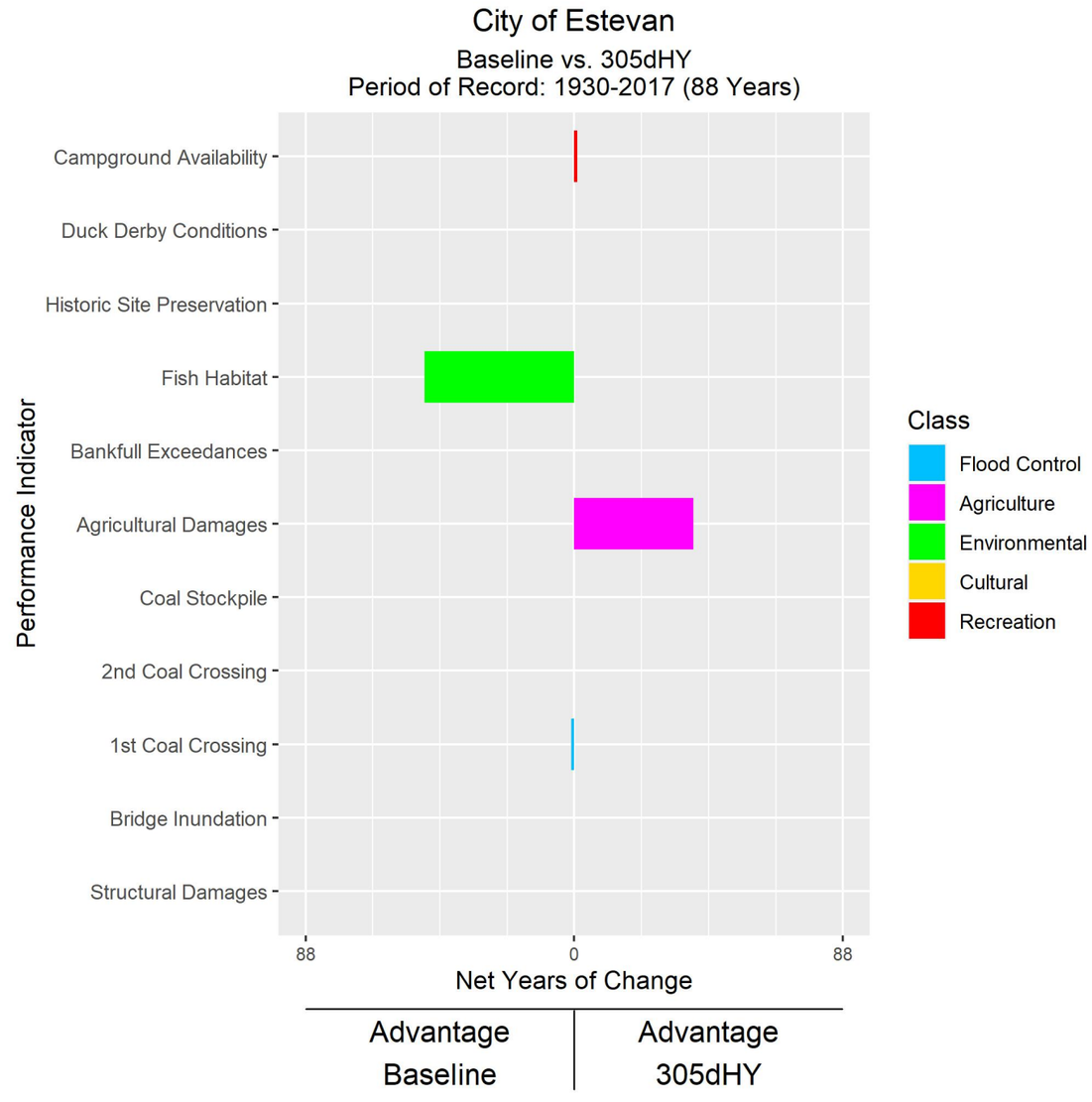
Alternative 305dLY

- Less aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months

Alternative 305dHY

- Highly aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months



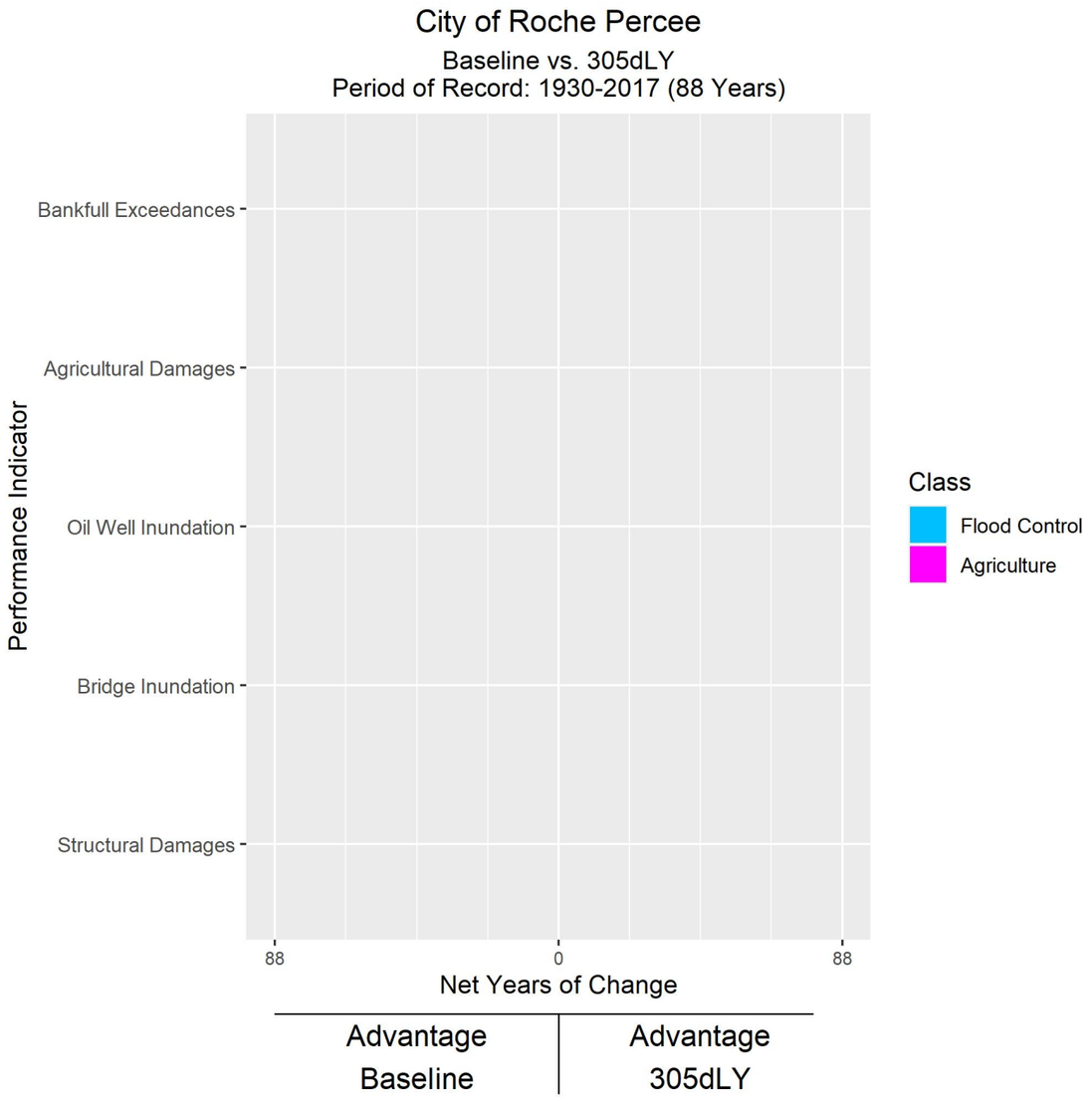


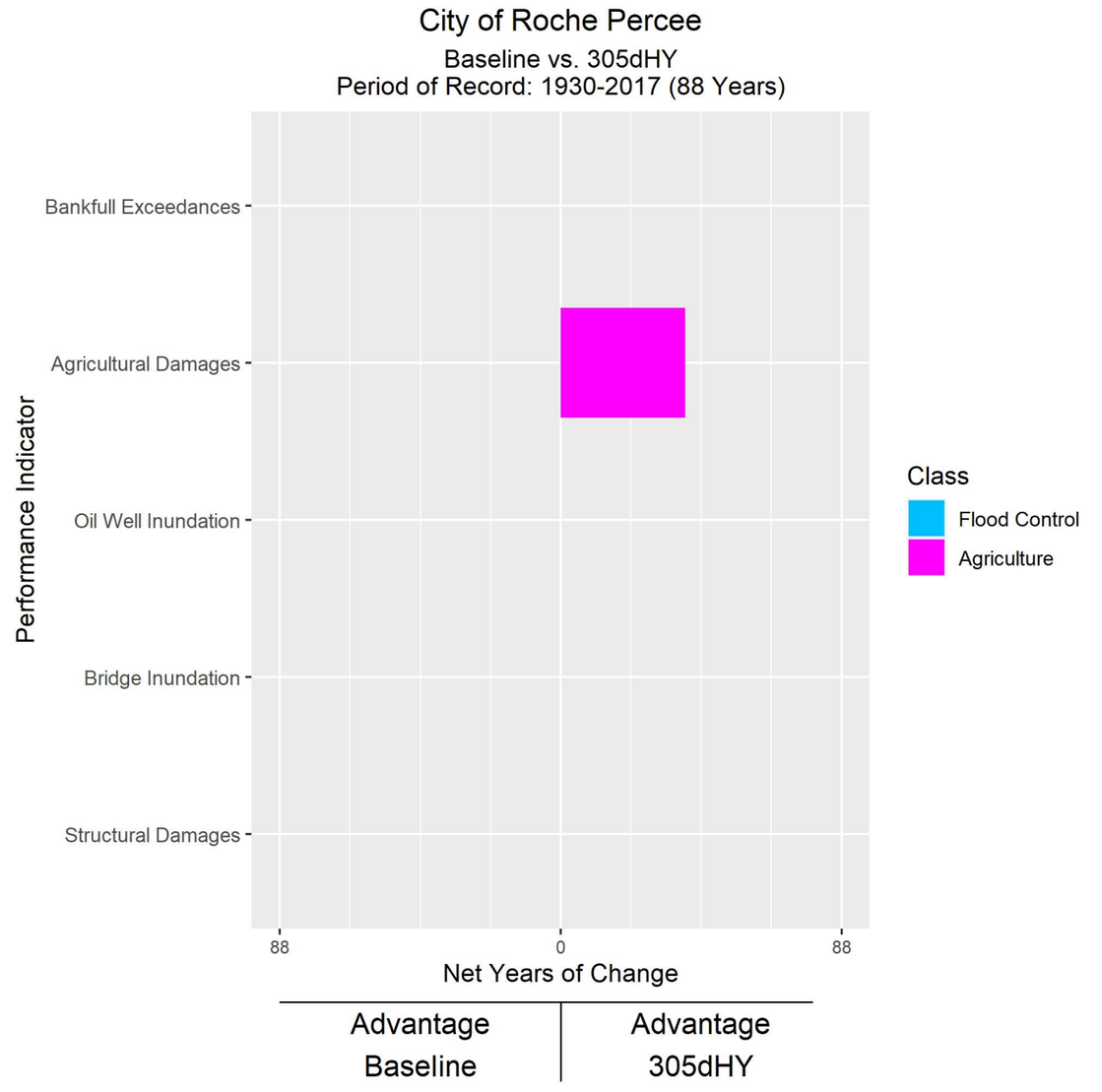
Alternative 305dLY

- Less aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months

Alternative 305dHY

- Highly aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months



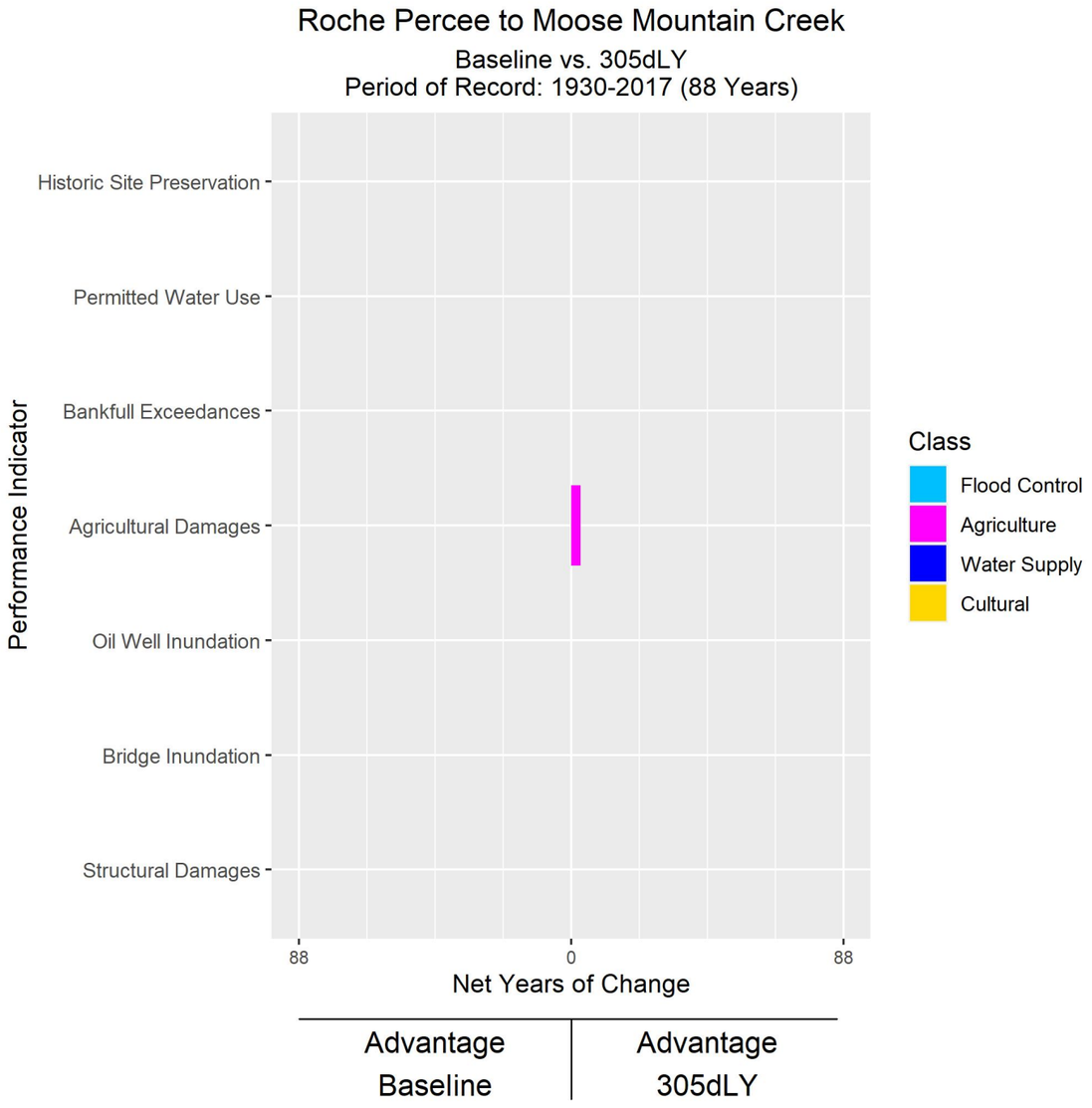


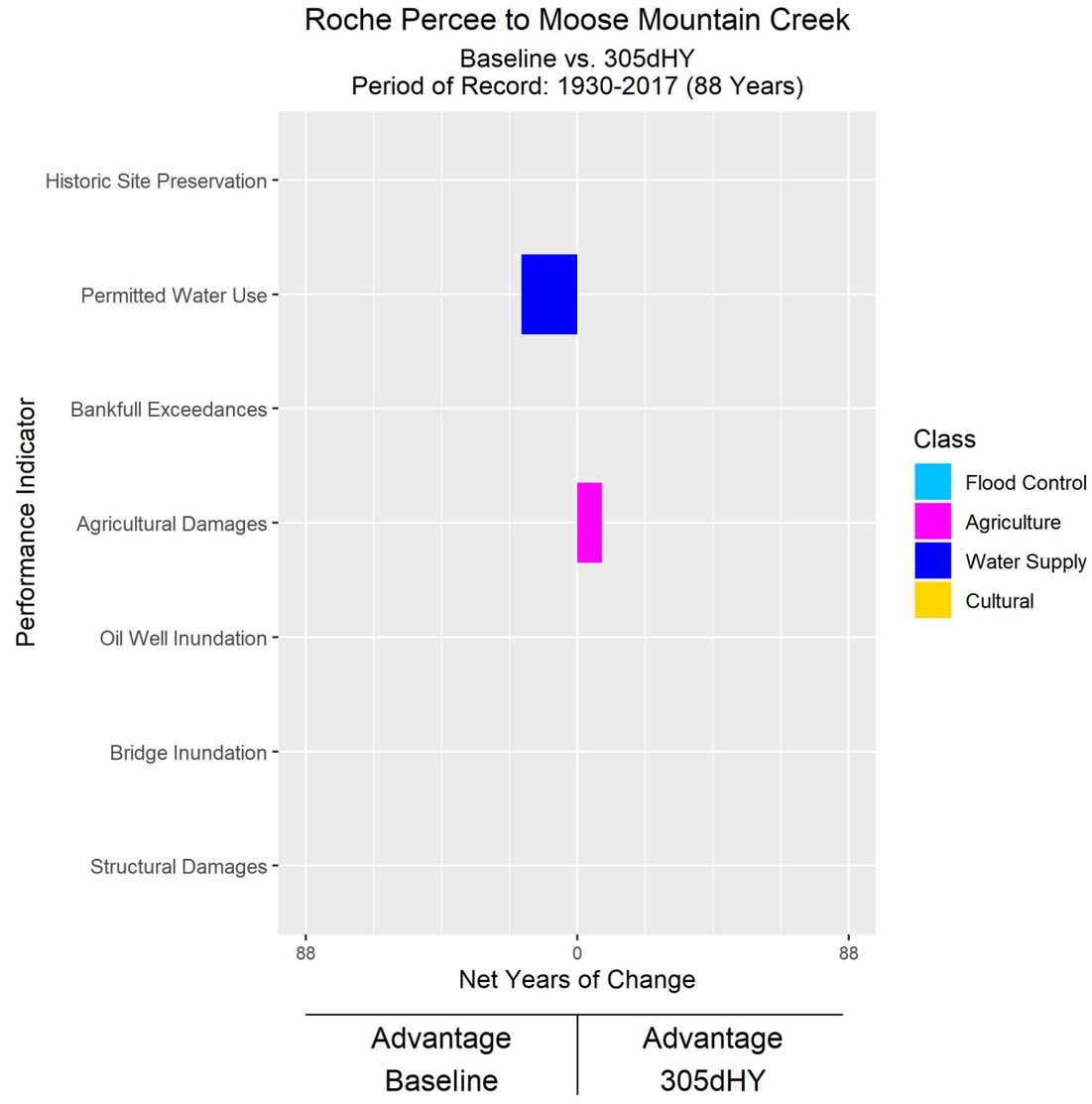
Alternative 305dLY

- Less aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months

Alternative 305dHY

- Highly aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months



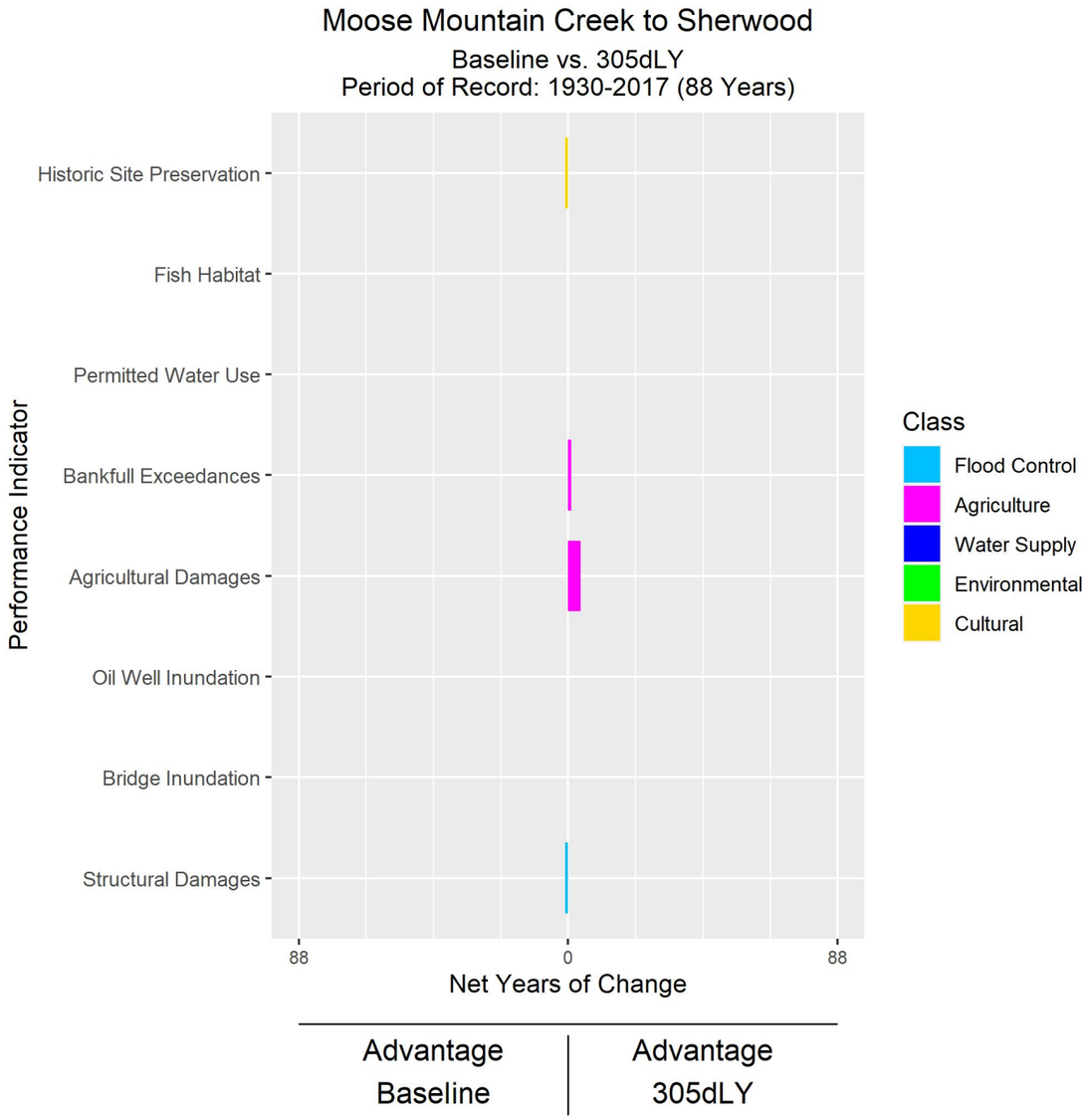


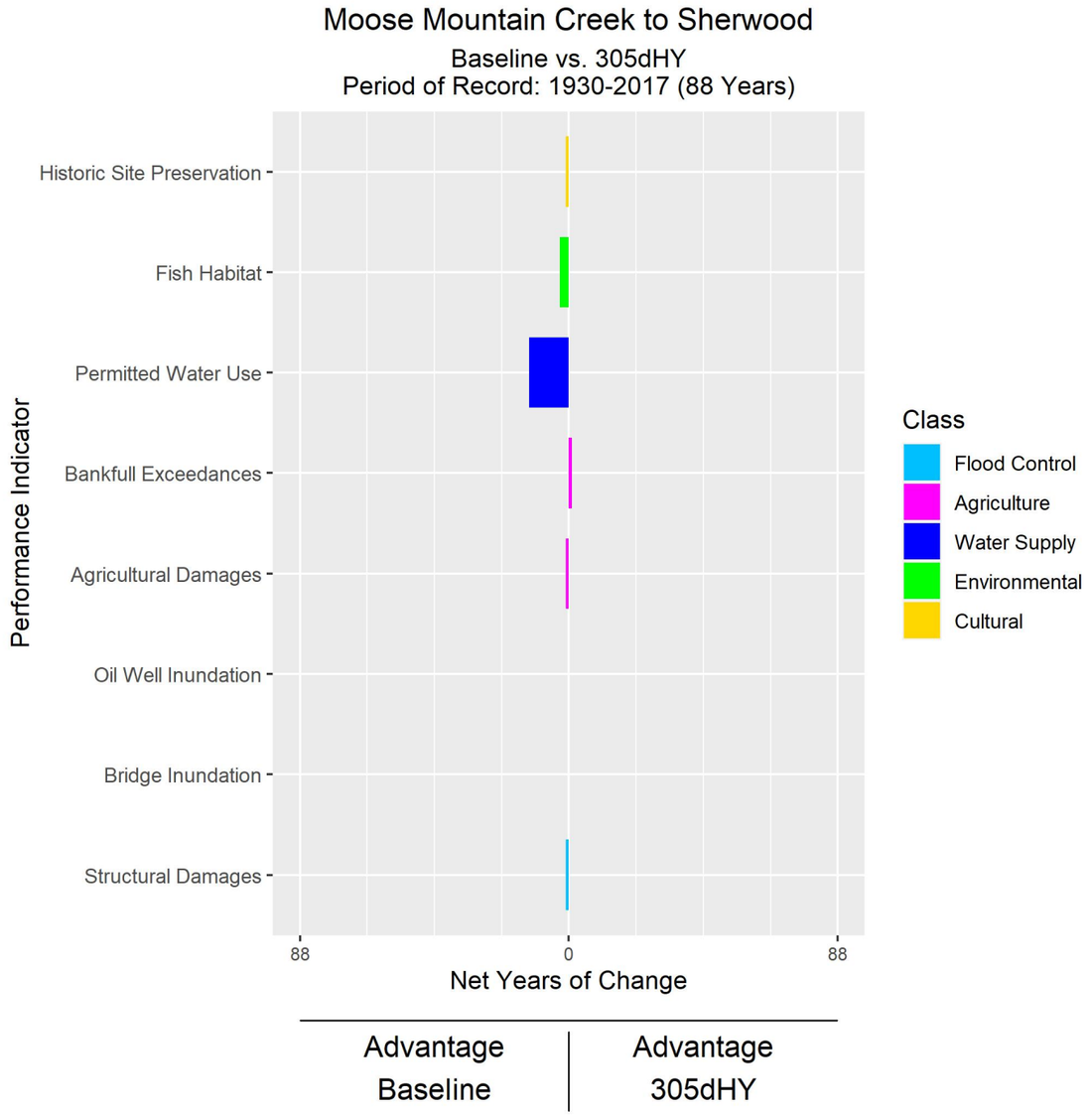
Alternative 305dLY

- Less aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months

Alternative 305dHY

- Highly aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months



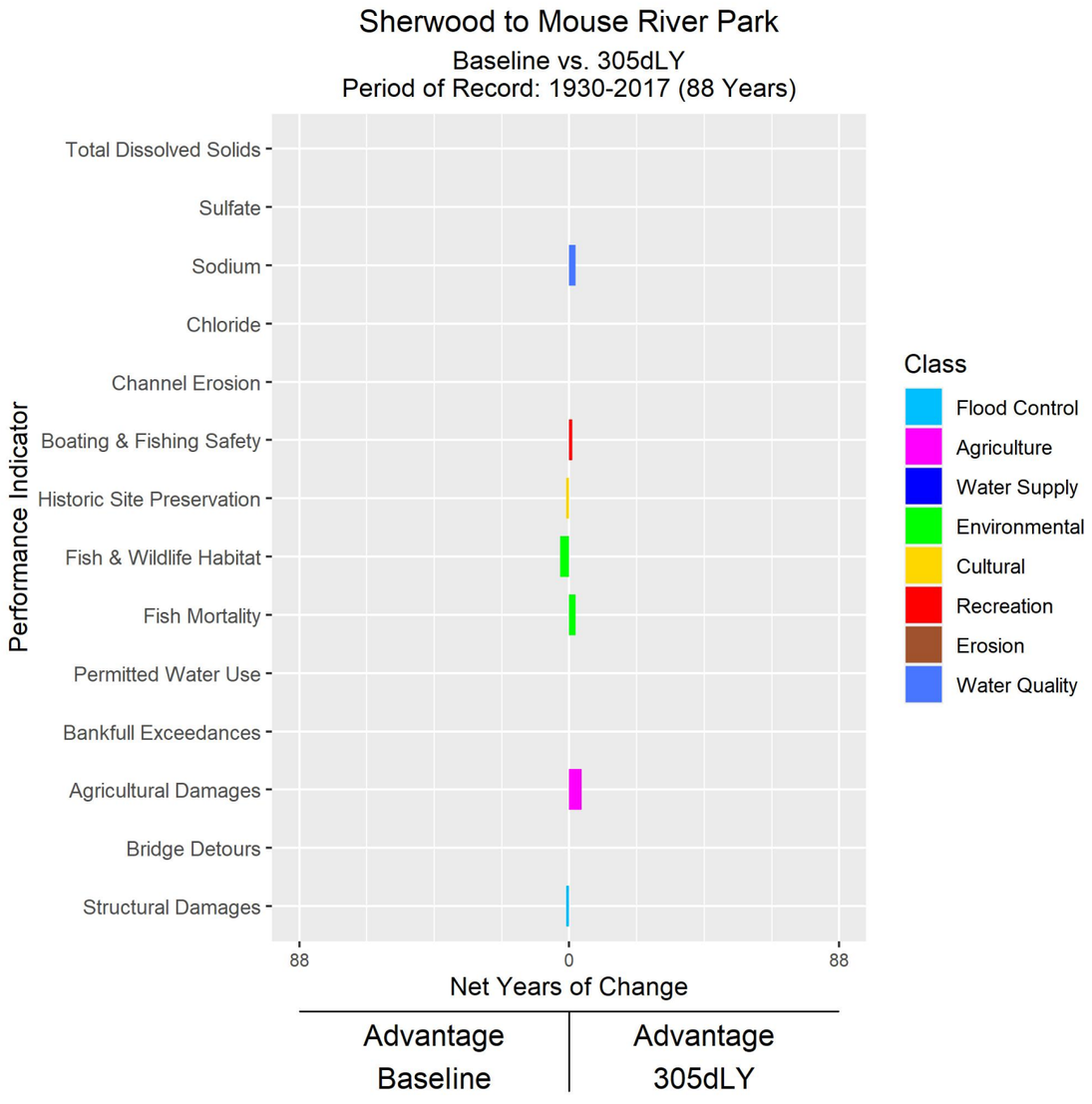


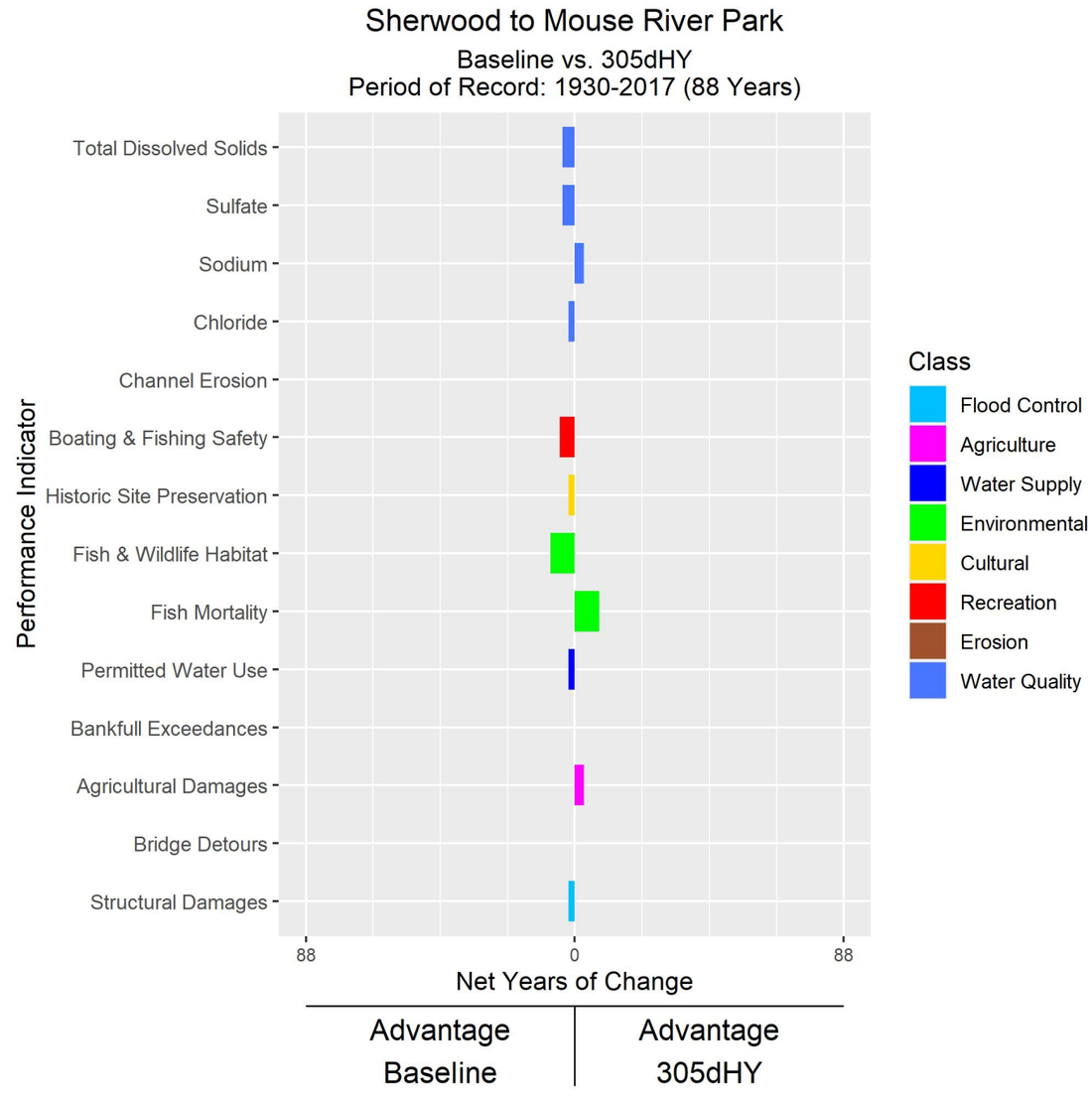
Alternative 305dLY

- Less aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months

Alternative 305dHY

- Highly aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months



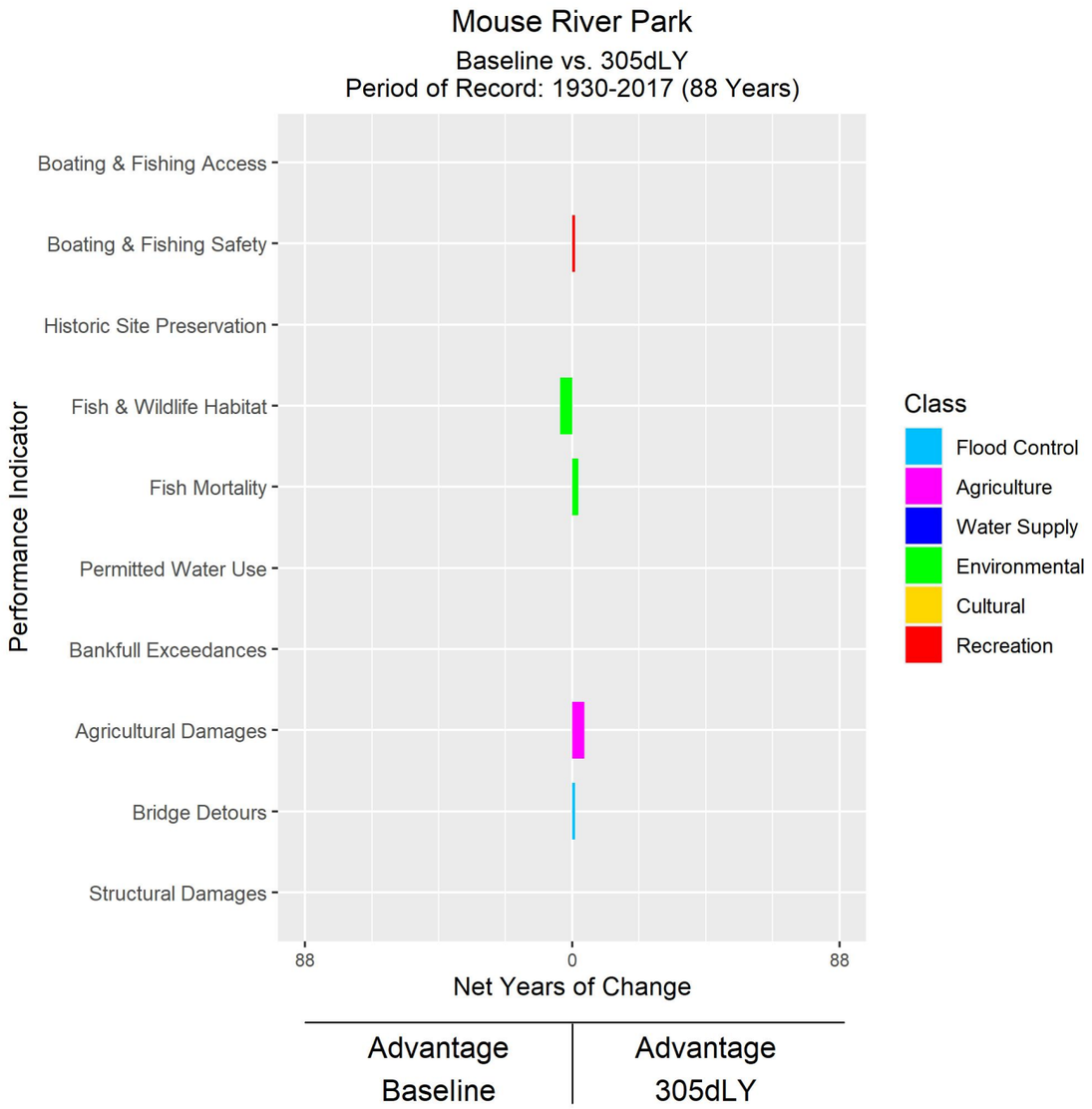


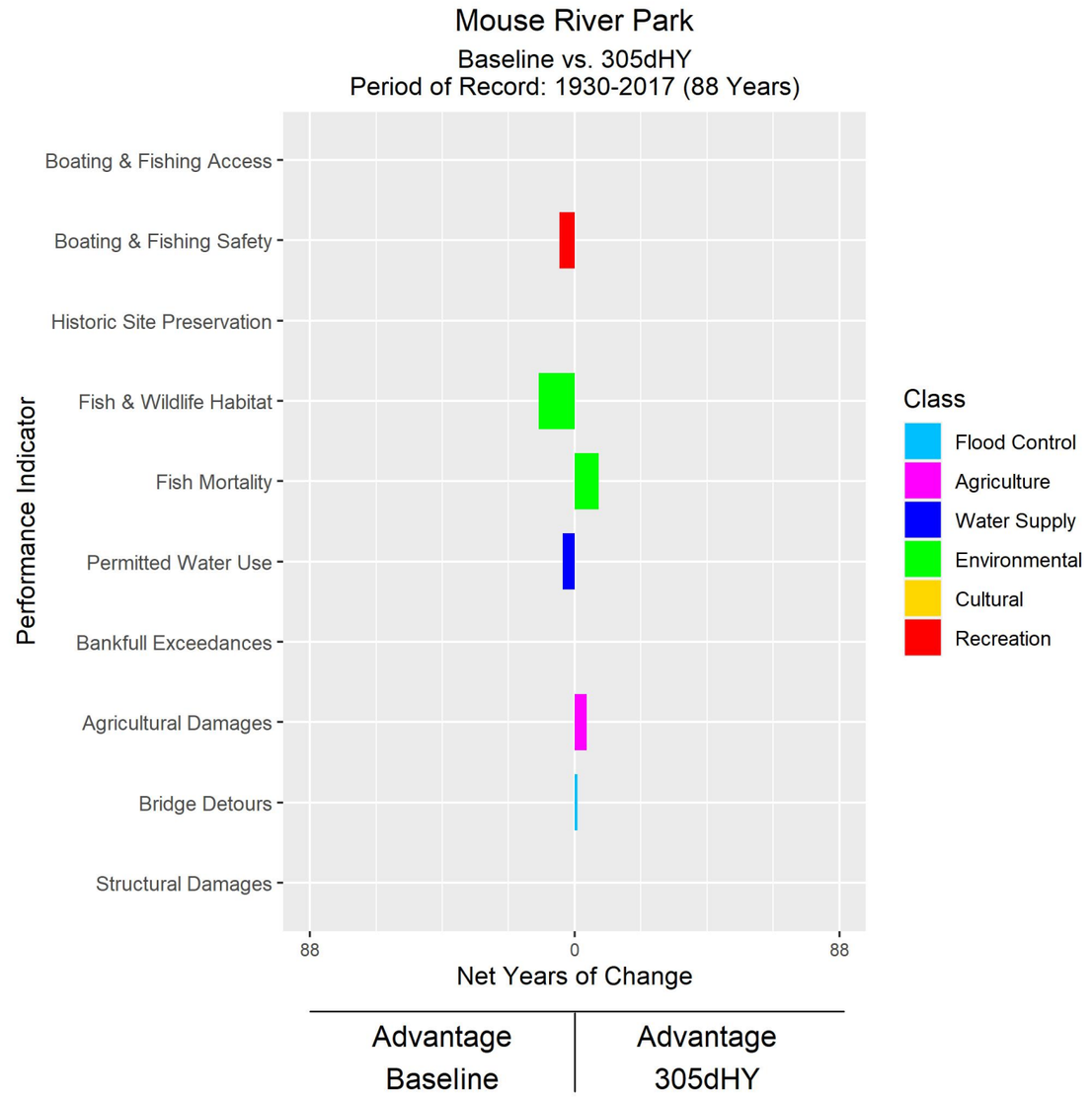
Alternative 305dLY

- Less aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months

Alternative 305dHY

- Highly aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months



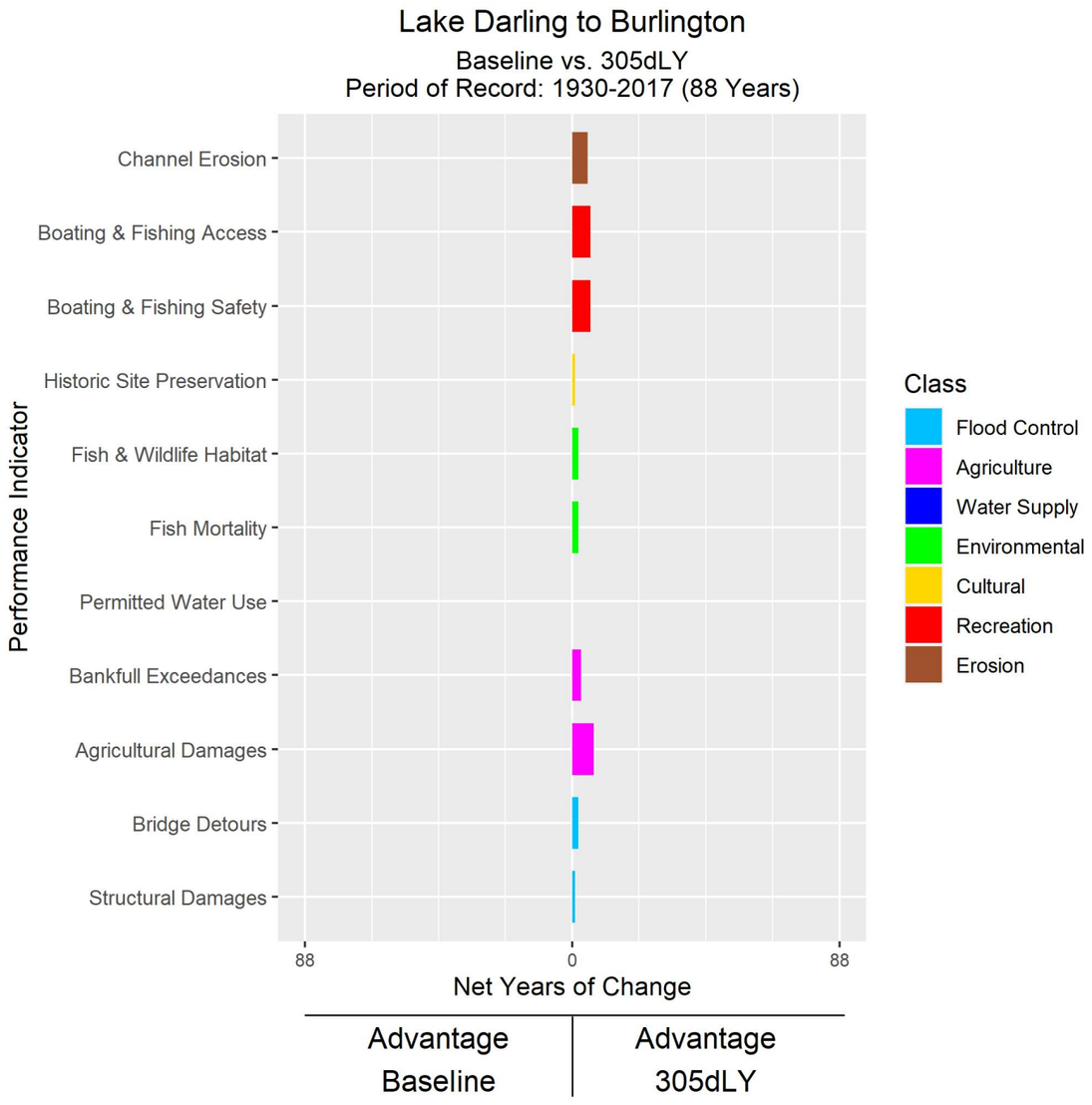


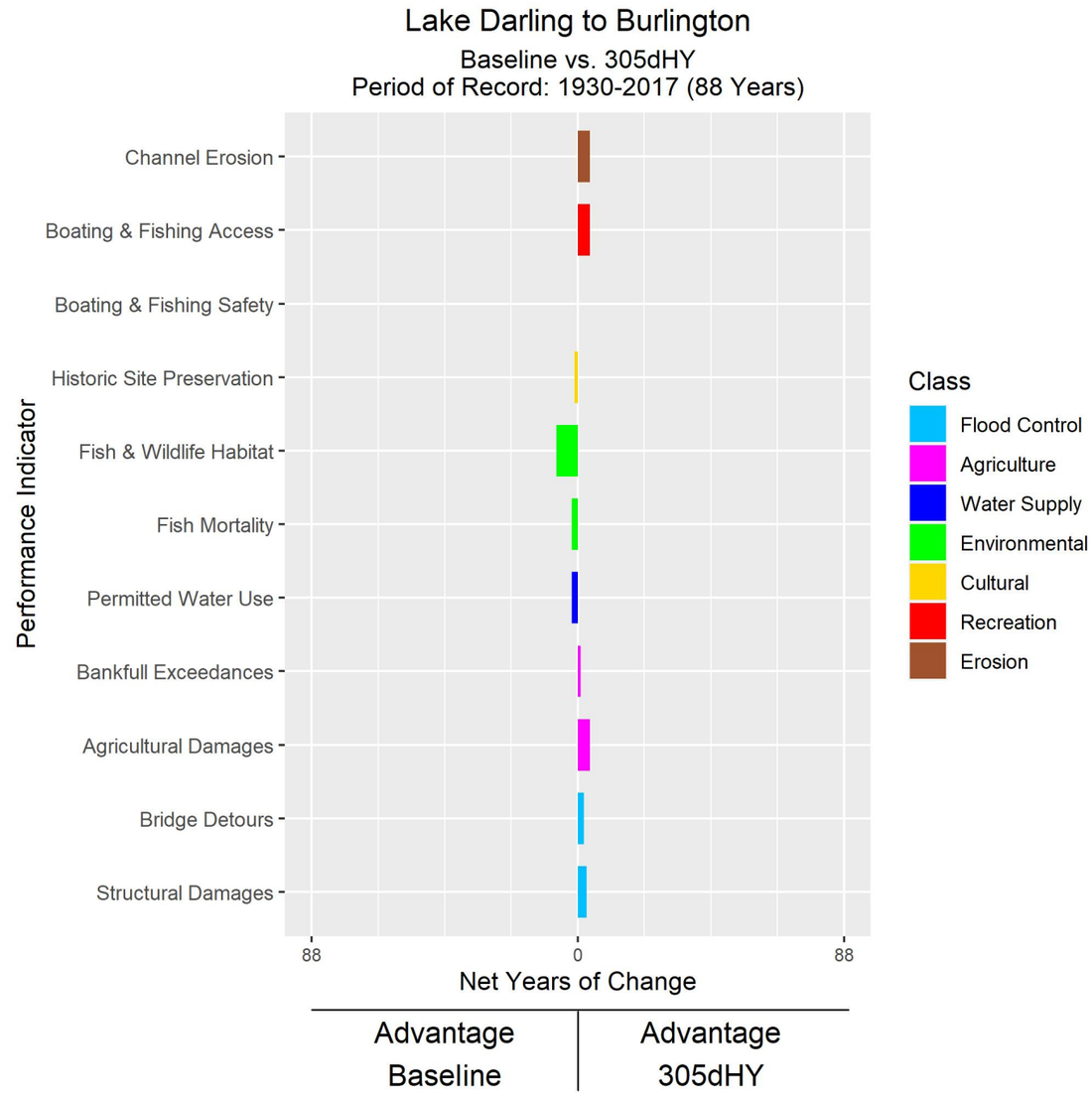
Alternative 305dLY

- Less aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months

Alternative 305dHY

- Highly aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months



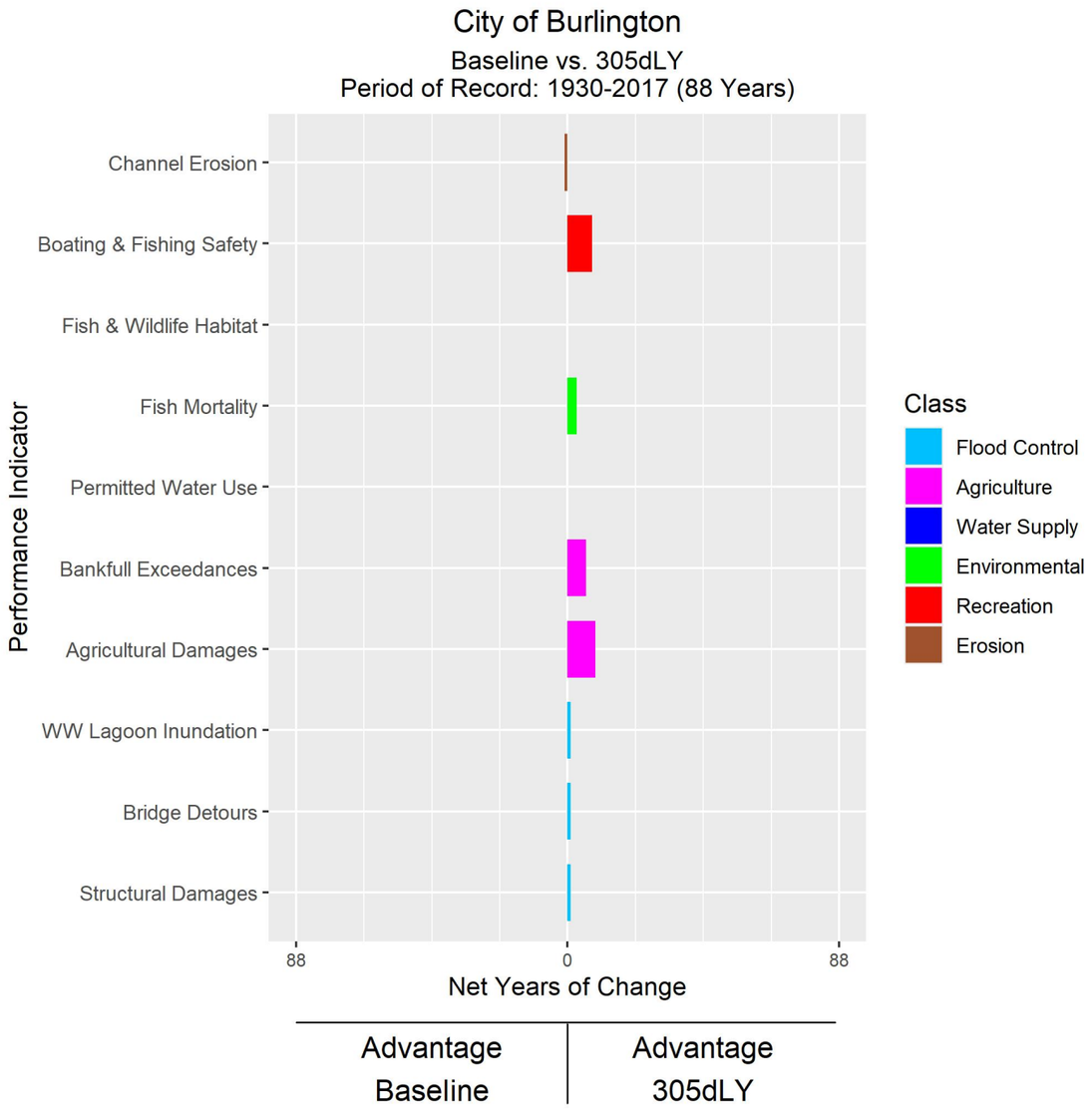


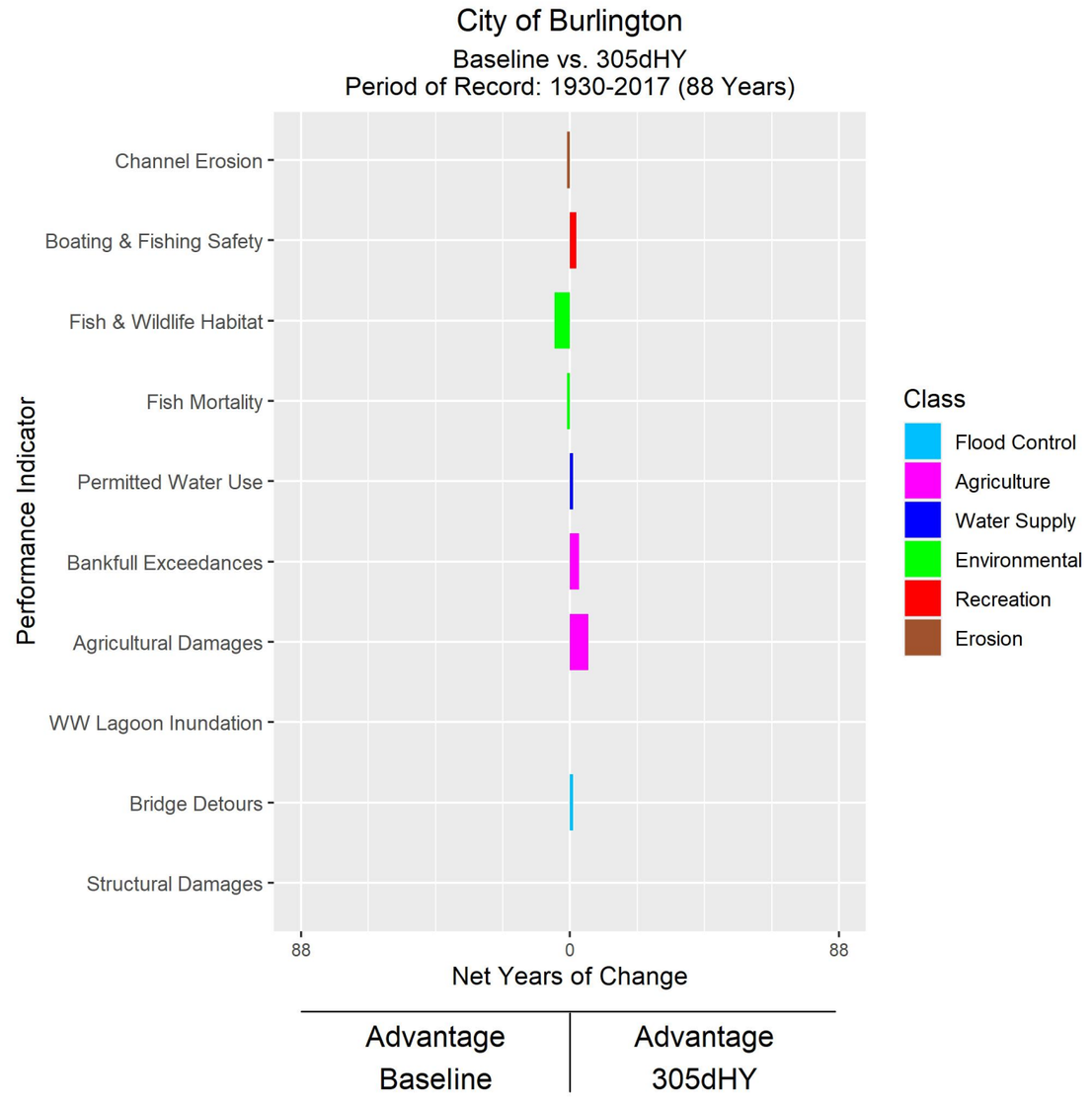
Alternative 305dLY

- Less aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months

Alternative 305dHY

- Highly aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months



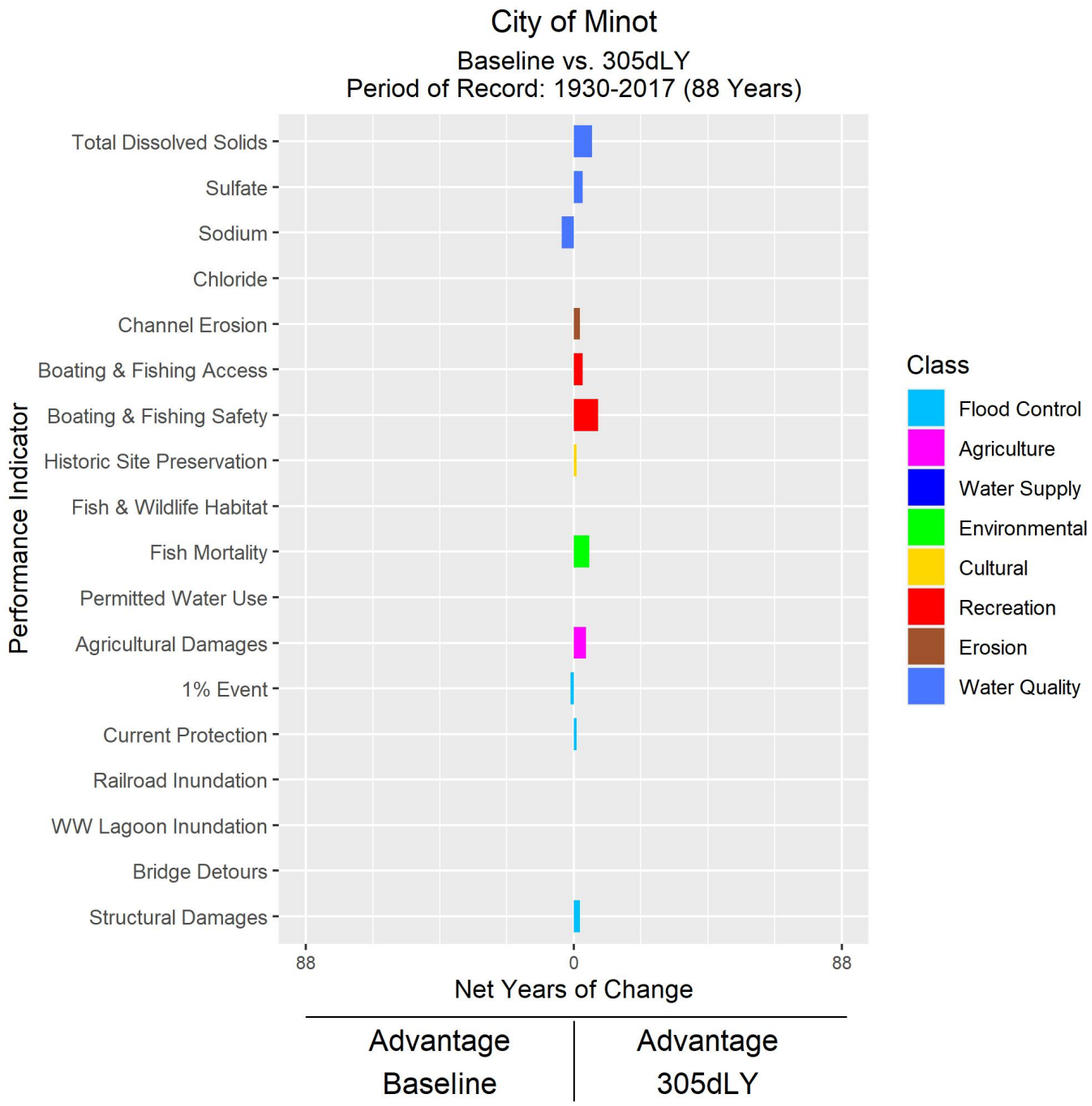


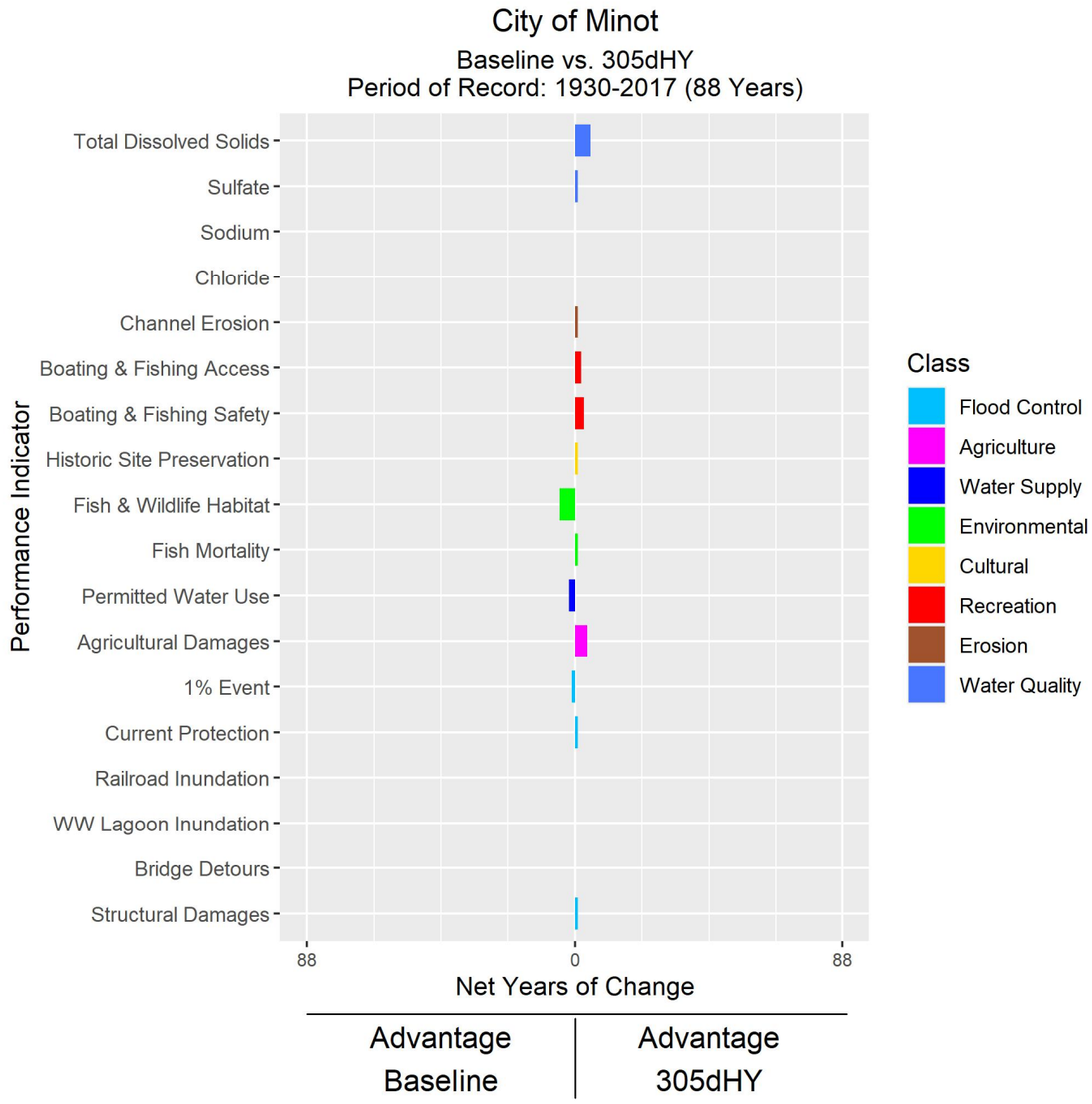
Alternative 305dLY

- Less aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months

Alternative 305dHY

- Highly aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months



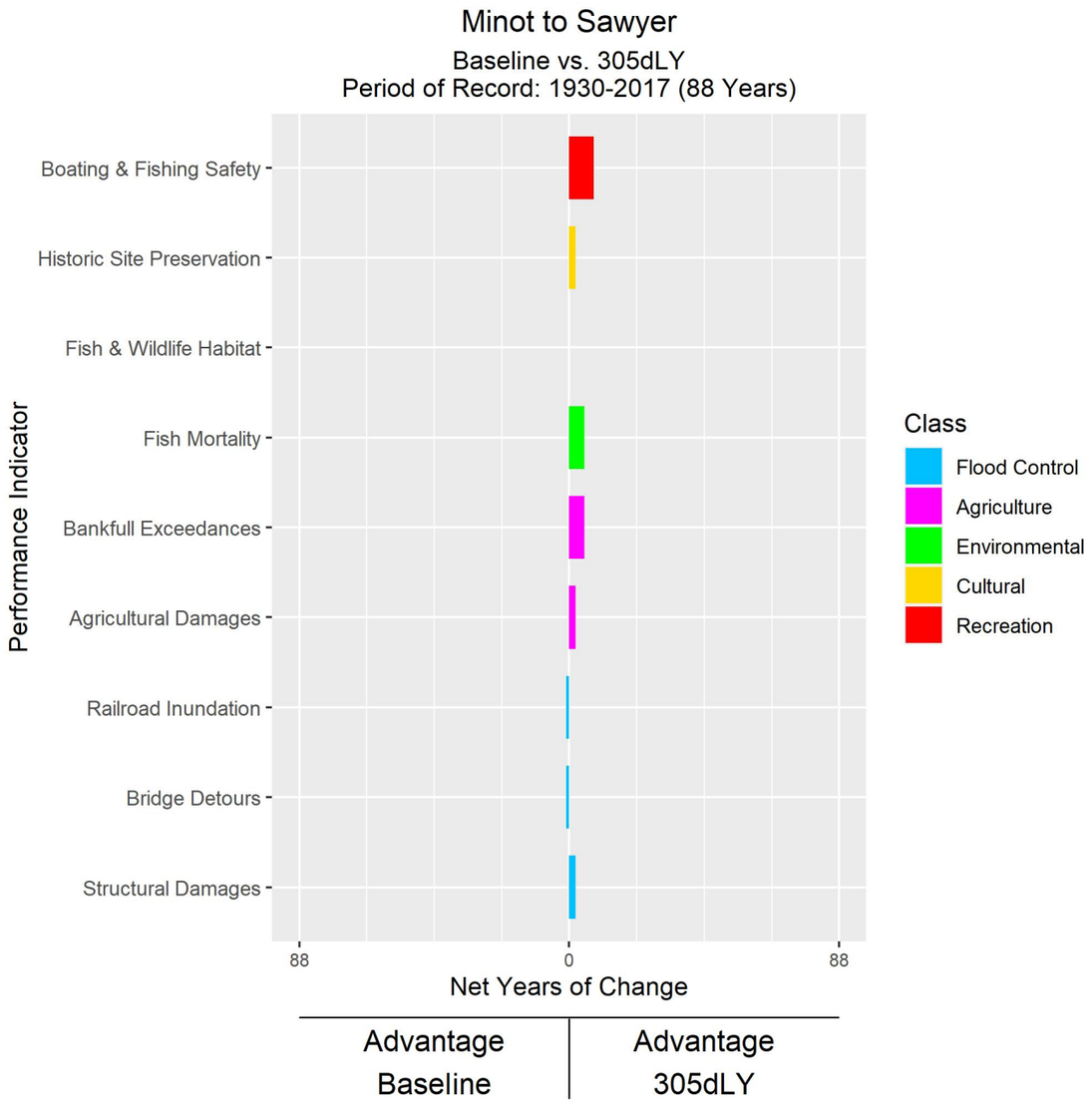


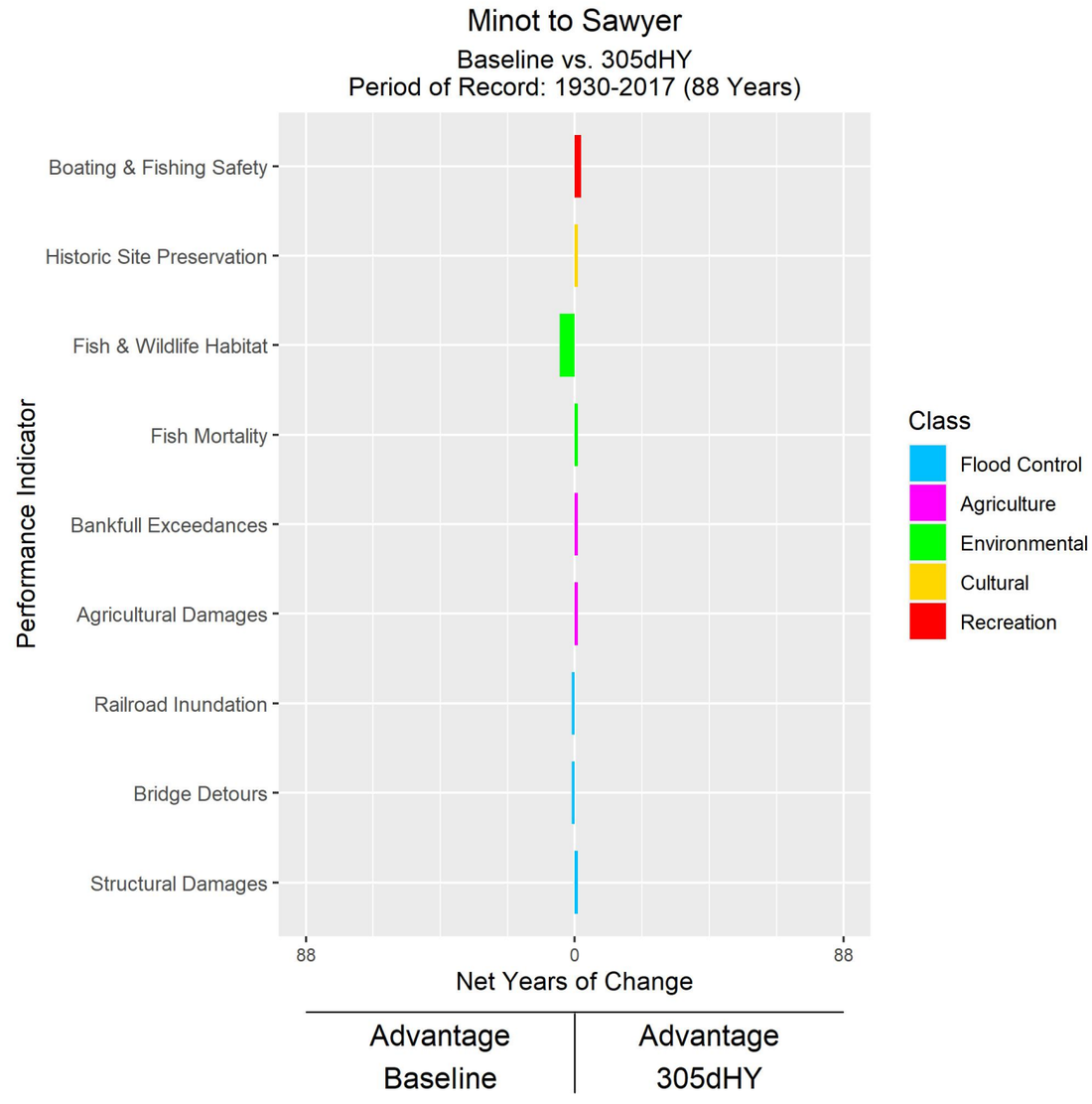
Alternative 305dLY

- Less aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months

Alternative 305dHY

- Highly aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months



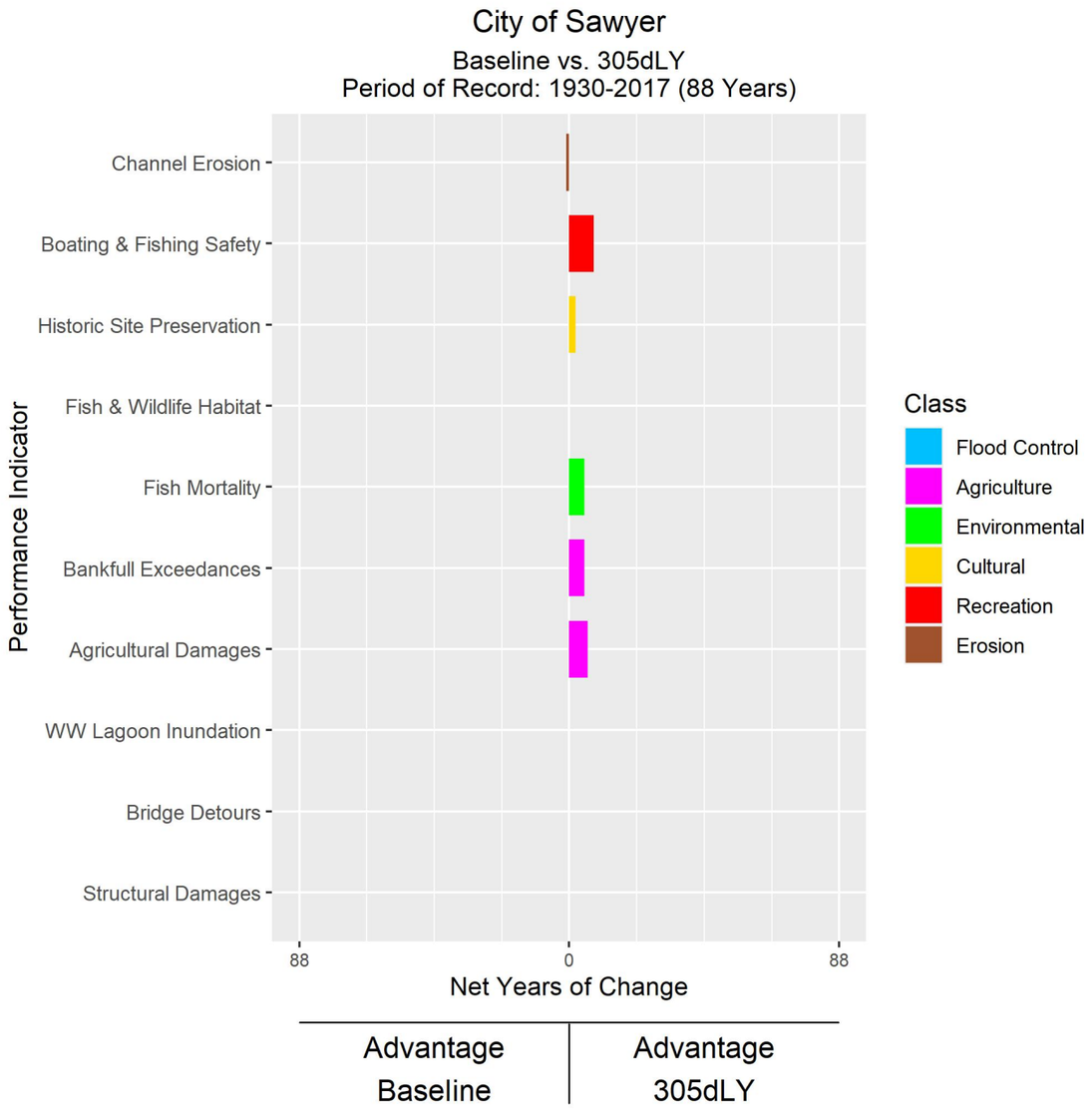


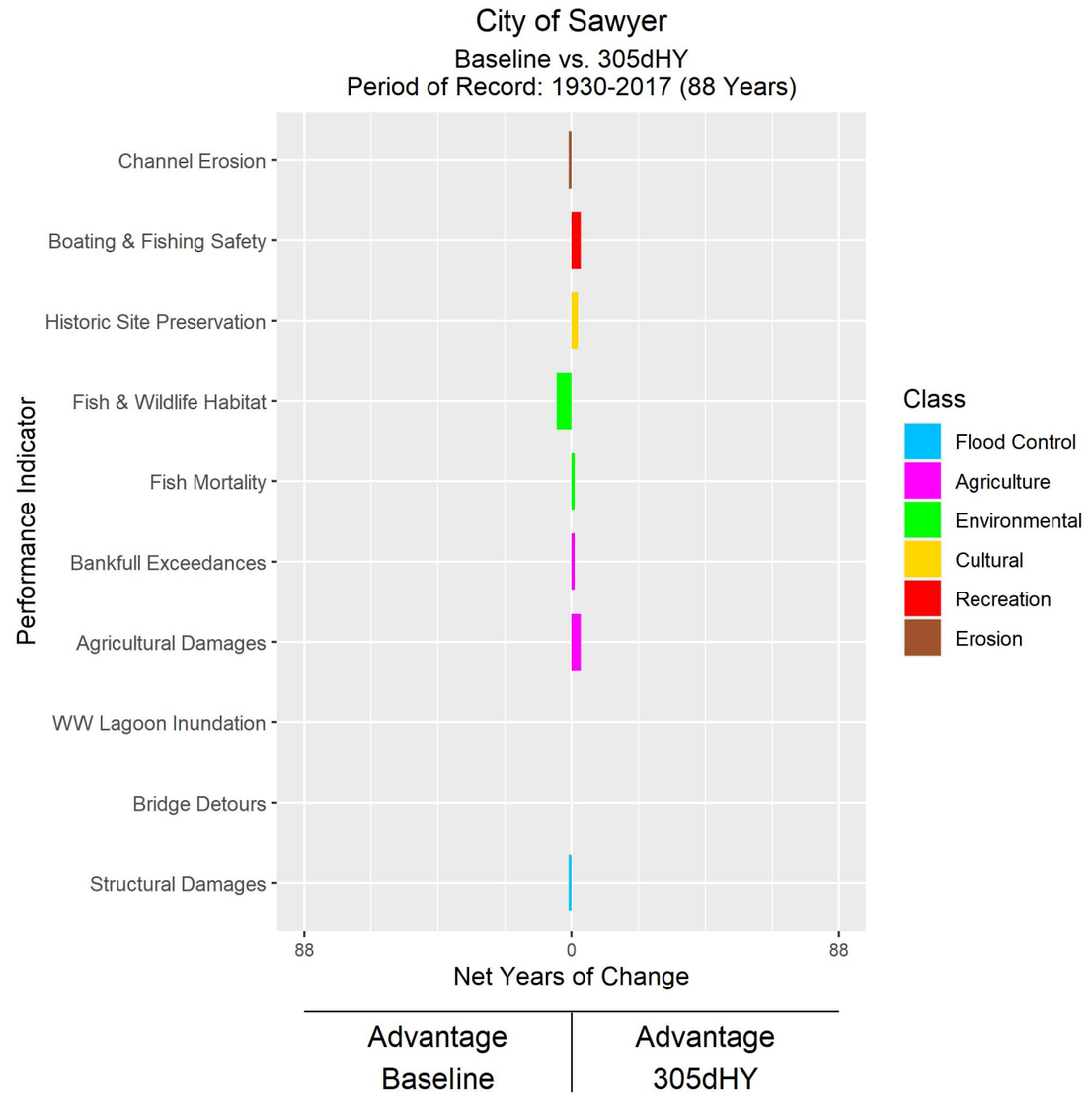
Alternative 305dLY

- Less aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months

Alternative 305dHY

- Highly aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months



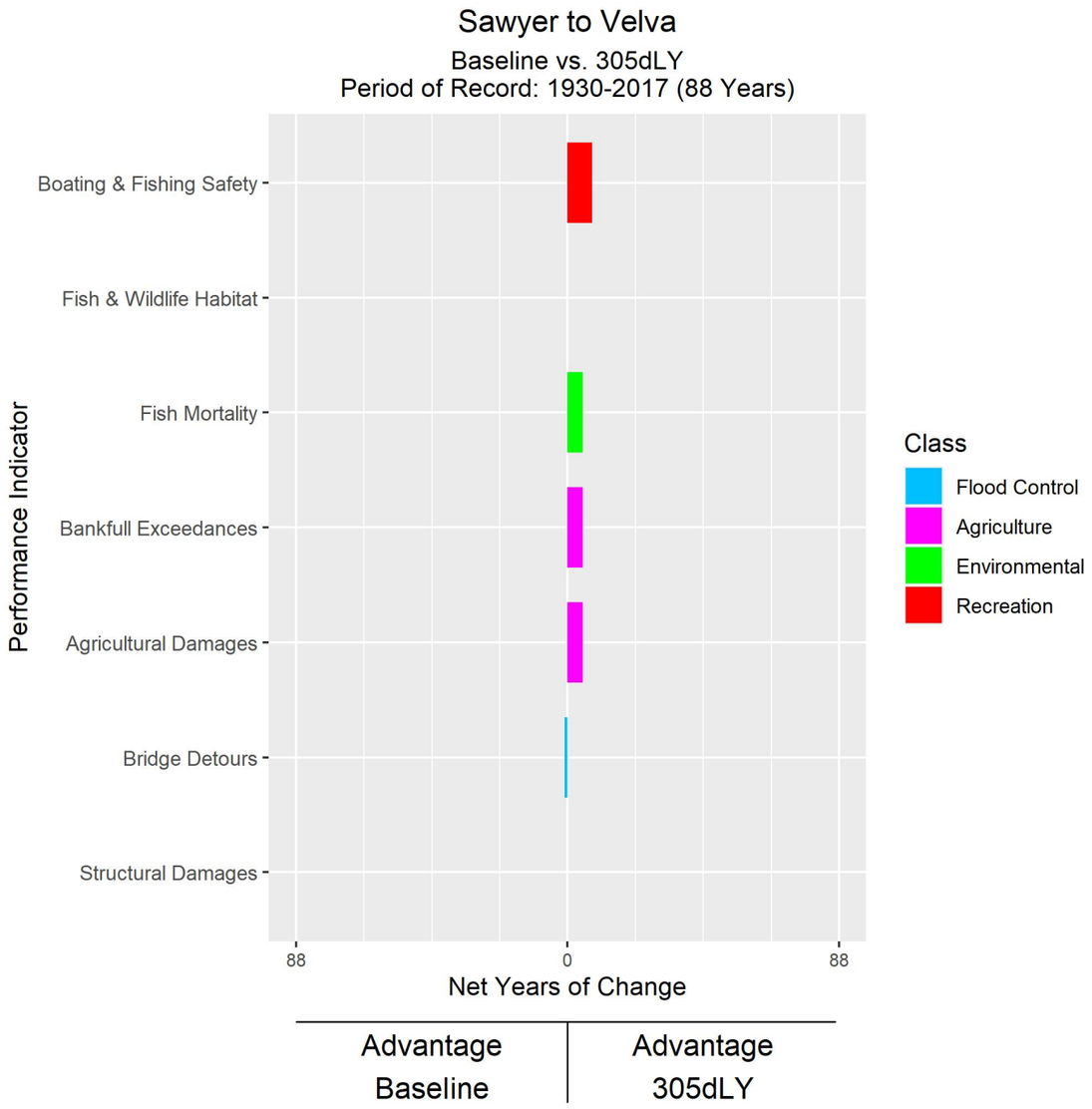


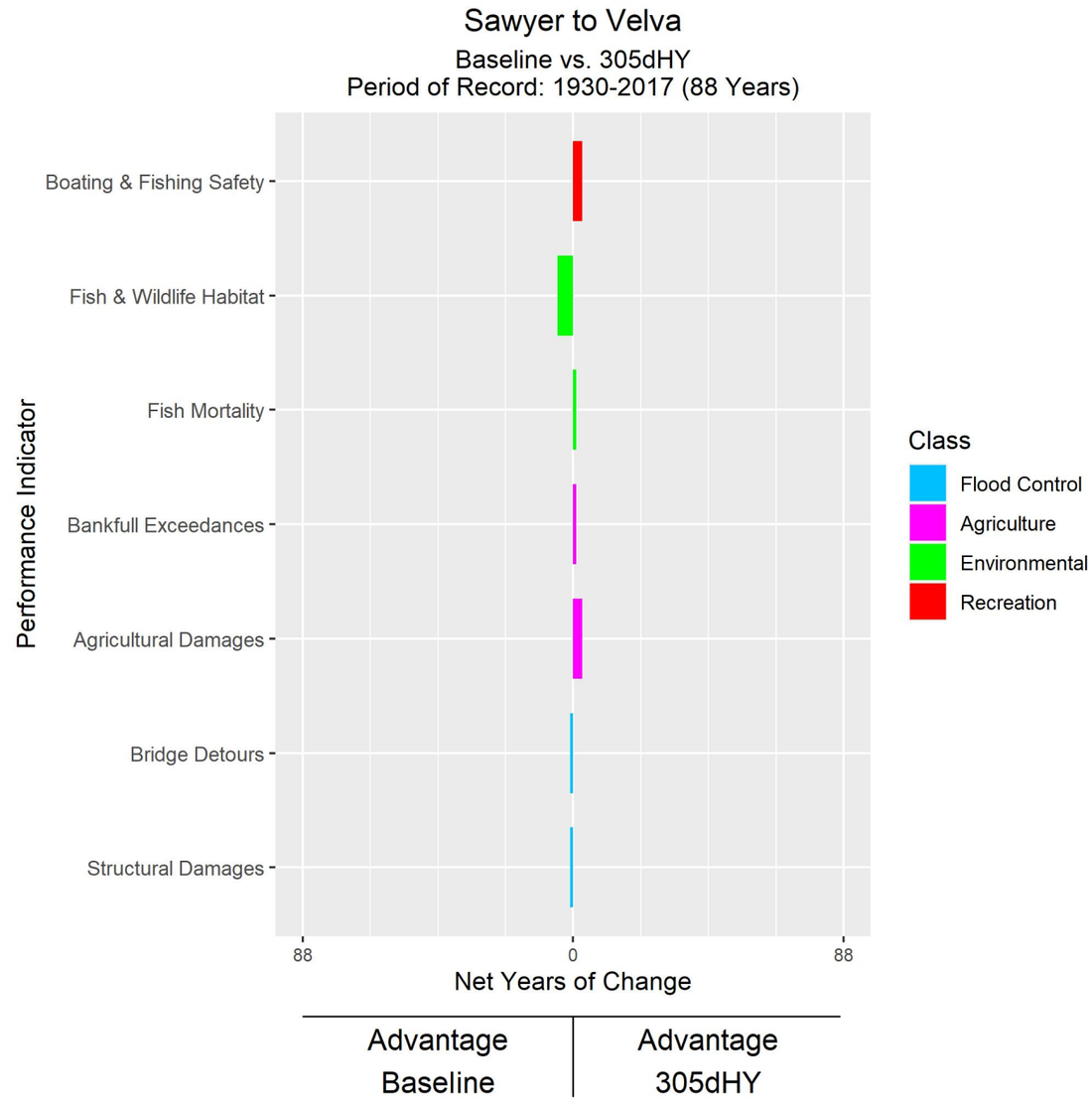
Alternative 305dLY

- Less aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months

Alternative 305dHY

- Highly aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months



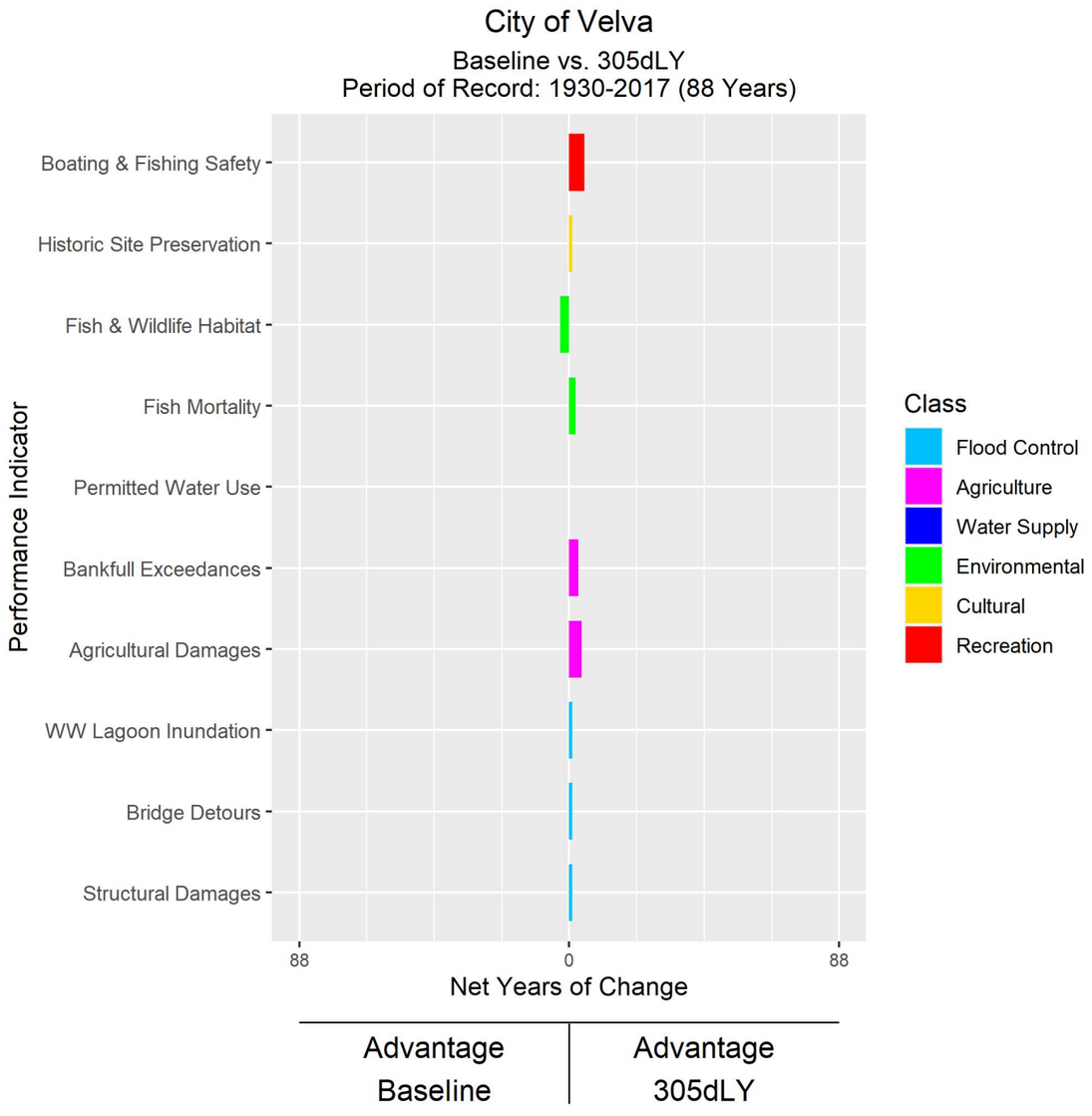


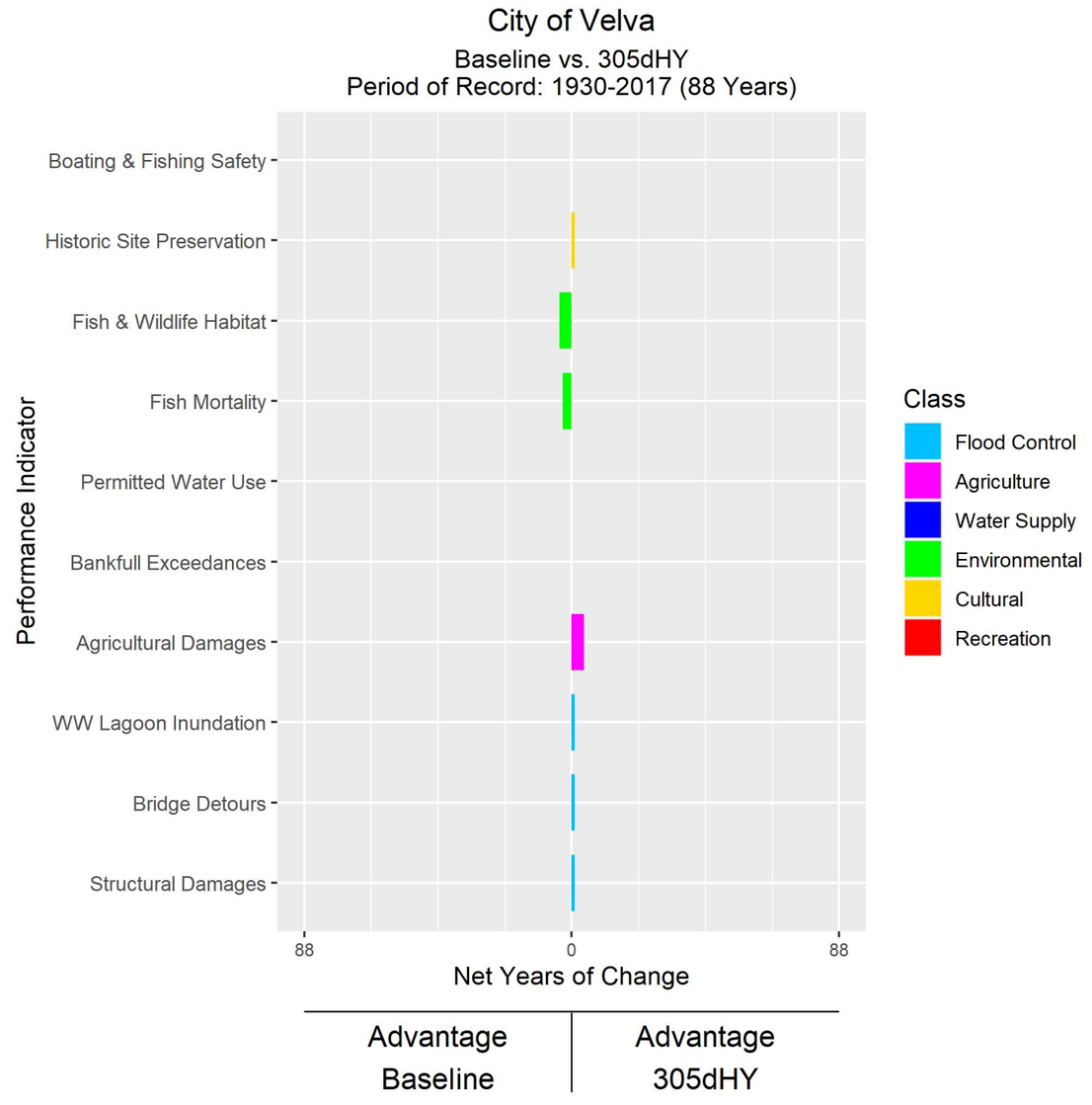
Alternative 305dLY

- Less aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months

Alternative 305dHY

- Highly aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months



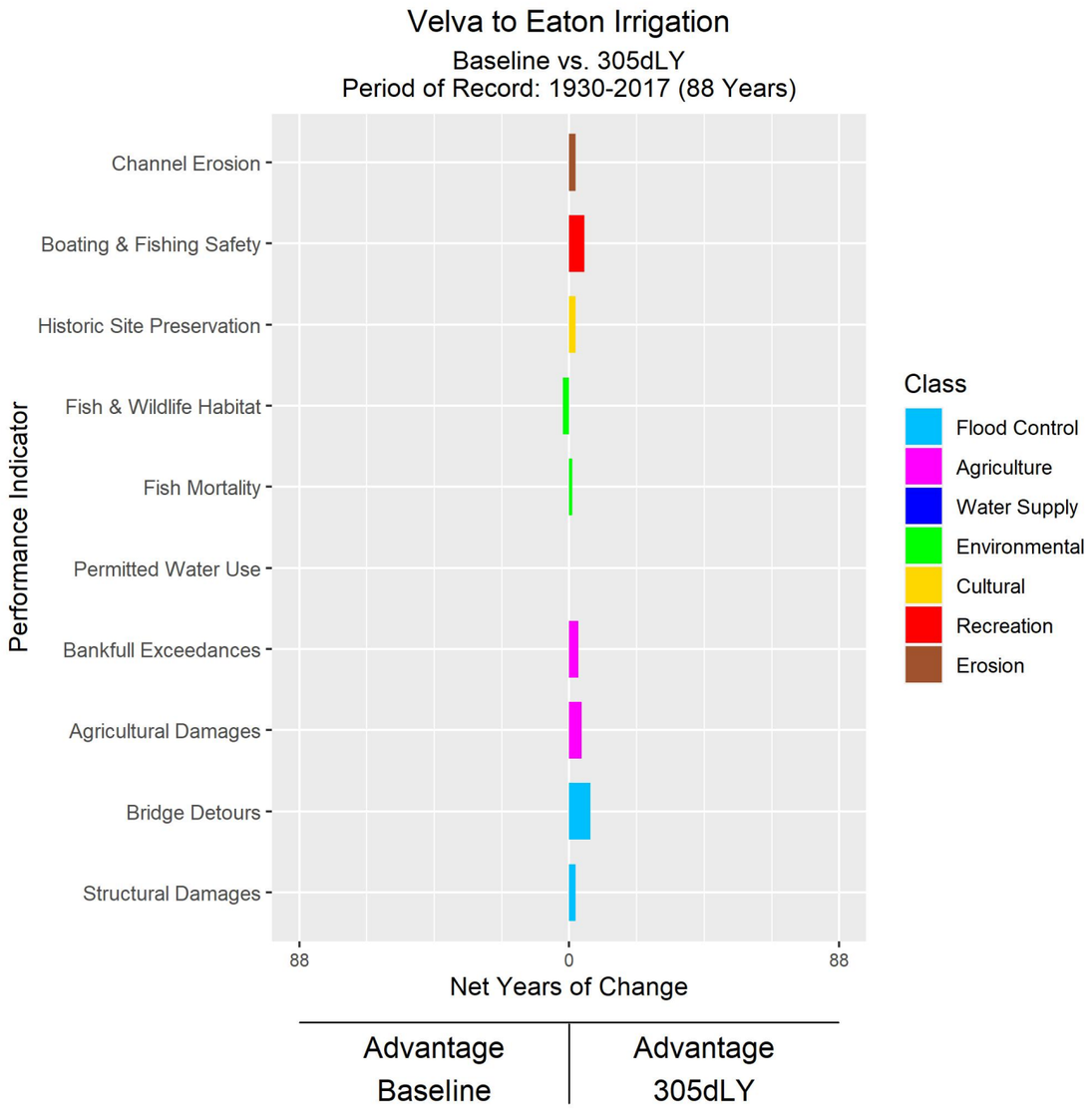


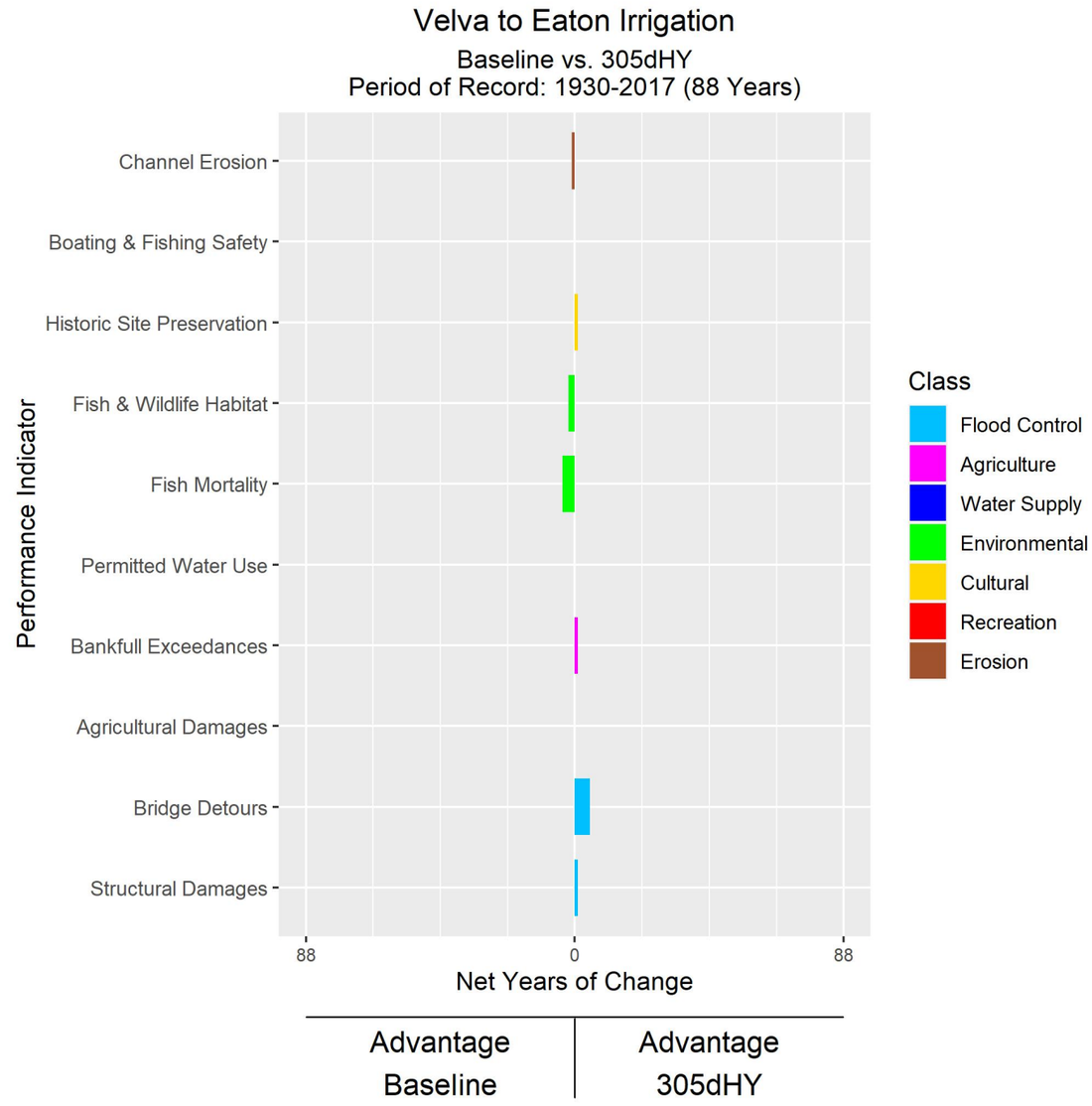
Alternative 305dLY

- Less aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months

Alternative 305dHY

- Highly aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months



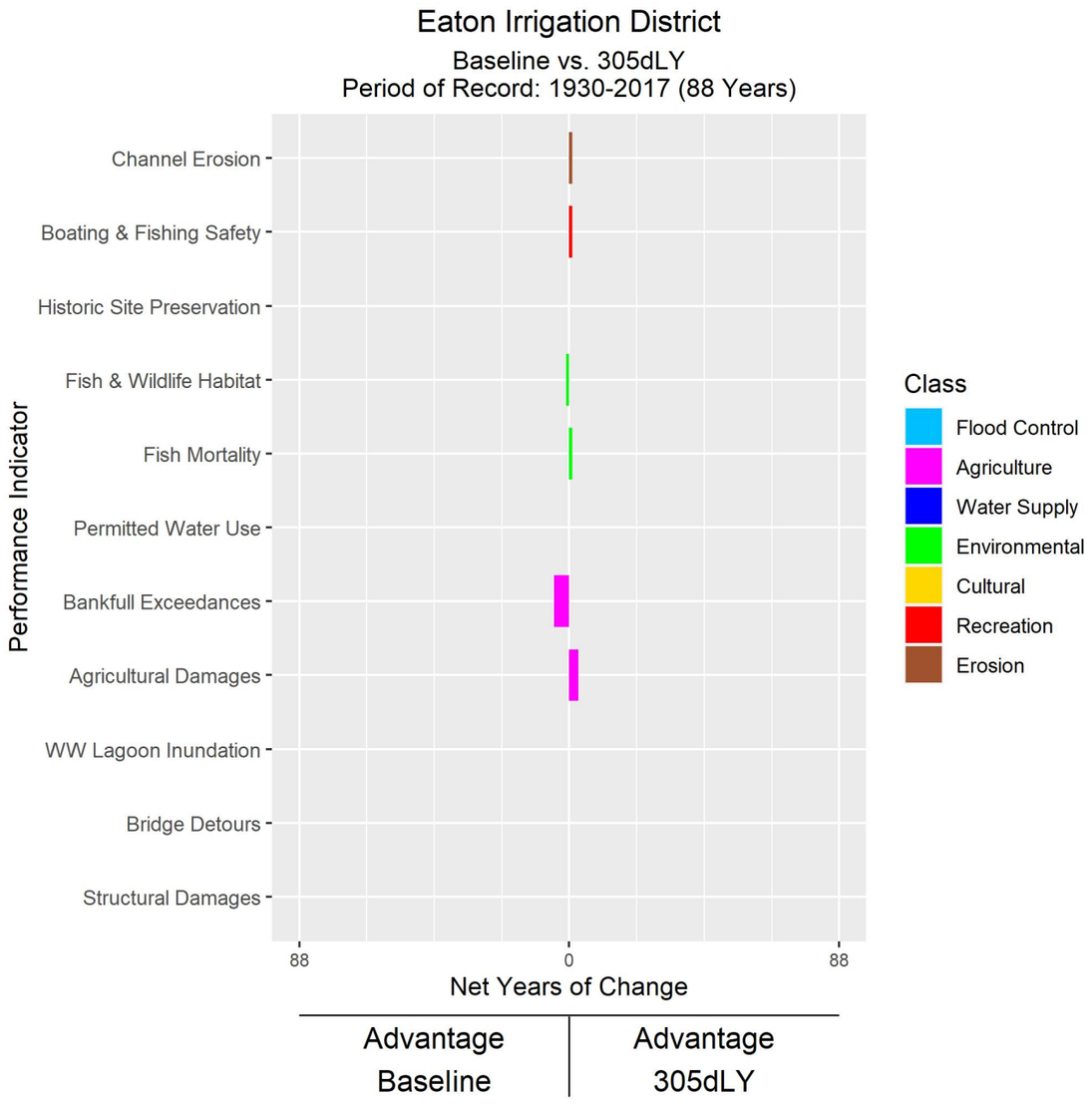


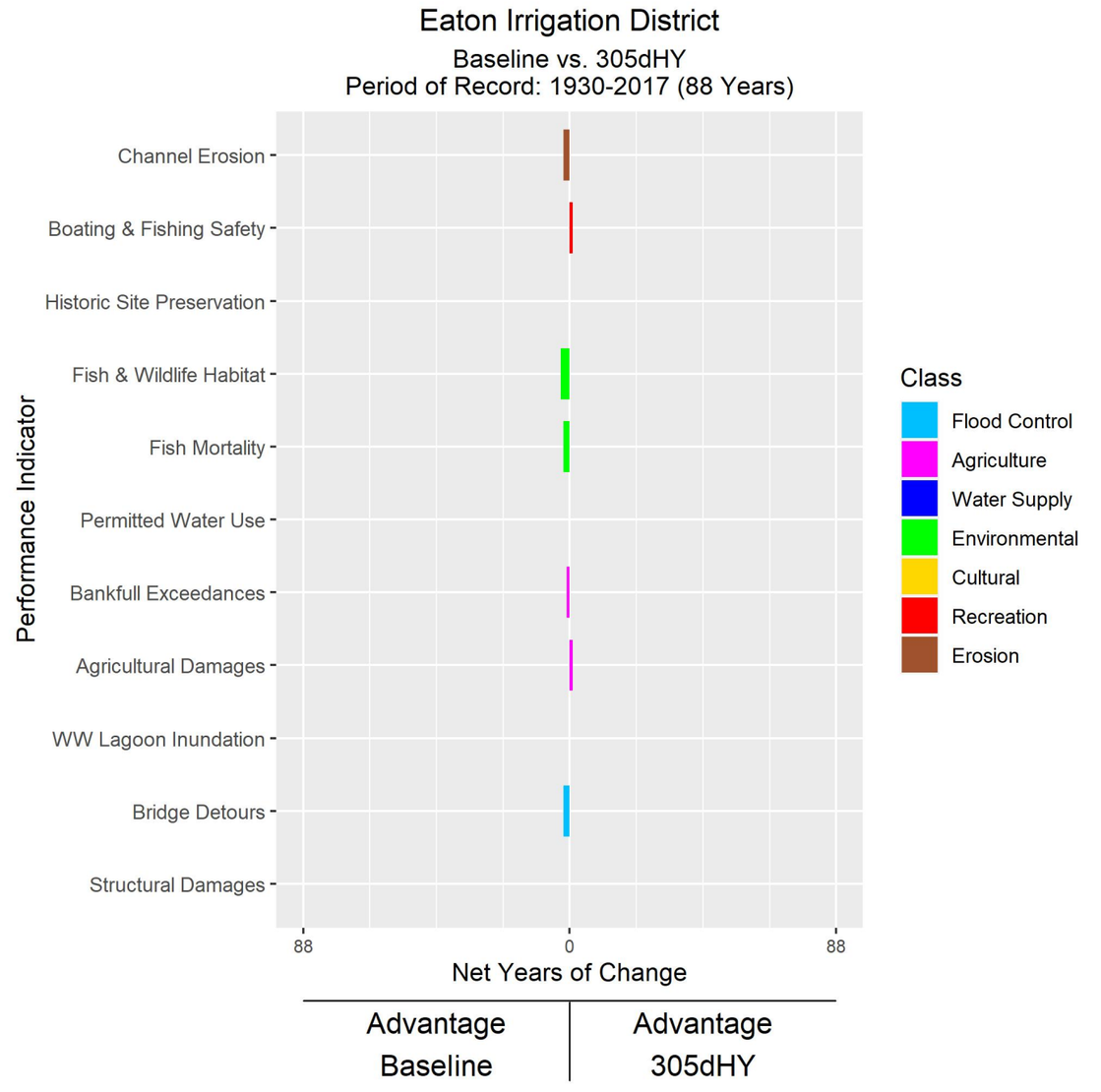
Alternative 305dLY

- Less aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months

Alternative 305dHY

- Highly aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months



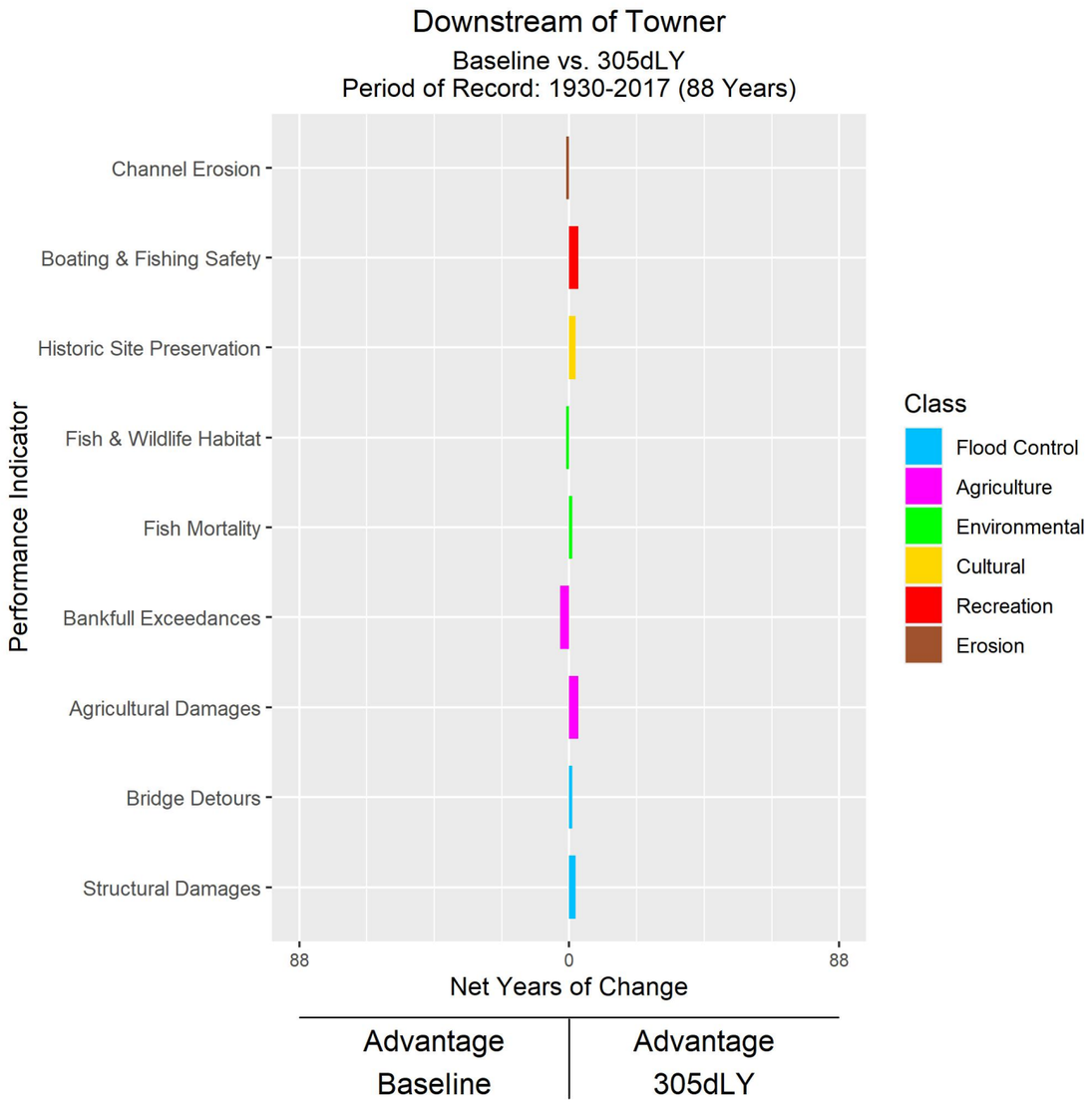


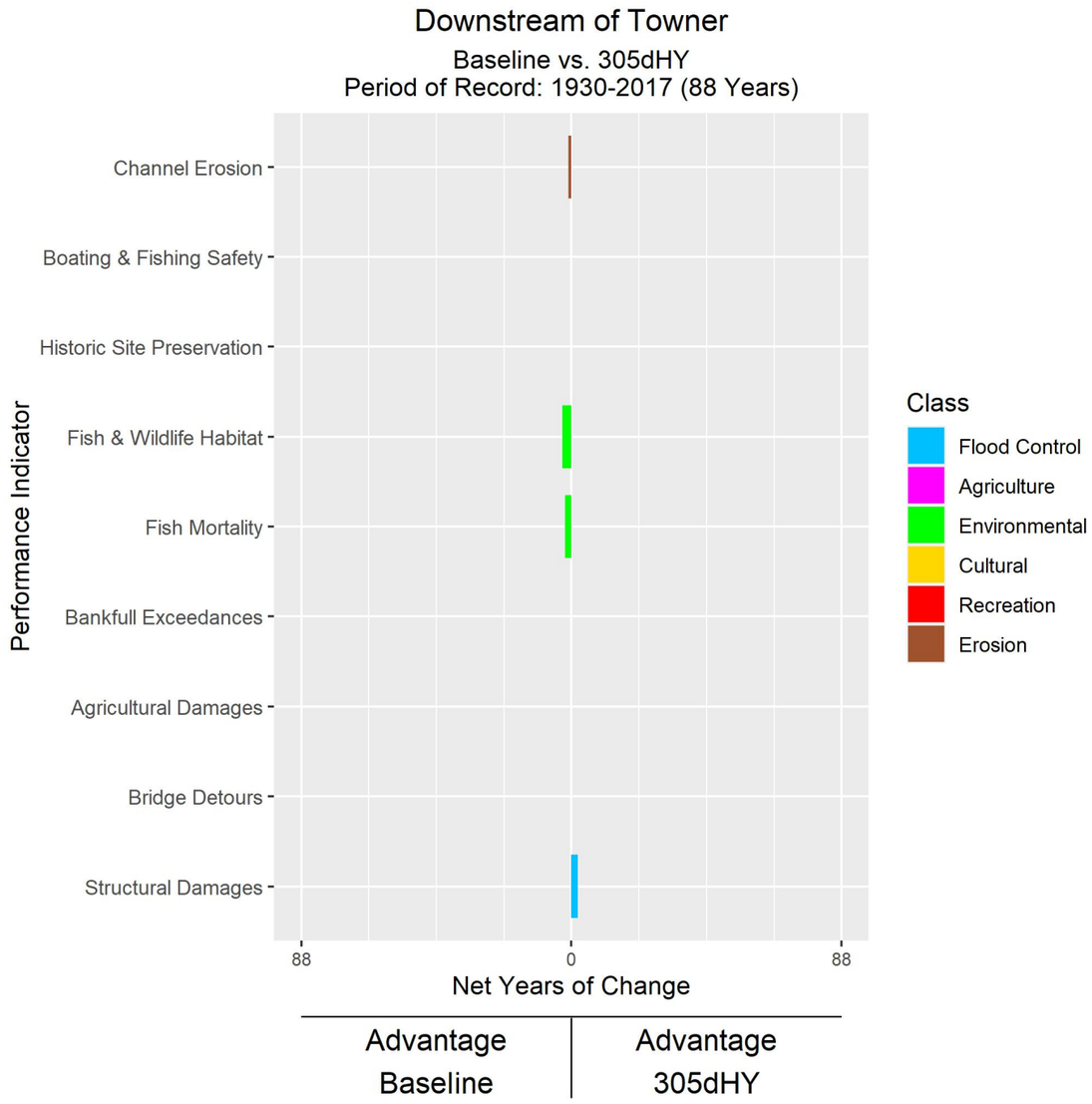
Alternative 305dLY

- Less aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months

Alternative 305dHY

- Highly aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months



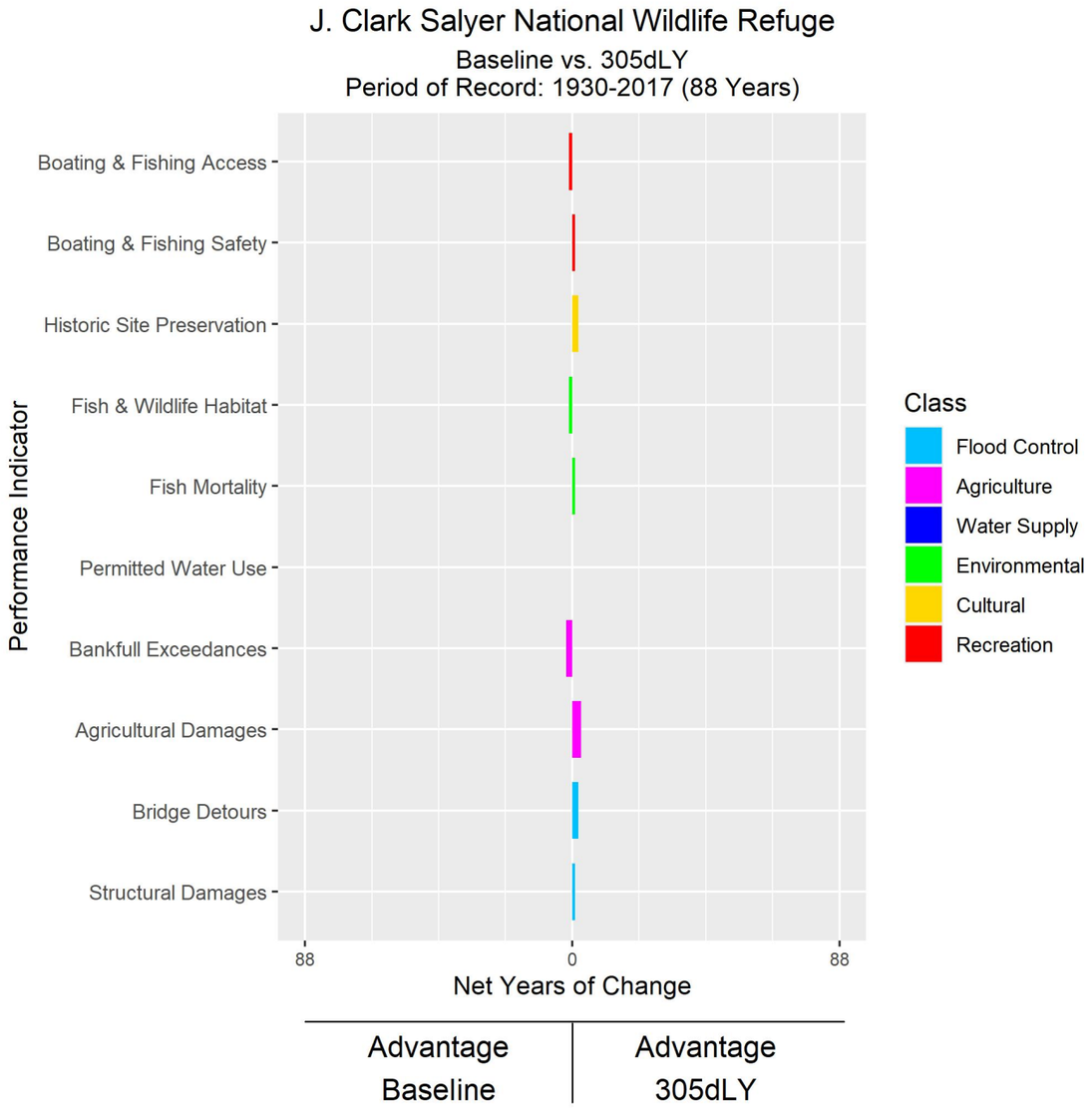


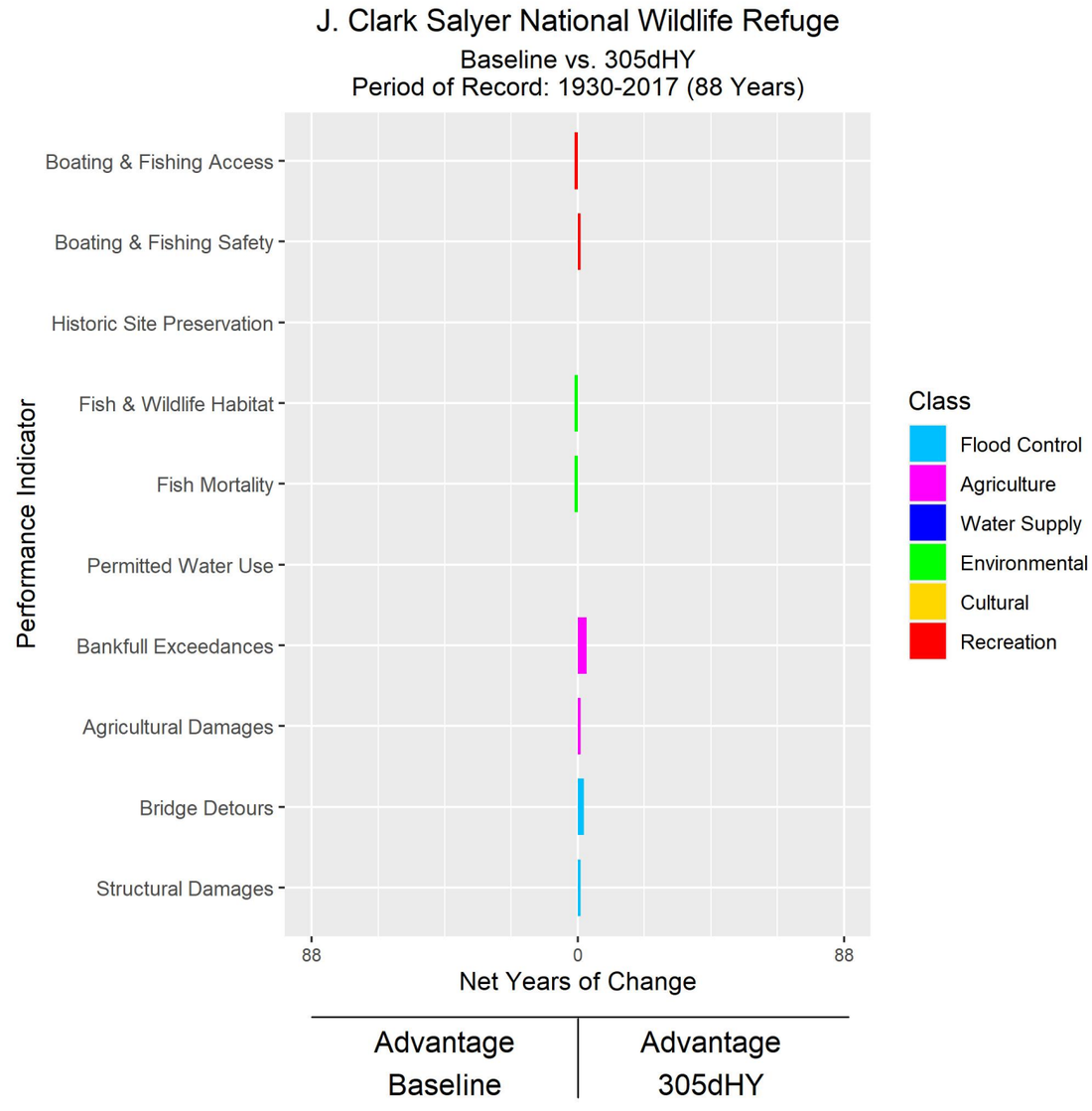
Alternative 305dLY

- Less aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months

Alternative 305dHY

- Highly aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months





Alternative 305dLY

- Less aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months

Alternative 305dHY

- Highly aggressive flow regime
- Flow constraints at Estevan and Grant Devine during summer months