Appendix C-5: Alternative 309

Apportionment Year Shift

HEC-ResSim Alternative Assessment

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1. Alternative Description & Objective

Alternative 309 is a continuation of Phase 2 Alternative 7, using additional stochastic datasets to further analyze the impacts of shifting the apportionment computation from calendar year (Jan 1 to Dec 31) closer to water year (Nov 1 to Oct 31). Shifting the apportionment year would allow Saskatchewan to count the volume of water released during the fall/winter drawdown towards its apportionment obligation in the following year. If the reservoirs are at FSL in the fall, draw down over the winter, and then receive little inflow in the spring, shifting the apportionment year could prevent Saskatchewan from needing to make an apportionment release in May or June. Since less water would be delivered to North Dakota in a case like this, this alternative specifically attempts to quantify the impacts of an apportionment year shift to North Dakota's water supply.

Since modeling for Phase 2 Alternative 7 showed limited changes from baseline, the 10 stochastic traces available to the modeling team were modeled in Phase 3. Each stochastic trace was approximately 100 years long.

1.1 HEC-ResSim Nomenclature

Within HEC-ResSim, a new network, alternative and simulation run was generated to run each stochastic trace. To generate the alternative network, a copy of the base network was made and modified to reflect the proposed alternative. A table indicating the nomenclature associated with the ResSim networks, alternatives and simulations used to model each stochastic trace is shown in Table 1.

Table 1. Model nomenclature

Scenario	Time Window	ResSim Model Name	Network Name	Alternative Name	Simulation Name
Baseline	1930-2017	SourisRiverPoS	cal2Fsl	Base	00_BL_AnxA_46_17
Apportionment Year Shift (Phase 2)	1930-2017 1930-1945	SourisRiverPoS	07_1NovAptYR_WS	7_ApYR_NP 7_ApYR_LP	07_1NovAptYR_WS_30_17 07_1NovAptYR_WS_30_45
Apportionment Year Shift (Phase 3)	Trace 6	SourisRiverPoS	Base_Stochastic 07_NovAptYR_WS_Stochastic	BaseSto_06 7_ApYr_T06	01_ApYr_T06
	Trace 20	SourisRiverPoS	Base_Stochastic 07_NovAptYR_WS_Stochastic	BaseSto_20 7_ApYr_T20	07_ApYr_T20
	Trace 25	SourisRiverPoS	Base_Stochastic 07_NovAptYR_WS_Stochastic	BaseSto_25 7_ApYr_T25	07_ApYr_T25
	Trace 52	SourisRiverPoS	Base_Stochastic 07_NovAptYR_WS_Stochastic	BaseSto_52 7_ApYr_T52	07_ApYr_T52

Apportionment Year Shift (Phase 3)	Trace 61	SourisRiverPoS	Base_Stochastic 07_NovAptYR_ WS_Stochastic	BaseSto_61 7_ApYr_T61	07_ApYr_T61
	Trace 69	SourisRiverPoS	Base_Stochastic 07_NovAptYR_ WS_Stochastic	BaseSto_69 7_ApYr_T69	07_ApYr_T69
	Trace 73	SourisRiverPoS	Base_Stochastic 07_NovAptYR_ WS_Stochastic	BaseSto_73 7_ApYr_T73	07_ApYr_T73
	Trace 86	SourisRiverPoS	Base_Stochastic 07_NovAptYR_ WS_Stochastic	BaseSto_86 7_ApYr_T86	07_ApYr_T86
	Trace 92	SourisRiverPoS	Base_Stochastic 07_NovAptYR_ WS_Stochastic	BaseSto_92 7_ApYr_T92	07_ApYr_T92
	Trace 100	SourisRiverPoS	Base_Stochastic 07_NovAptYR_ WS_Stochastic	BaseSto100 7_ApYr_100	07_ApYr_T100

2. Operational Rules

Table 2 presents the operational rules that were included in the base HEC-ResSim model alternative to specifically reflect the changes required in support of the running of the stochastic traces for this scenario.

Table 2. Operation Rules Added Specific to Alternative

Name of Dam	Name of Rule, Outlet or IF Statement or State Variable Element	Rule Description
Dam 320	a_fld_320	Slave state variables to change the J. Clark Salyer guide curves from external timeseries to state variables.
Dam 326	a_fld_326	
Dam 332	a_fld_gc_332	
Dam 341	a_fld_gc_341	
Dam 357	a_fld_gc_357	

To make this scenario run with the stochastic traces, the J. Clark Salyer structure guide curves were moved from external timeseries to state variables. Then, in the conservation pool for each dam, the guide curves were related to the state variable as a one to one function. Figure 1 shows Dam 357 as an example.

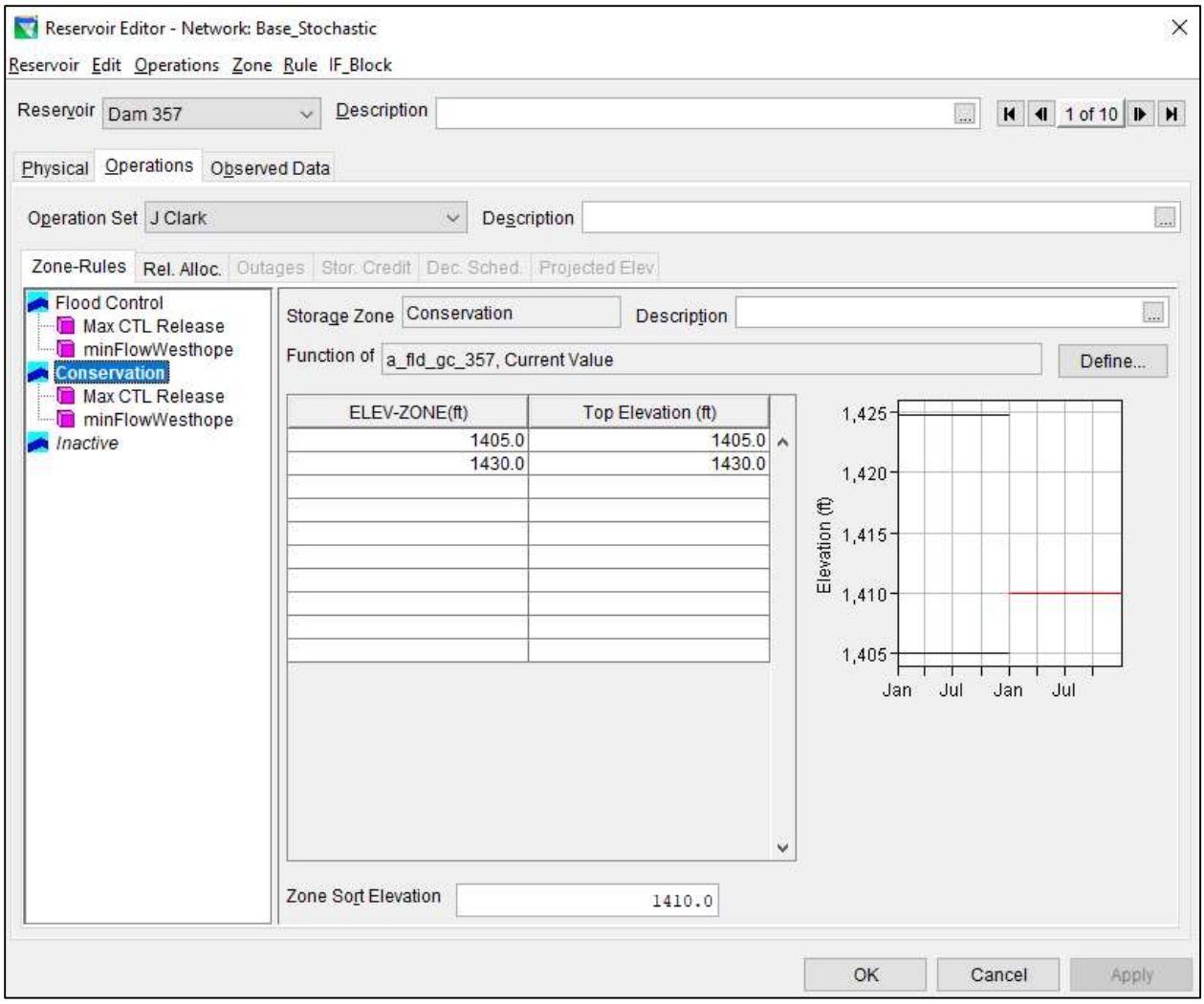


Figure 1: Changes made to J. Clark Salyer structures to change the guide curves to state variables

For this alternative, no operational rules were modified or added to the user interface. Changes to the script were made in the main tab. Figure 3 shows the changes made to account for the leap year. Additionally, the model needed to stop accumulating the unregulated and regulated Sherwood and inflow to Rafferty flows for the apportionment calculations. This was done by resetting the daystoaccumulate variable back to 0 after October 31. Figure 4 shows the change from calculating volume left for the rest of the year from December 31 to the new October 31.

Figure 2 to Figure 4 are screenshots of where the state variable script was modified to model the alternative. Relevant lines of the state variable script are indicated by the red boxes.

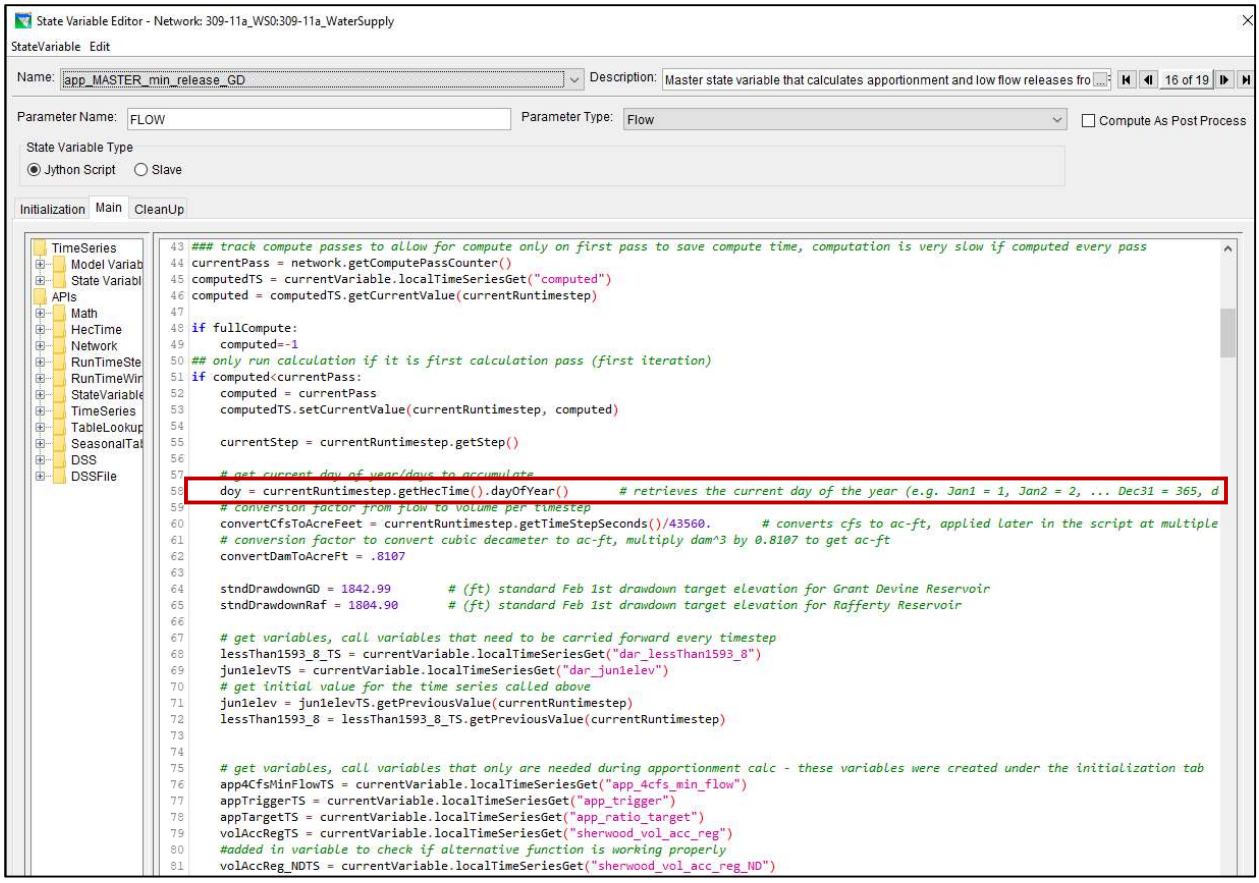


Figure 2: Change so that daysToAccumulate is not defined here, but further down

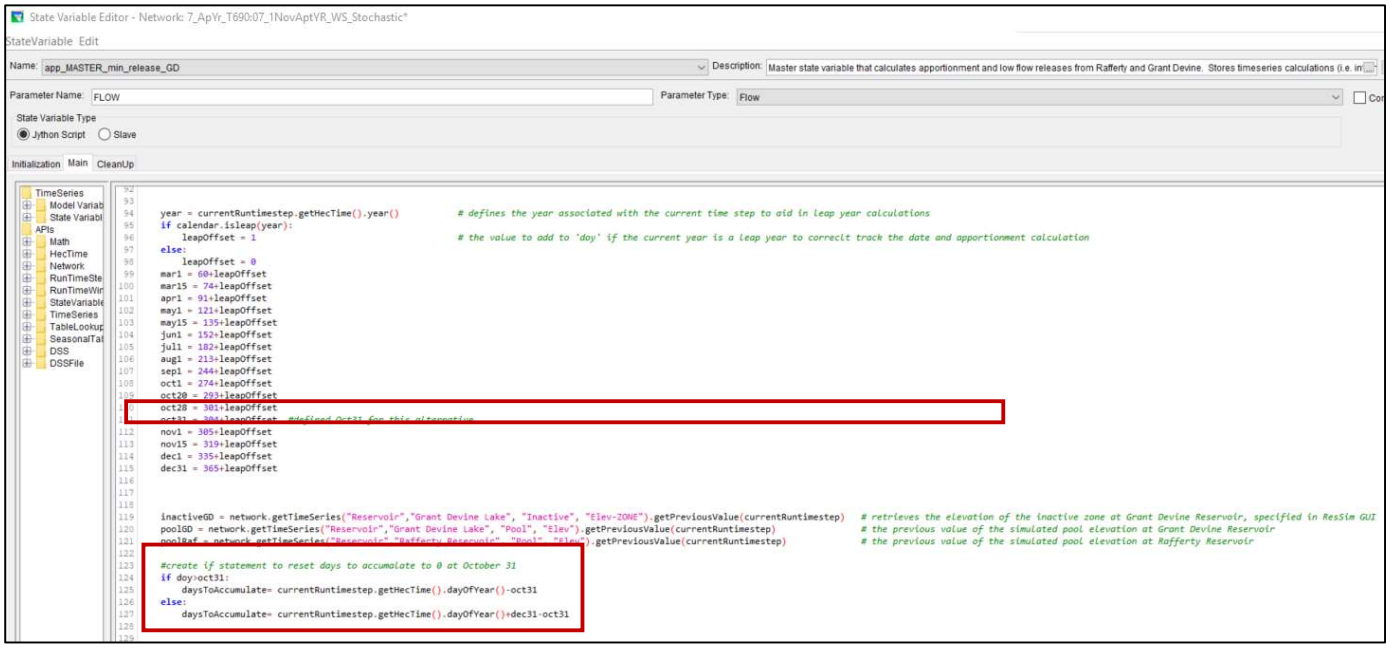


Figure 3. Defined October 31 for the leap year offset and created an IF statement that sets the daystoAccumulate variable to zero on October 31 and resets the previous year's November and December sum to 0 after October 31

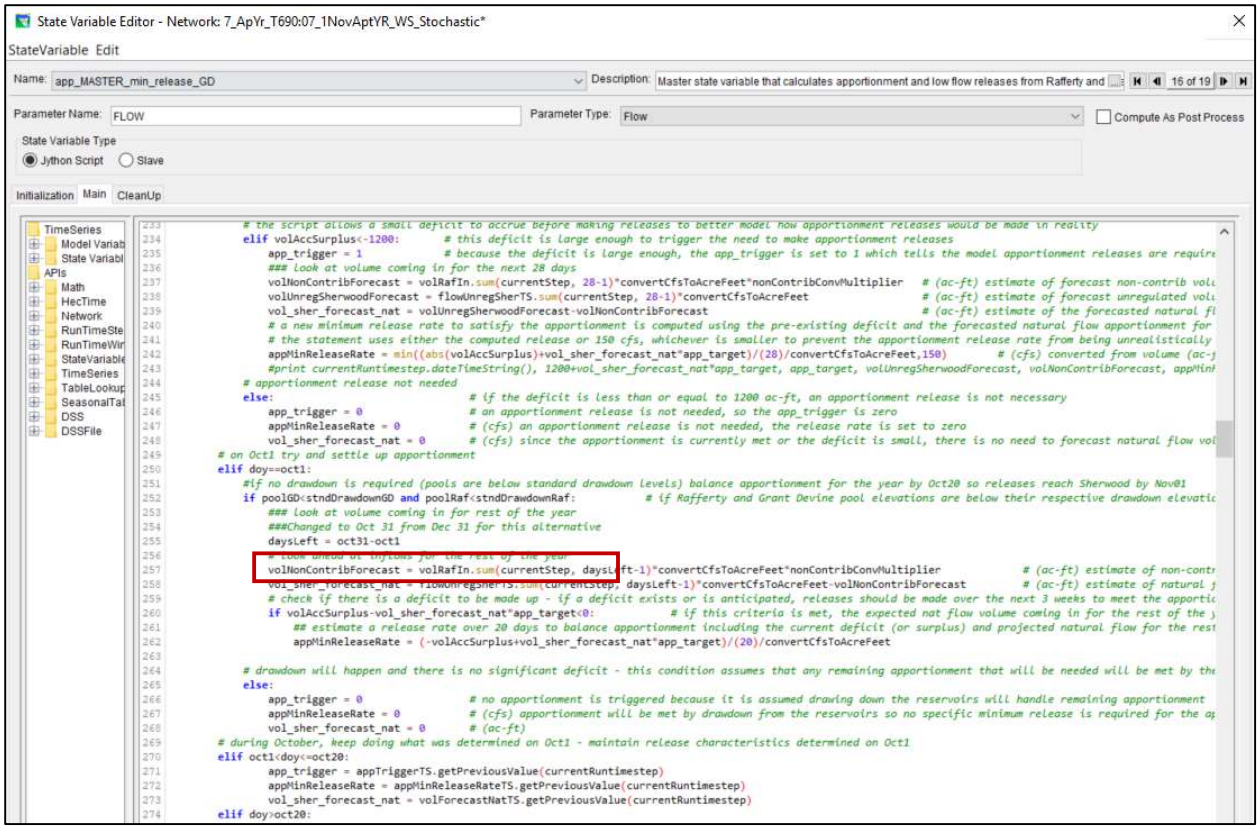


Figure 4. Changed the end date to look at volume coming in for the rest of the year from December 31 to October 31

3. Alternative vs Baseline Scenario Results

Plates 01-04 show hydrographs detailing the results of Alternative 309 relative to the baseline scenario at Rafferty, Boundary, Grant Devine, and Lake Darling reservoirs, as well as seven critical mainstem flow locations, for periods in two traces – Trace 6 (3045-3051) and Trace 52 (3083-3089). These plots show examples of years in which there was a large reduction in the volume of water delivered to Sherwood Crossing relative to the same years in the baseline simulation.

Performance indicators were not developed for this alternative due to the nature of this analysis.

4. Summary of Results

To determine Alternative 309's impact to North Dakota's water supply, the study team computed volume delivered at Sherwood from March 1 to June 1 for each year in each stochastic trace. In each trace, the team identified years in which the decrease in volume delivered at Sherwood relative to the baseline was 25% or more. In all 10 traces, it was determined the greatest impact occurred during drier periods (not droughts) when reservoir elevations were around the normal drawdown elevations.

Throughout all the stochastic traces, the cases where there was a 25% or more difference in the volumes at Sherwood from March 1 to June 1 occurred when in the previous fall, the reservoirs (Rafferty and/or Grant Devine) were near FSL. This resulted in the reservoirs going into November with higher pool levels than the baseline. The resulting release needed to bring the elevation down to the normal February 1 drawdown target, in combination with local runoff below the reservoirs, was enough to meet

the June 1 apportionment obligations in that year. As such, no releases needed to be made throughout the spring, whereas additional releases were needed in the baseline. This, in combination with lower flows, resulted in larger decreases in the volume delivered at Sherwood.

Trace 6

For Trace 6 of the Stochastic Hydrology Dataset, over all 98 years, the average decrease in volume delivered to Sherwood was 7.6%. There were a total of 14 years with a 25% or greater reduction in the volume of flows at Sherwood. These 14 years, along with the total March 1 to June 1 volume for both the baseline and 309 simulations are shown in

Table 3 below. The most significant difference in spring volume delivered occurred in the dry period of 3045 to 3052, with 3047 having a 61% decrease in the volume of flow at Sherwood. The combination of the flows in the fall counting towards apportionment, and inflows being low in 1947, resulted in a 61% decrease in volume delivered at Sherwood this year.

Table 3. Trace 6 March 1 to June 1 volume at Sherwood Crossing

	Sherwood Volume from March 1 to June 1		
	Base (ac-ft)	309 (ac-ft)	%
3034	10,668.04	6,355.86	40%
3046	21,521.65	15,926.44	26%
3047	8,653.57	3,347.97	61%
3048	20,379.39	13,672.08	33%
3049	16,059.13	11,657.58	27%
3051	14,347.91	9,538.04	34%
3065	17,411.31	12,804.21	26%
3067	10,857.35	7,371.98	32%
3073	9,381.07	6,949.73	26%
3077	17,548.69	12,018.60	32%
3078	6,836.62	3,093.45	55%
3096	16,788.07	12,619.20	25%
3098	23,987.23	16,791.86	30%

Trace 20

When looking at the Stochastic Hydrology Dataset, Trace 20, the average decrease was the lowest of all 10 traces at only 4.2%. There were only 5 years where the volume at Sherwood from March 1 to June 1 differed by 25% or more from the baseline when compared to this scenario, as shown in **Error! Reference source not found.**.

Table 4. Trace 20 March 1 to June 1 volume at Sherwood Crossing

	Sherwood Volume from March 1 to June 1		
	Base (ac-ft)	309 (ac-ft)	%
3032	7,165.14	4,778.64	33%
3062	13,036.41	8,278.41	36%
3064	19,280.18	13,531.22	30%
3079	9,101.00	4,663.53	49%
3087	13,652.60	9,172.81	33%

Trace 25

For Trace 25, the average decrease in the volume of spring flow at Sherwood was 10.1%. There were 17 years with differences in volume of 25% or greater, as shown in **Error! Reference source not found.**.

Table 5. Trace 25 March 1 to June 1 volume at Sherwood Crossing

	Sherwood Volume from March 1 to June 1		
	Base (ac-ft)	309 (ac-ft)	%
3013	10,694.83	5,531.78	48%
3023	17,534.41	11,567.43	34%
3028	12,841.75	7,154.64	44%
3029	16,897.94	11,770.56	30%
3032	14,506.28	9,464.26	35%
3033	14,479.39	10,190.55	30%
3048	12,701.52	7,778.62	39%
3049	4,689.35	2,484.44	47%
3053	6,352.90	3,063.60	52%
3065	18,488.67	13,796.01	25%
3066	23,981.57	17,879.76	25%
3067	16,237.16	8,703.72	46%
3069	18,032.08	12,209.68	32%
3072	10,602.90	6,885.78	35%
3087	8,025.80	4,167.85	48%
3089	21,166.39	13,742.58	35%
3091	11,307.81	6,116.74	46%

Trace 52

The 98 years in Trace 52 had the greatest overall average decrease in the volume delivered to Sherwood of 11.3%. This trace also had the most years with a greater than 25% difference in volume at Sherwood, with a total of 32 years. As shown in Table 6, the largest percentage decreases were observed in 3087 and 3094. 3087 is shown in Plates 03 and 04.

Table 6. Trace 52 March 1 to June 1 volume at Sherwood Crossing

	Sherwood Volume from March 1 to June 1		
	Base (ac-ft)	309 (ac-ft)	%
3003	6,149.37	4,138.42	33%
3007	21,111.50	15,498.89	27%
3008	14,370.16	8,573.50	40%
3009	22,888.58	16,343.16	29%
3012	16,882.43	11,846.65	30%
3016	11,312.17	6,881.38	39%
3017	15,835.99	11,912.64	25%
3018	16,761.44	11,012.96	34%
3023	10,398.21	7,104.21	32%
3028	15,670.85	11,243.49	28%
3037	11,215.21	5,701.16	49%
3042	17,609.36	12,772.24	27%
3064	13,649.77	8,340.86	39%

3065	16,845.30	10,464.63	38%
3072	10,436.78	6,166.05	41%
3073	9,827.92	7,213.98	27%
3074	9,321.28	4,849.28	48%
3083	8,640.52	4,657.86	46%
3086	11,184.65	7,710.47	31%
3087	10,108.34	5,098.50	50%
3094	4,727.21	2,369.37	50%
3095	15,647.91	11,584.03	26%

Trace 61

Trace 61 had an average decrease in March 1 to June 1 volume at Sherwood of 8.7%. There was a total of 17 years in which the difference was 25% or greater, as shown in Table 7.

Table 7. Trace 61 March 1 to June 1 volume at Sherwood Crossing

	Sherwood Volume from March 1 to June 1		
	Base (ac-ft)	**309 (ac-ft)**	**%**
3003	5,822.50	3,403.83	42%
3009	8,163.79	4,629.11	43%
3017	24,167.25	18,208.21	25%
3021	17,182.71	12,281.41	29%
3039	14,570.68	10,121.46	31%
3046	9,045.65	5,761.53	36%
3049	22,261.00	16,608.14	25%
3050	25,578.91	19,108.38	25%
3058	19,835.52	14,686.11	26%
3064	15,036.31	10,195.04	32%
3065	19,662.40	13,840.55	30%
3066	12,414.94	8,198.47	34%
3067	17,334.50	12,168.86	30%
3068	16,321.09	12,305.04	25%
3069	11,524.16	5,783.76	50%
3085	4,802.29	2,779.72	42%
3092	13,426.55	8,382.85	38%

Trace 69

For the 98 years, Trace 69 had an average decrease of 4.6%. This trace also only had 5 years where the difference in spring volume at Sherwood was 25% or more, as shown in Table 8.

Table 8. Trace 69 March 1 to June 1 volume at Sherwood Crossing

	Sherwood Volume from March 1 to June 1		
	Base (ac-ft)	**309 (ac-ft)**	**%**
3045	11,072.28	7,424.88	33%
3056	15,343.39	11,561.06	25%
3057	9,299.88	4,012.82	57%
3058	14,634.16	9,067.69	38%
3090	12,520.79	8,891.73	29%

Trace 73

Trace 73 had an average decrease of 10.2% with a total of 17 years that had a 25% or more decrease in the volume of flows at Sherwood form March 1 to June 1, as show in Table 9.

Table 9. Trace 73 March 1 to June 1 volume at Sherwood Crossing

	Sherwood Volume from March 1 to June 1		
	Base (ac-ft)	309 (ac-ft)	%
3012	7,391.82	4,983.28	33%
3013	8,666.87	6,277.32	28%
3017	5,933.36	2,370.10	60%
3020	13,194.48	9,694.67	27%
3021	11,692.31	5,582.08	52%
3023	9,319.56	3,578.19	62%
3025	6,075.31	2,923.95	52%
3036	11,358.41	6,674.36	41%
3053	8,529.30	4,123.23	52%
3062	16,114.13	10,763.12	33%
3066	15,966.75	10,472.33	34%
3072	17,752.21	13,068.11	26%
3074	22,671.85	15,687.54	31%
3077	11,202.36	7,389.80	34%
3088	18,974.24	13,063.93	31%
3089	29,201.14	21,237.54	27%
3090	22,587.40	16,825.65	26%

Trace 86

Trace 86 had an average decrease of 6.6% with 10 years where was a decrease of 25% or more was observed at Sherwood from March to June. These years are shown in Table 10.

Table 10. Trace 86 March 1 to June 1 volume at Sherwood Crossing

	Sherwood Volume from March 1 to June 1		
	Base (ac-ft)	309 (ac-ft)	%
3005	11,173.22	6,881.53	38%
3006	9,341.43	6,887.82	26%
3041	15,538.48	9,698.31	38%
3055	13,584.66	10,014.43	26%
3060	15,725.74	9,071.47	42%
3061	11,054.52	4,187.96	62%
3065	16,303.27	11,245.45	31%
3069	15,774.56	10,970.24	30%
3071	6,734.82	3,535.24	48%
3086	7,902.18	3,399.38	57%

Trace 92

For Trace 92, the average decrease in spring volume at Sherwood was 8.8%. There were a total of 15 years in which the flows at Sherwood were decreased by 25% or more between March and June, as shown in Table 11.

Table 11. Trace 92 March 1 to June 1 volume at Sherwood Crossing

	Sherwood Volume from March 1 to June 1

	Base (ac-ft)	309 (ac-ft)	%
3014	5,979.05	3,244.10	46%
3026	8,214.45	5,455.76	34%
3031	8,796.42	5,599.76	36%
3034	14,023.85	9,735.41	31%
3036	13,813.15	9,999.72	28%
3040	8,831.86	5,848.03	34%
3042	12,887.75	7,448.77	42%
3050	14,560.90	10,809.74	26%
3054	14,608.84	8,808.23	40%
3056	22,754.45	16,545.80	27%
3060	19,304.63	13,525.27	30%
3064	16,416.31	10,988.85	33%
3081	19,133.27	11,825.61	38%
3082	22,828.40	15,164.81	34%
3083	20,594.99	13,982.17	32%

Trace 100

The final trace, Trace 100, had an averaged decrease of 8.5%. This trace had a total of 14 years where this shifting the apportionment year decreased the volume of water at Sherwood from March to June by at least 25%. These are shown in Table 12.

Table 12. Trace 100 March 1 to June 1 volume at Sherwood Crossing

	Sherwood Volume from March 1 to June 1		
	Base (ac-ft)	309 (ac-ft)	%
3014	8,308.89	6,299.29	24%
3015	20,433.70	14,502.30	29%
3016	6,351.18	3,912.75	38%
3028	8,015.72	3,869.19	52%
3029	8,179.26	3,531.53	57%
3045	9,853.15	5,293.09	46%
3046	19,405.51	14,050.16	28%
3052	8,667.26	4,392.47	49%
3056	15,621.91	11,303.64	28%
3061	18,388.85	12,533.83	32%
3062	23,736.33	17,727.03	25%
3082	8,380.94	5,323.46	36%
3083	10,349.61	7,258.57	30%
3084	11,522.70	6,925.33	40%
3088	19,455.95	13,309.25	32%
3014	8,308.89	6,299.29	24%
3015	20,433.70	14,502.30	29%

5. Path Forward

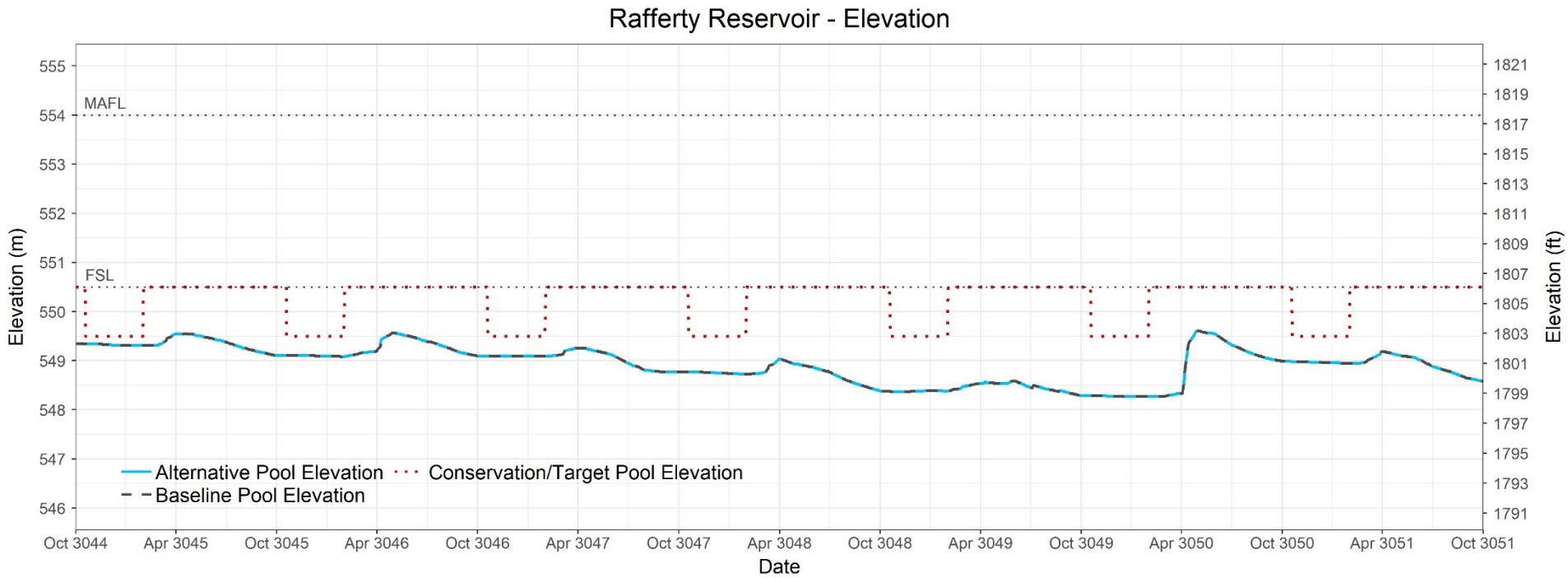
After analysis in multiple phases, the study team found shifting the apportionment year to Nov 1-Oct 31 provides some benefit to Saskatchewan's water supply while having an impact on North Dakota's water supply. Further analysis should be conducted focusing on the years with the largest benefits to Saskatchewan and the largest impacts to North Dakota. These years are most likely to be during a relatively dry spring following a particularly wet fall.

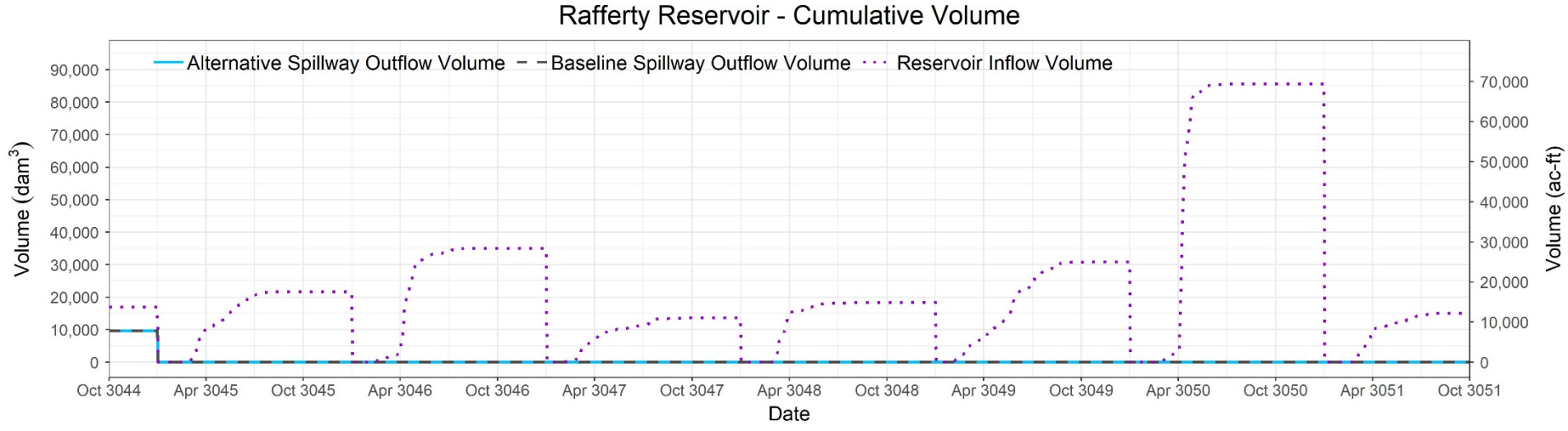
Alternative 311, which increases the normal drawdown elevation or eliminates the normal drawdown all together, has been shown to provide some benefit to Saskatchewan's water supply. This alternative, when combined with Alternative 309, may negate any effects of shifting the apportionment year. Therefore, these two scenarios will be combined, and results will be analyzed in Phase 3.5.

6. References

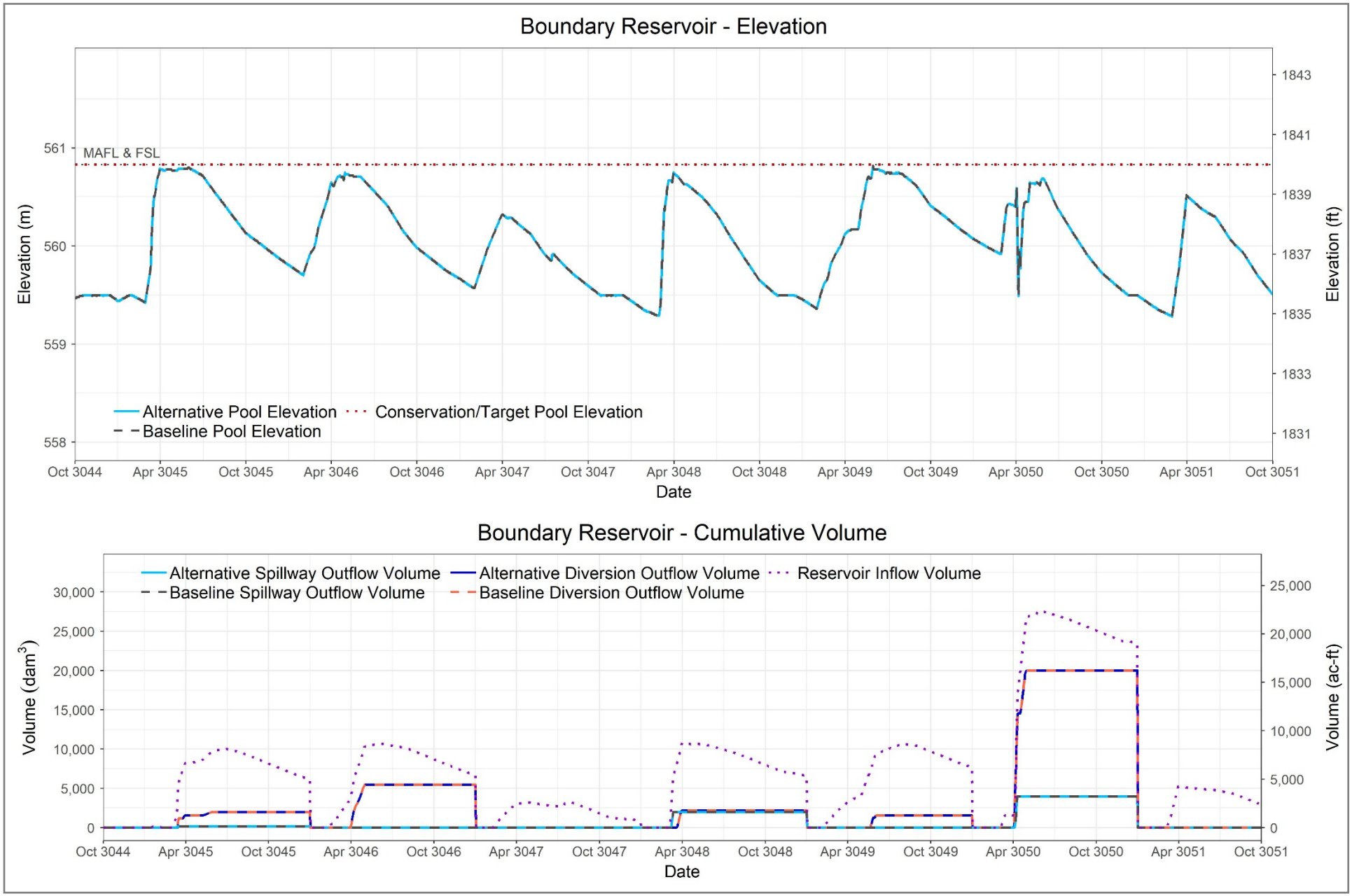
1. "HEC-DSSVue," U.S Army Corps of Engineers, Hydraulic Engineering Center, February 2010.
2. "HEC-ResSim, Reservoir System Simulation, Version 3.3", U.S Army Corps of Engineers, Hydraulic Engineering Center, December 2018.
3. Canada and USA, 1989. Agreement between the Government of Canada and the United 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.
5. Curtis Hallborg, "ISRSB Alternative 7-Apportionment shift" received by Rachel Weller, April 24, 2019
6. Souris River Study Board, Plan Formulation Committee Face-to-Face Meeting, May 21-24, 2019, Saskatoon, Saskatchewan.

Plate 01	Reservoirs – 3045-3051 (Trace 6)	Alternative 309 (Phase 3) Souris River Plan of Study





**MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level*



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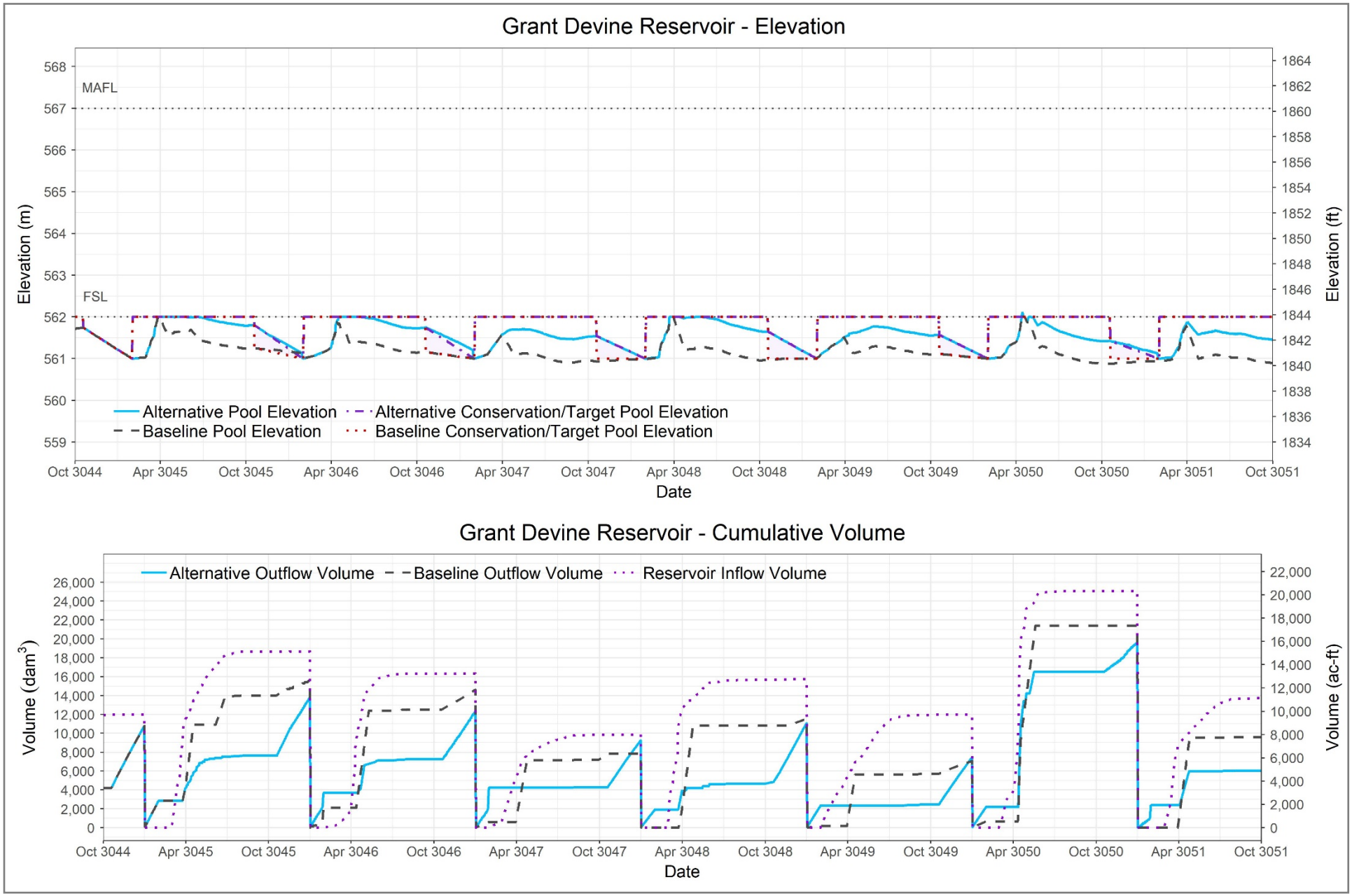

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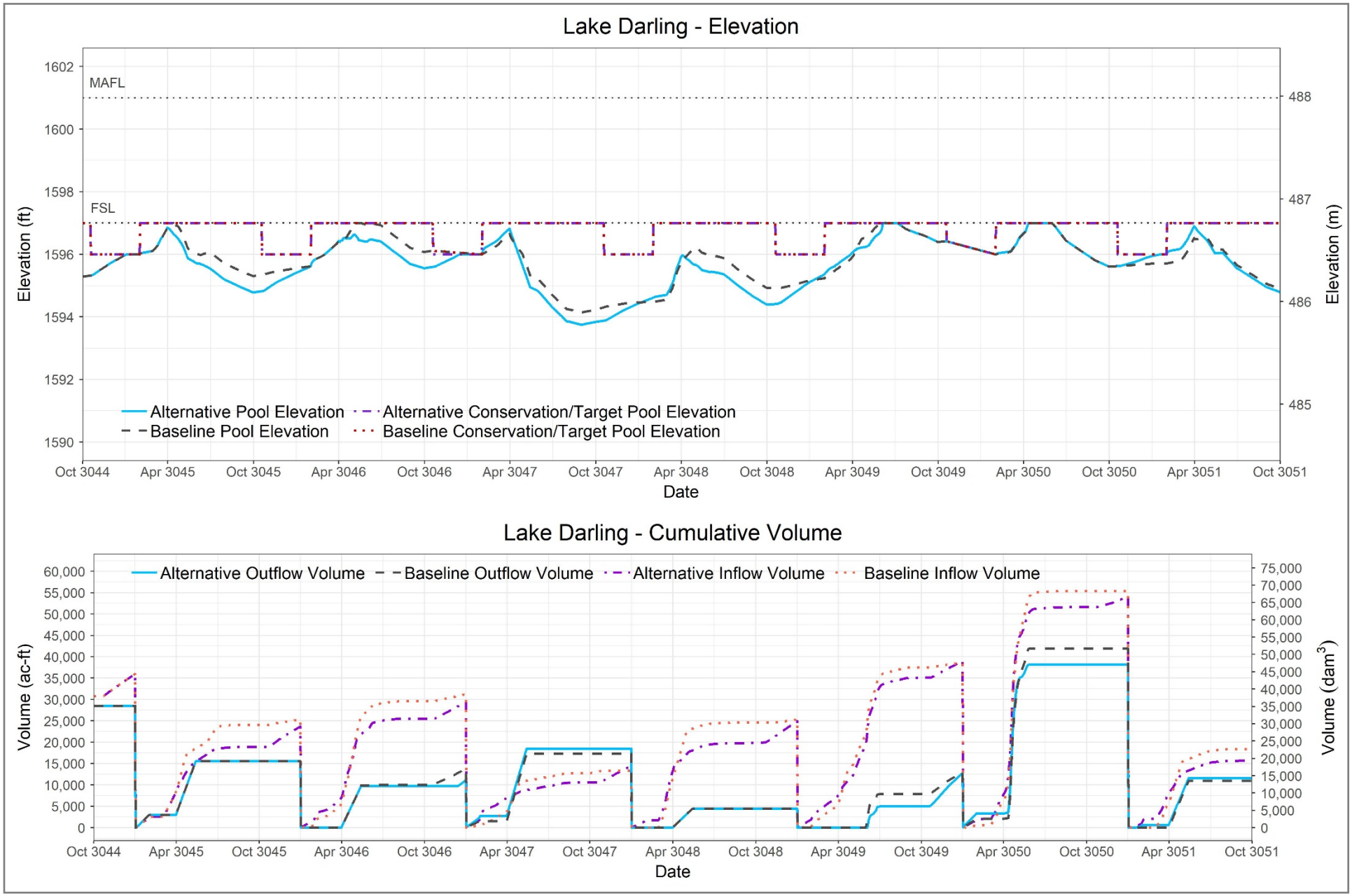


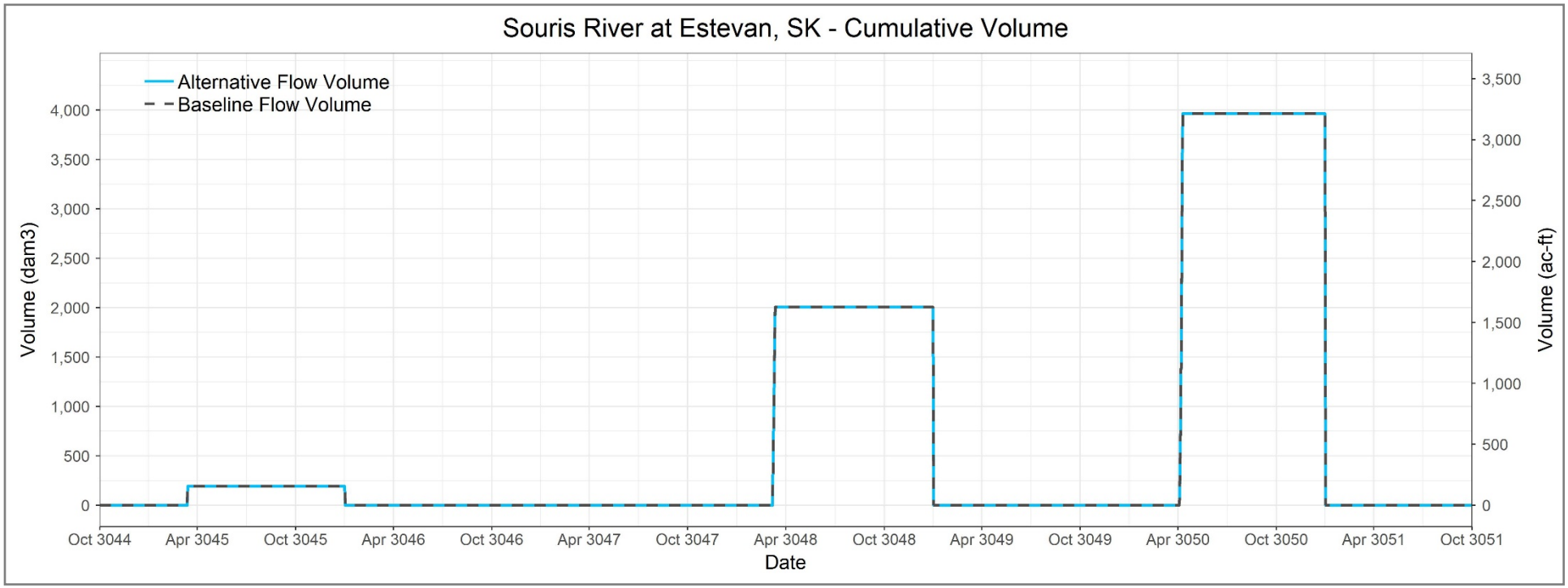
**MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level, IDFSL = Inflow Design Flood Supply Level*

Plate 02

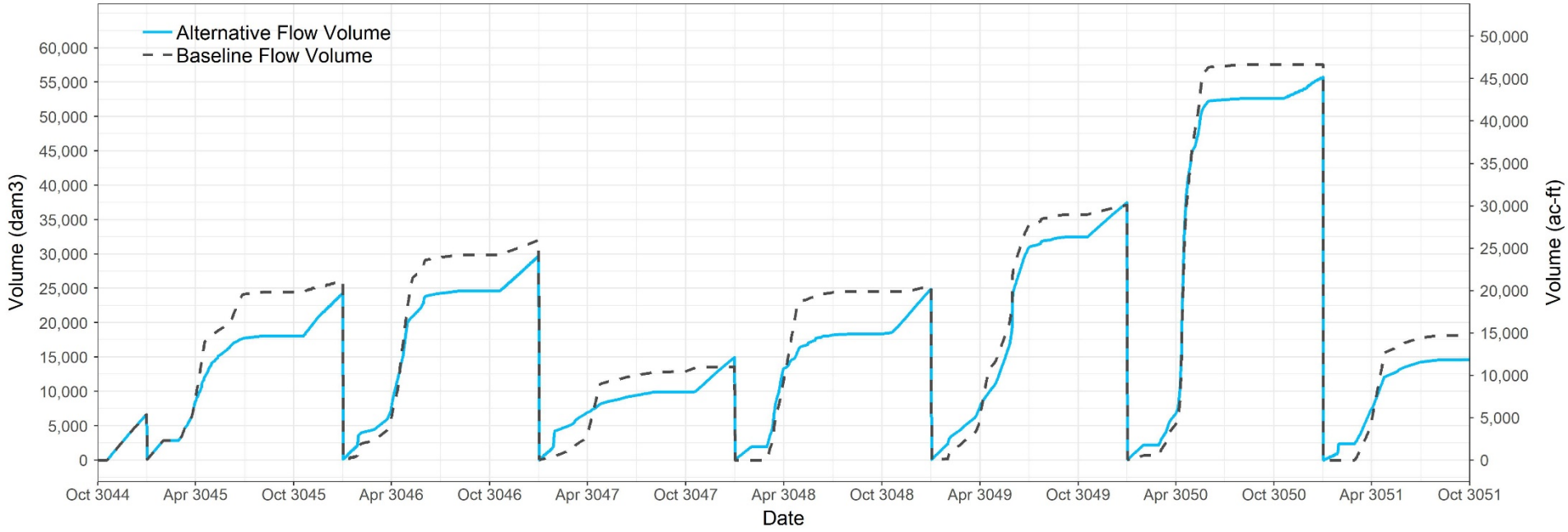
Critical Flow Locations – 3045-3051 (Trace 6)

Alternative 309 (Phase 3)

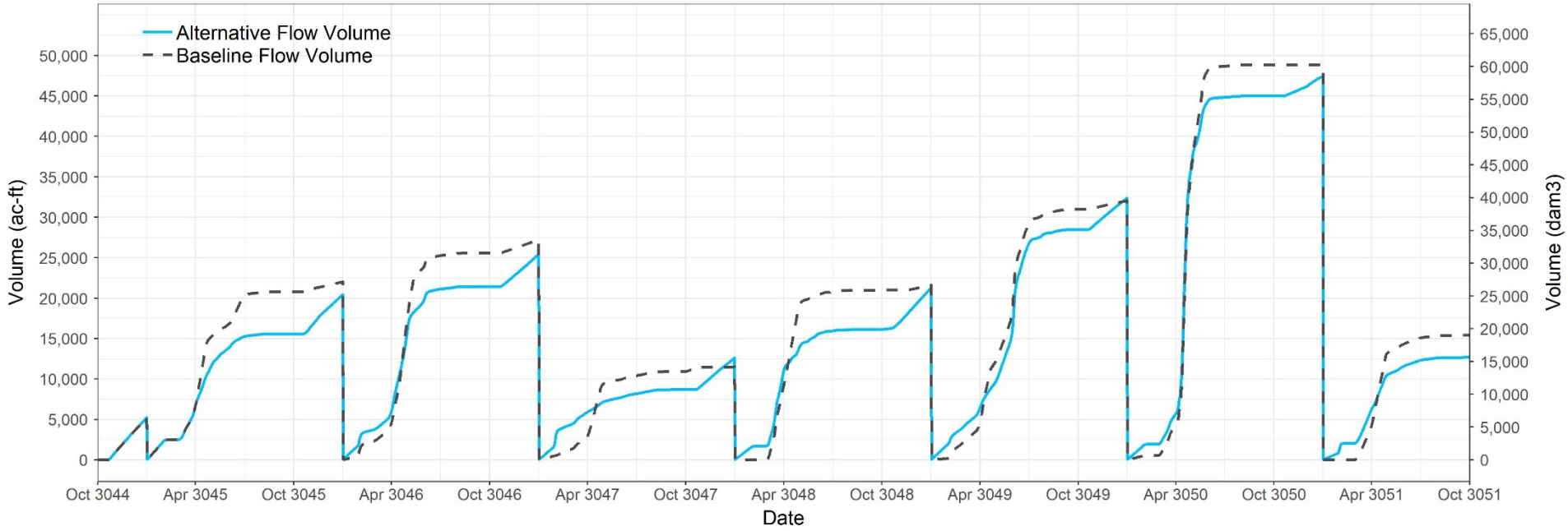
Souris River Plan of Study



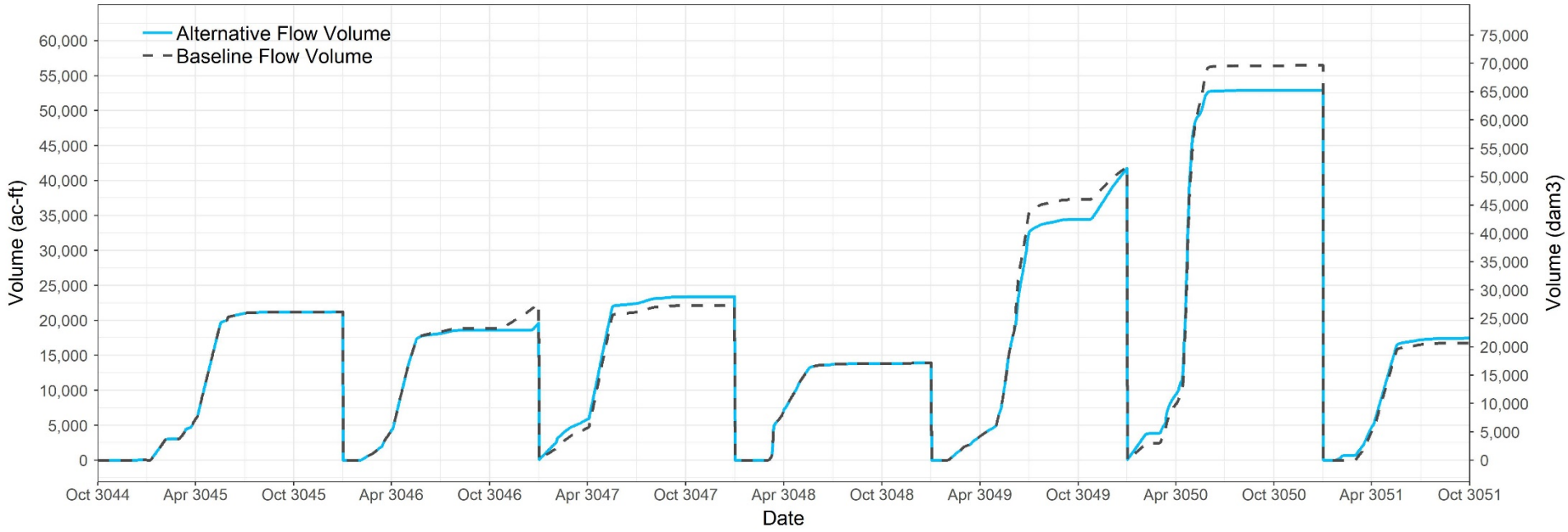
Souris River at Oxbow, SK - Cumulative Volume



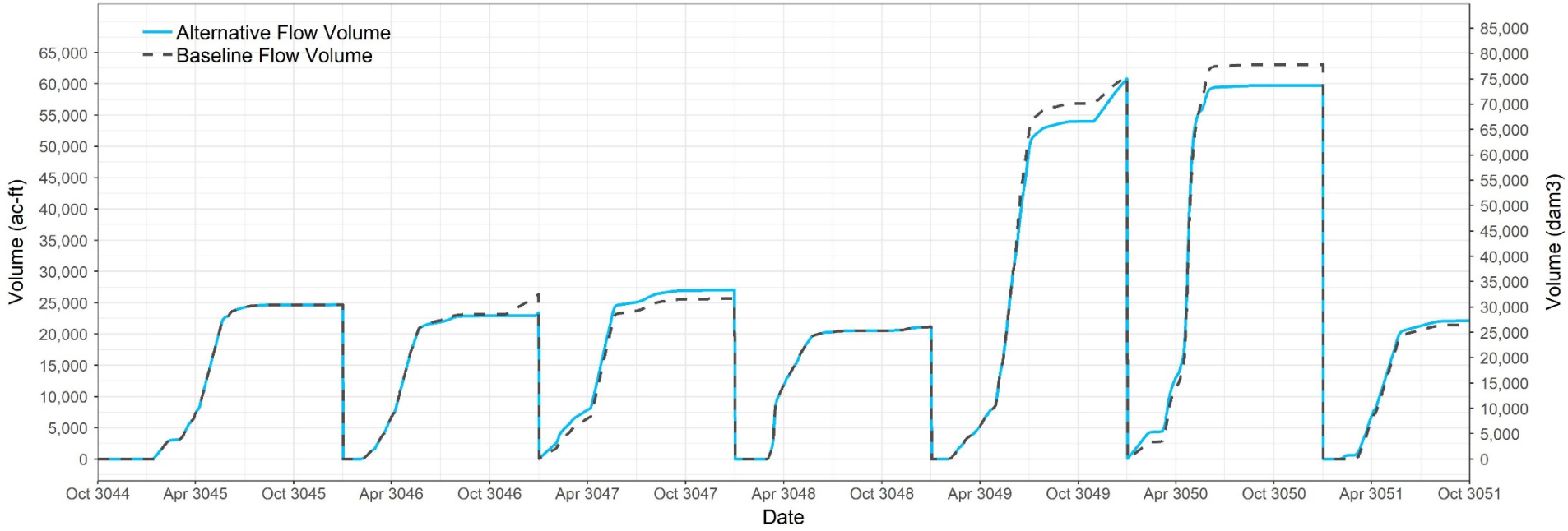
Souris River at Sherwood, ND - Cumulative Volume



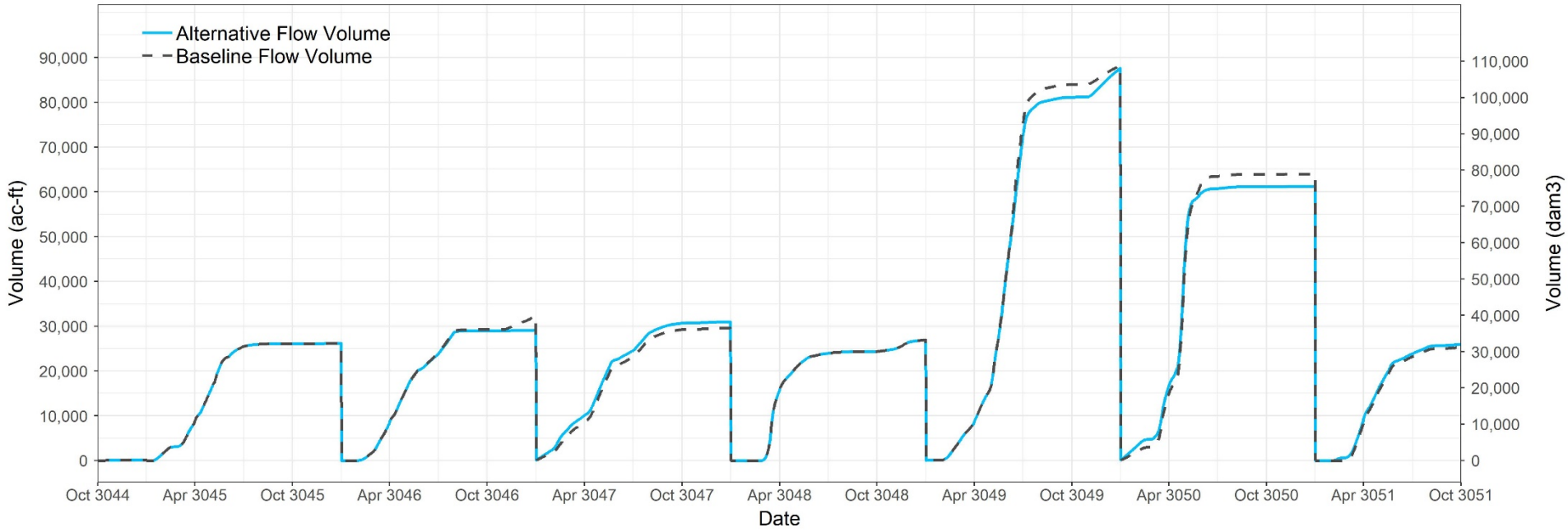
Souris River at Minot, ND - Cumulative Volume



Souris River at Verendrye, ND - Cumulative Volume



Souris River at Bantry, ND - Cumulative Volume



Souris River at Westhope, ND - Cumulative Volume

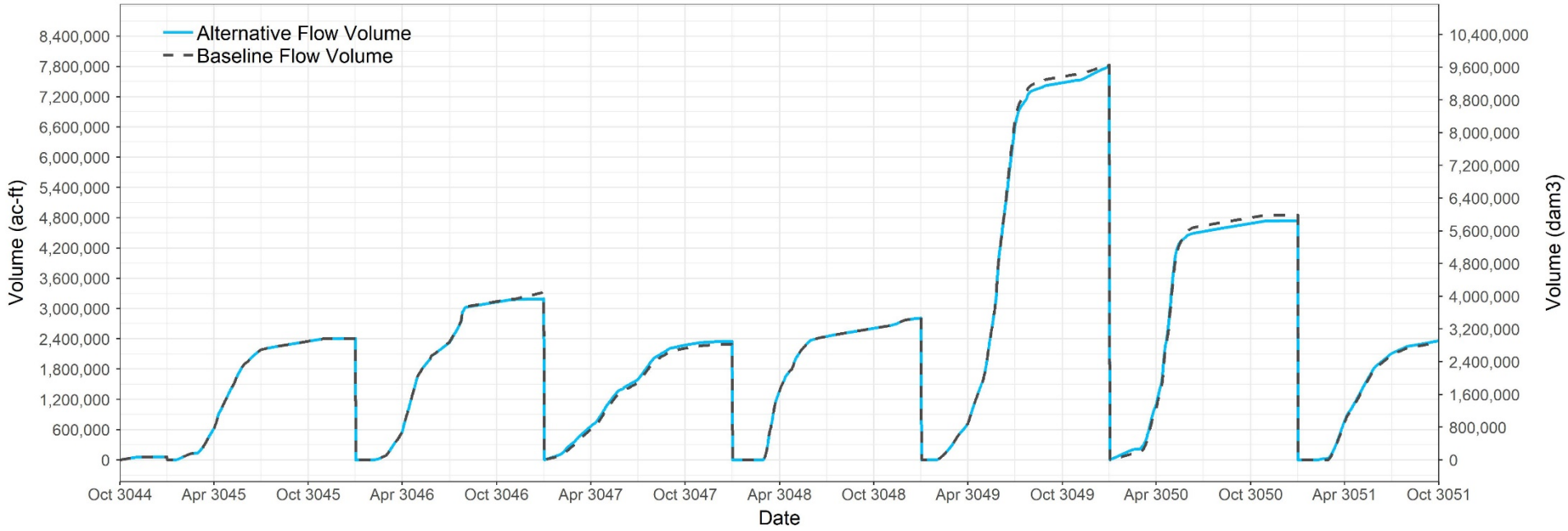
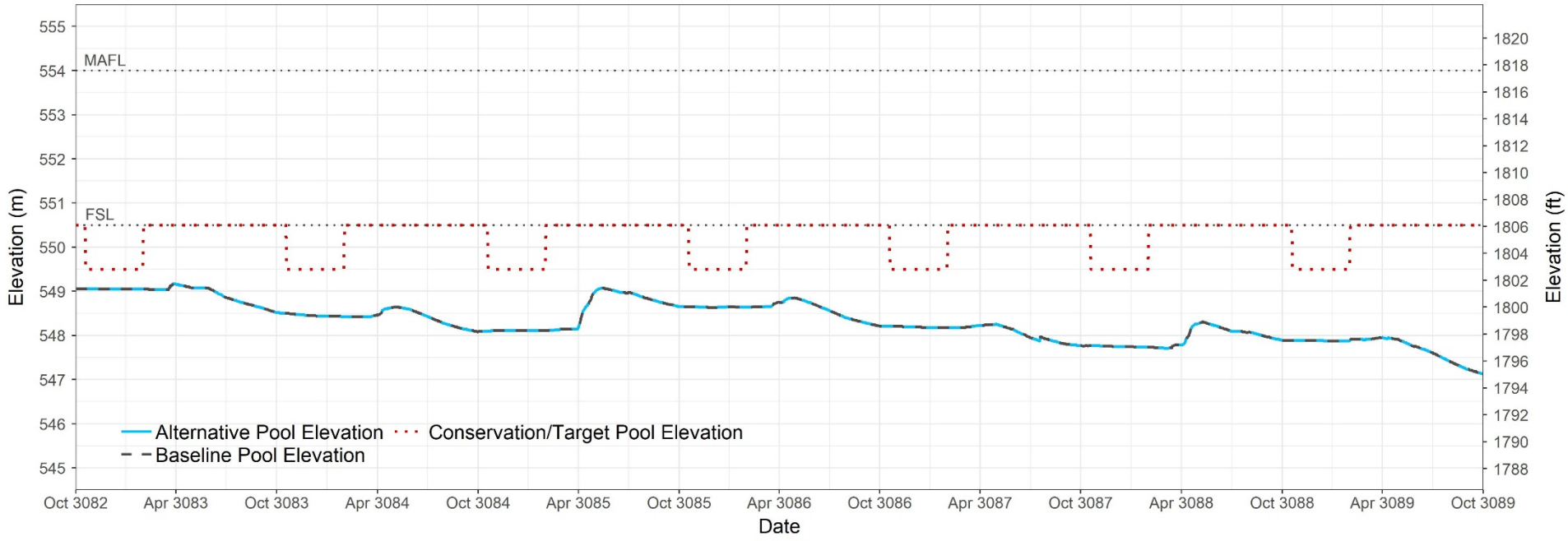
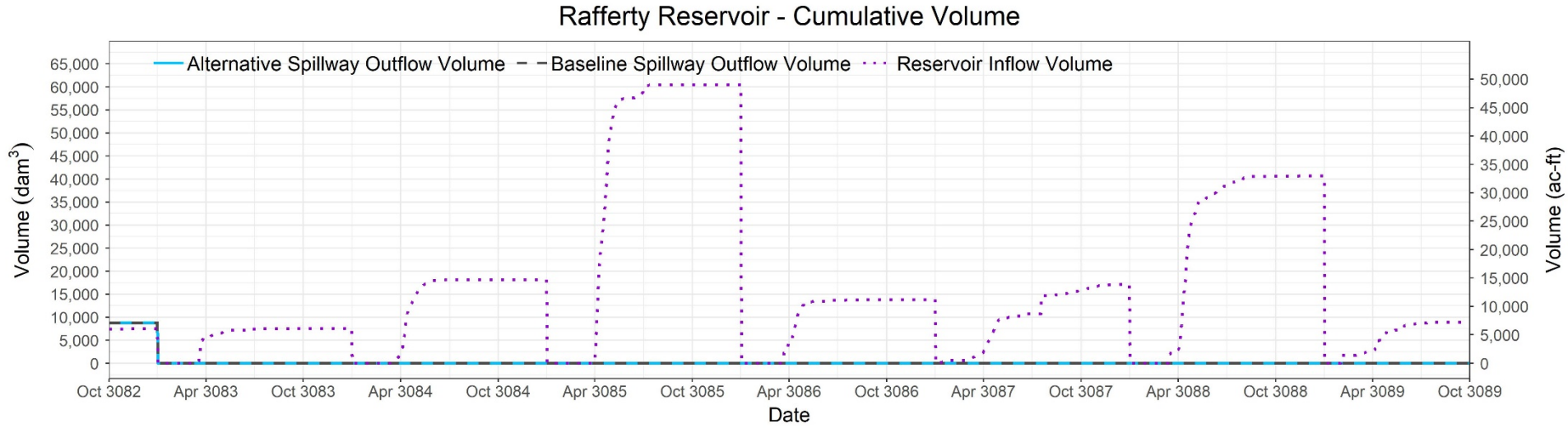
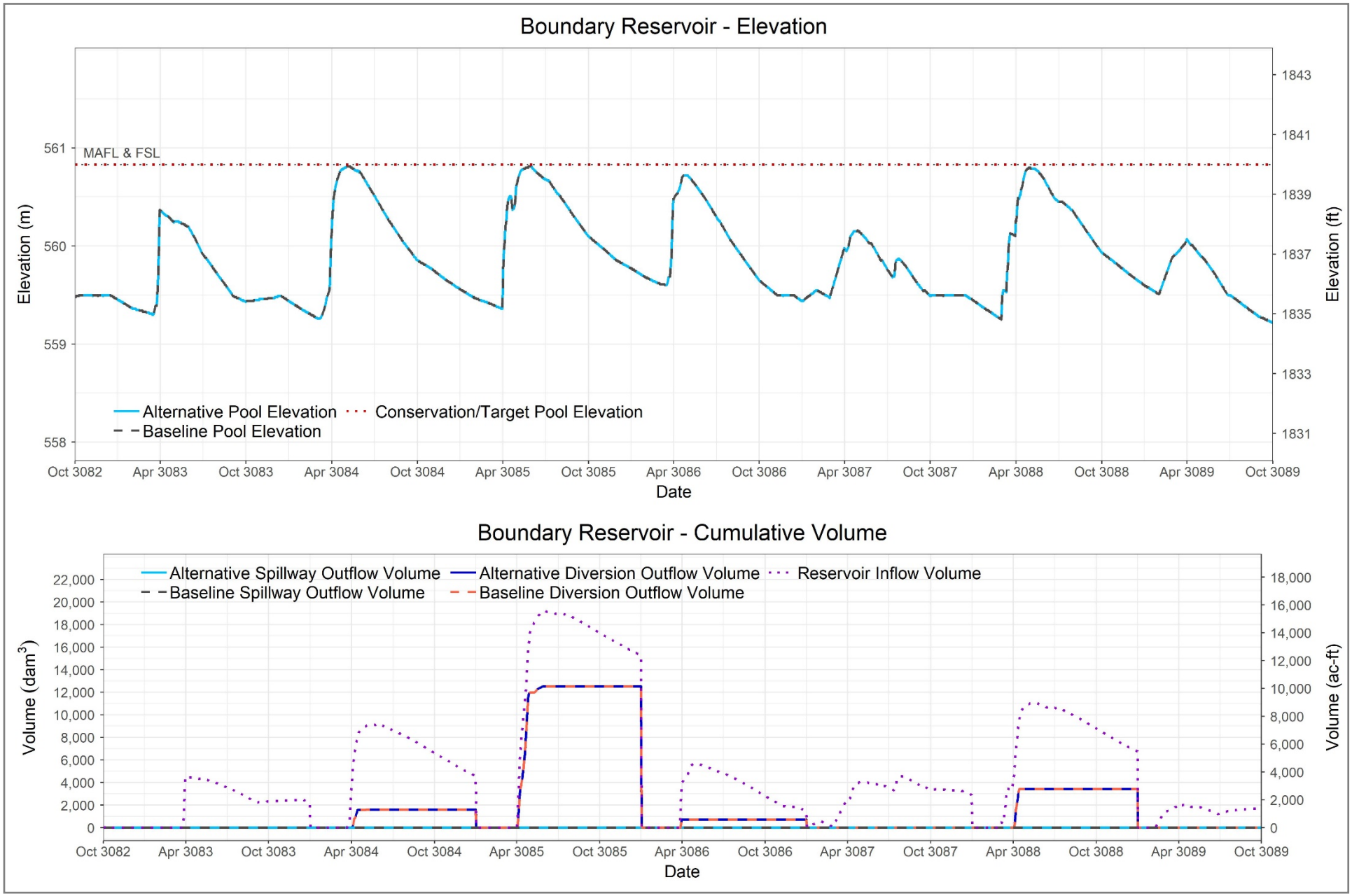


Plate 03	Reservoirs – 3083-3089 (Trace 52)	Alternative 309 (Phase 3) Souris River Plan of Study

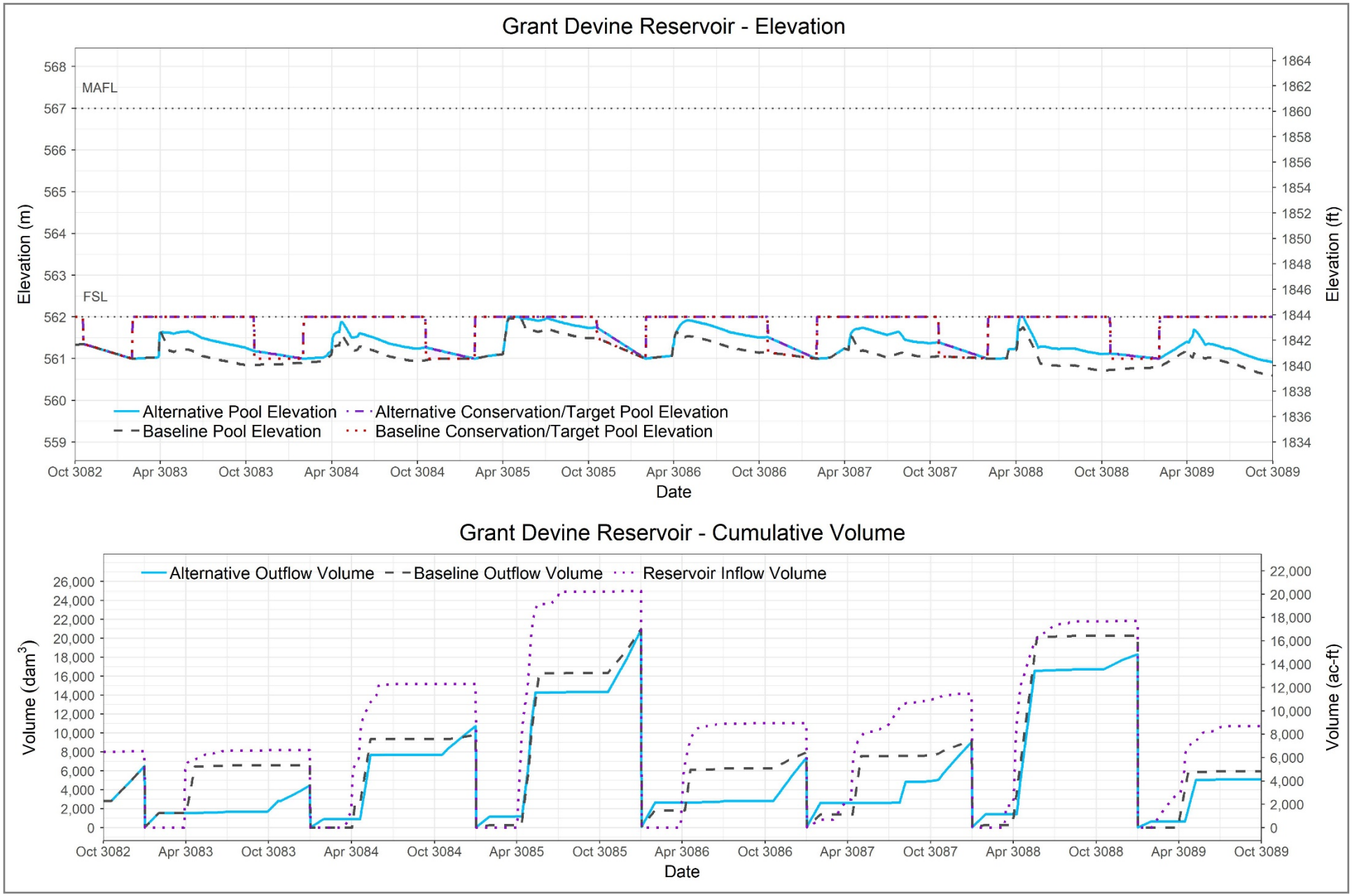




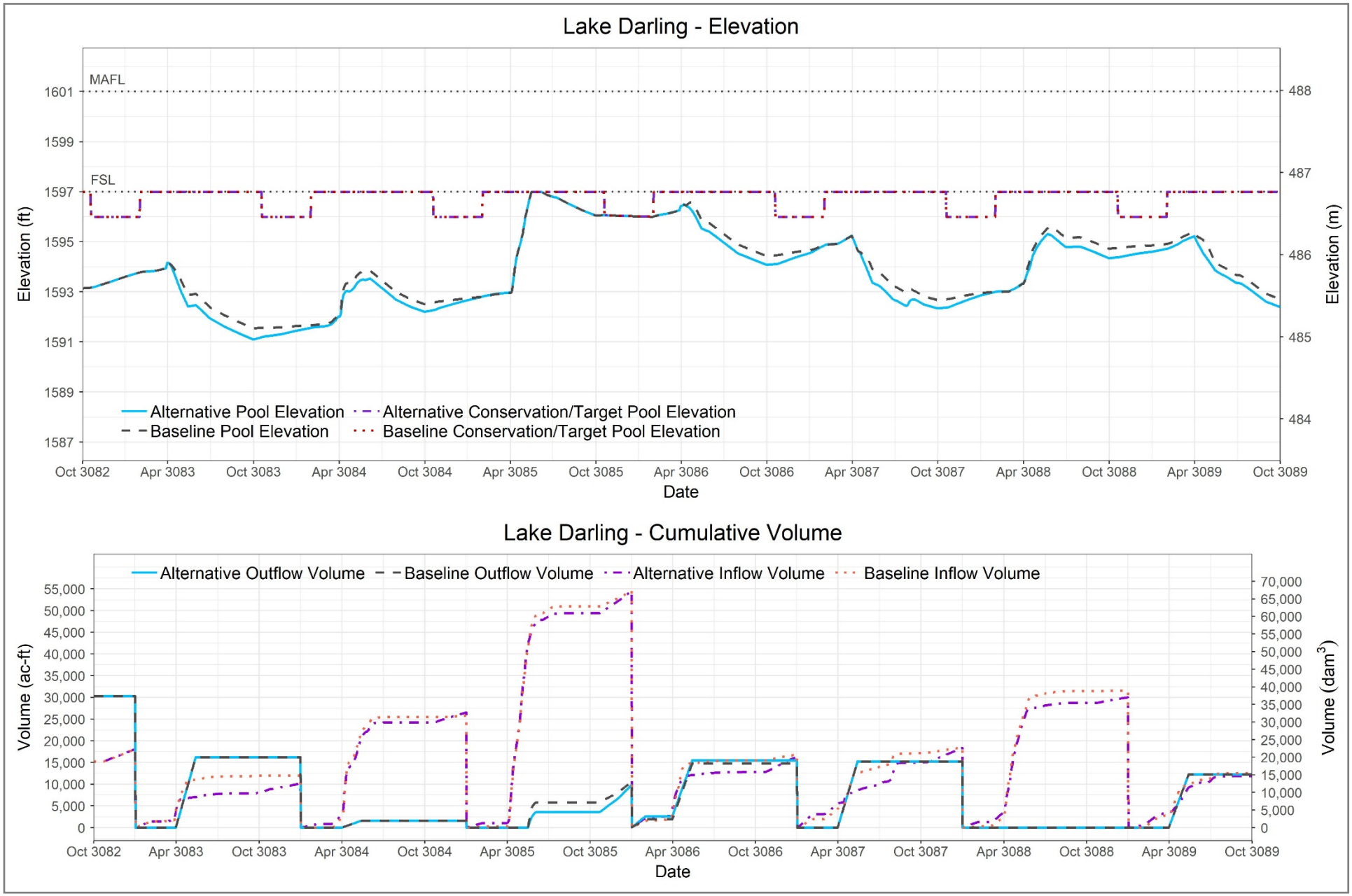
**MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level*



**MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level*



**MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level*



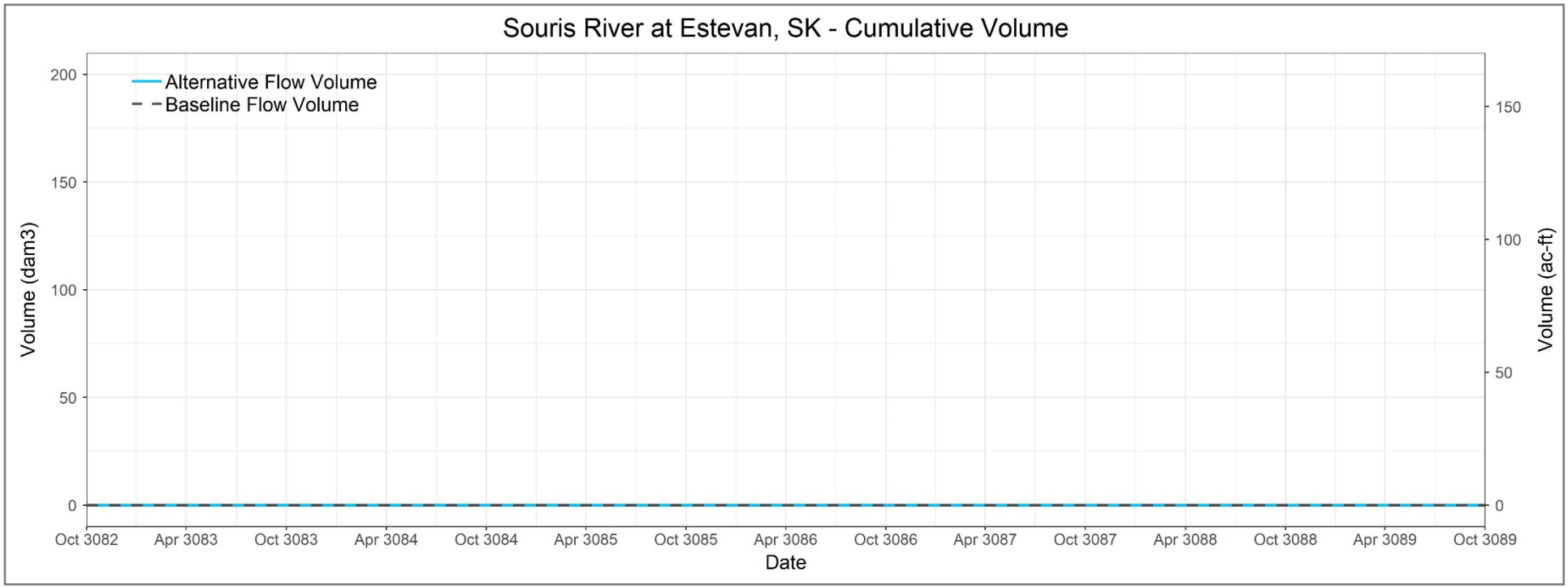
**MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level, IDFSL = Inflow Design Flood Supply Level*

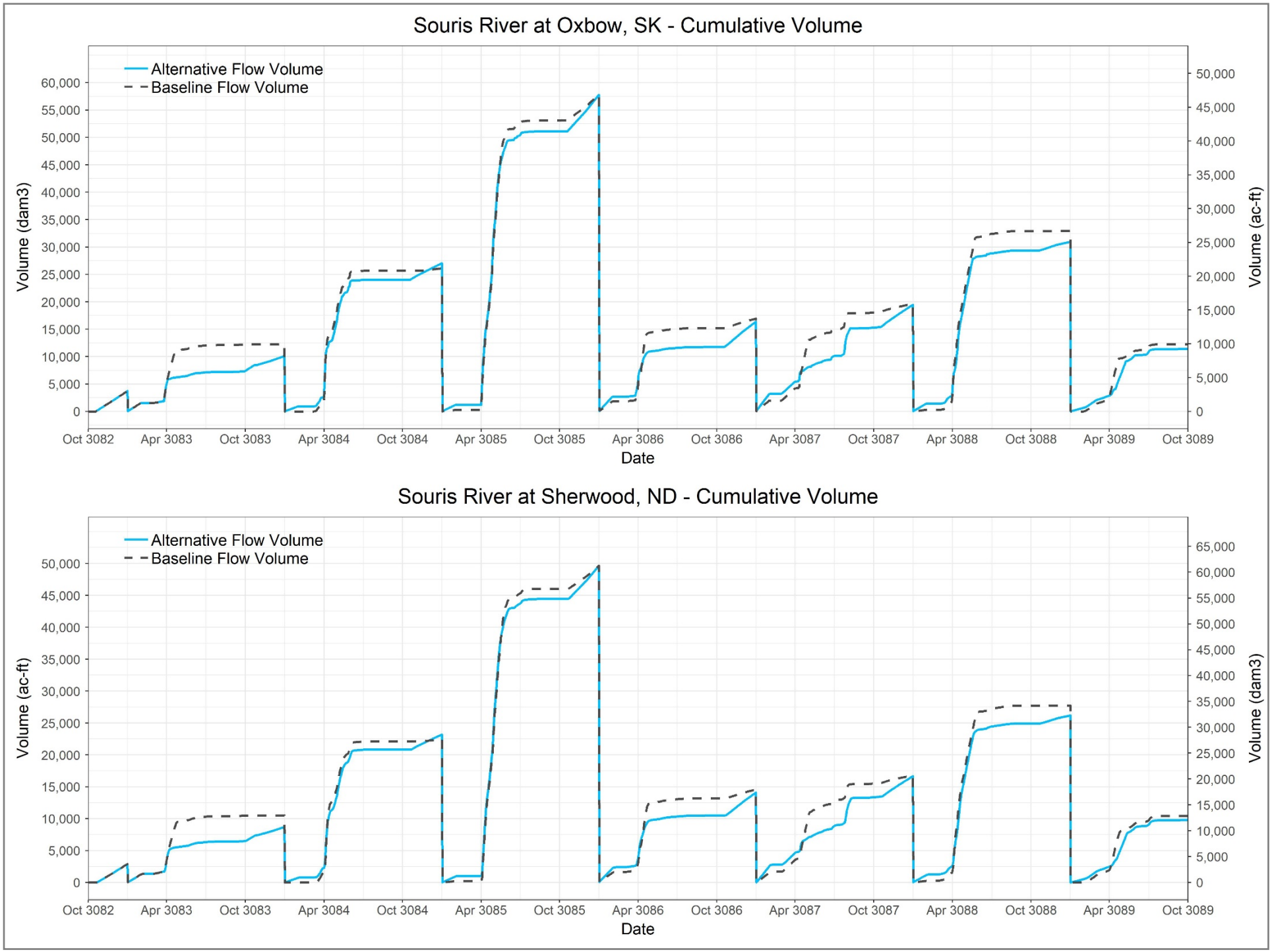
Plate 04

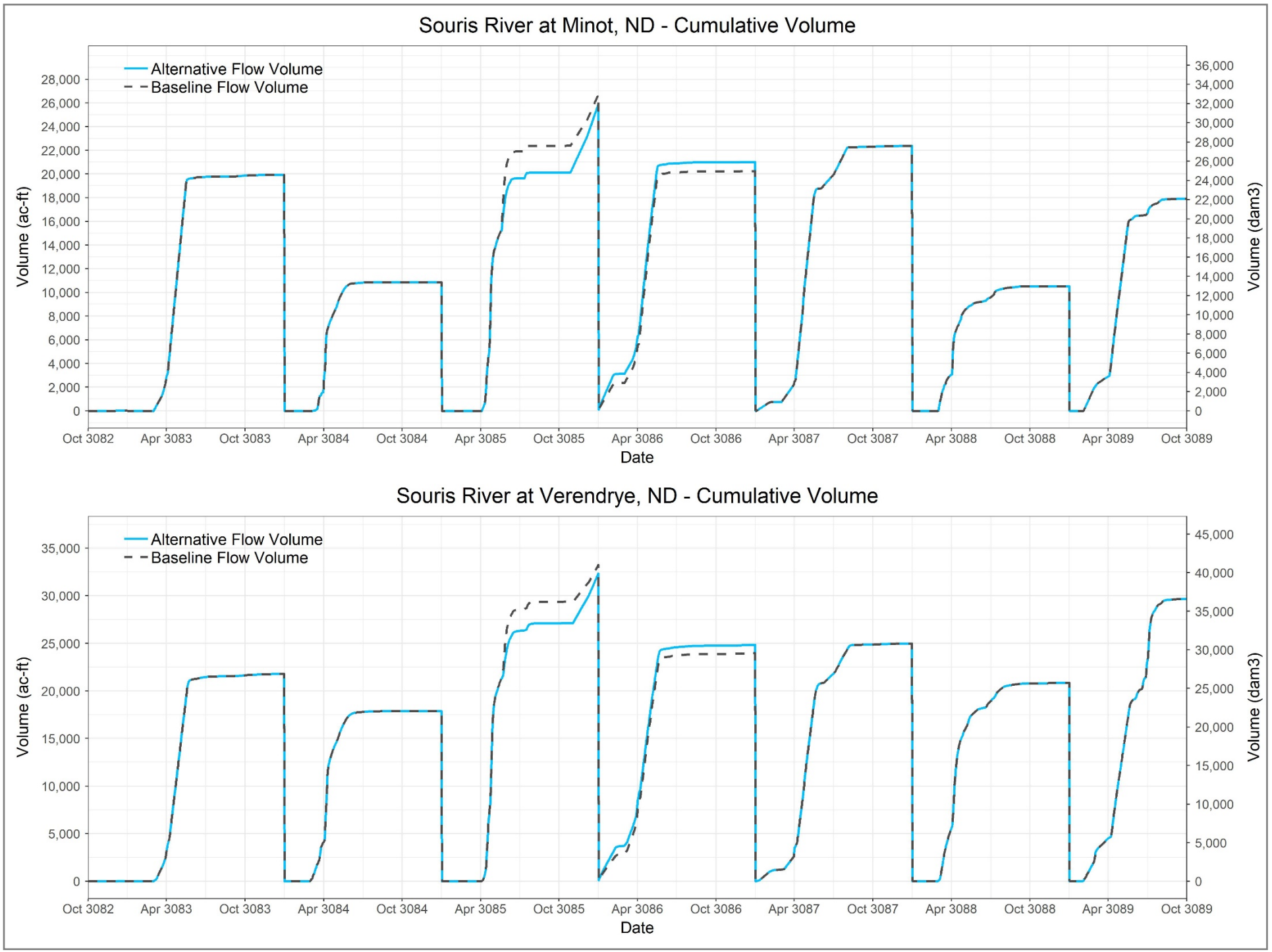
Critical Flow Locations – 3083-3089 (Trace 52)

Alternative 309 (Phase 3)

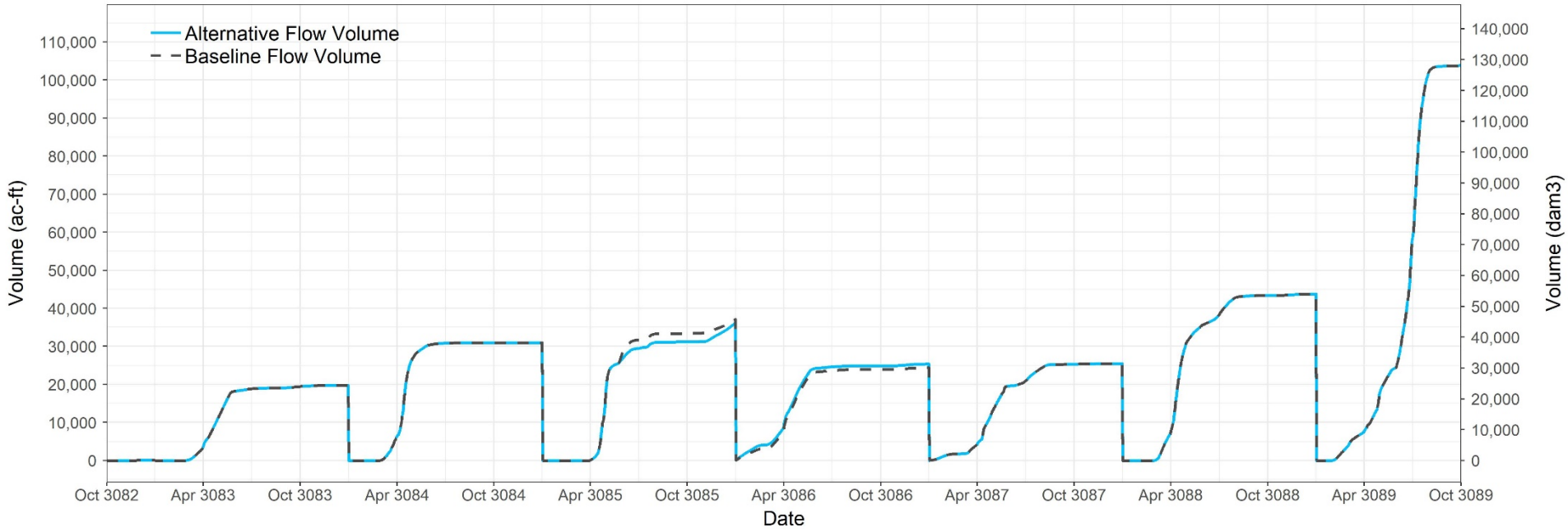
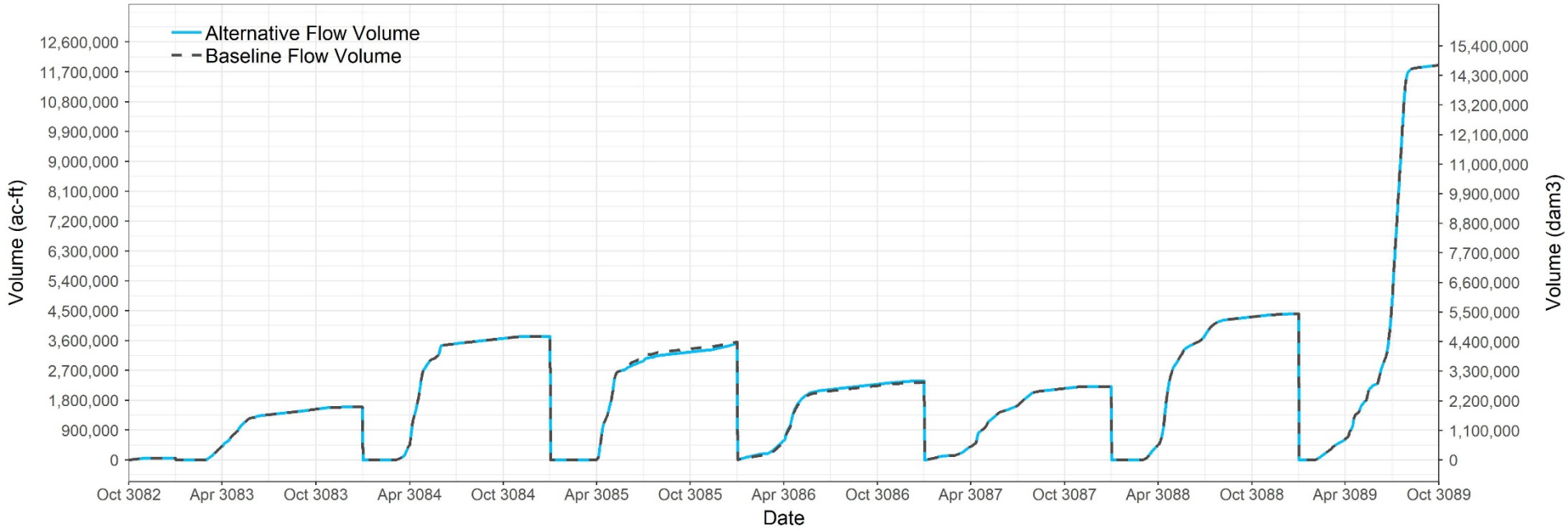
Souris River Plan of Study




Souris River at Oxbow, SK - Cumulative Volume
Alternative Flow Volume
Baseline Flow Volume
Volume (dam3)
Volume (ac-ft)
Date
Oct 3082
Apr 3083
Oct 3083
Apr 3084
Oct 3084
Apr 3085
Oct 3085
Apr 3086
Oct 3086
Apr 3087
Oct 3087
Apr 3088
Oct 3088
Apr 3089
Oct 3089
Souris River at Sherwood, ND - Cumulative Volume
Alternative Flow Volume
Baseline Flow Volume
Volume (ac-ft)
Volume (dam3)
Date


Souris River at Minot, ND - Cumulative Volume
Alternative Flow Volume
Baseline Flow Volume
Volume (ac-ft)
Volume (dam3)
Date
Oct 3082
Apr 3083
Oct 3083
Apr 3084
Oct 3084
Apr 3085
Oct 3085
Apr 3086
Oct 3086
Apr 3087
Oct 3087
Apr 3088
Oct 3088
Apr 3089
Oct 3089
Souris River at Verendrye, ND - Cumulative Volume
Alternative Flow Volume
Baseline Flow Volume
Volume (ac-ft)
Volume (dam3)
Date

Souris River at Bantry, ND - Cumulative Volume



Souris River at Westhope, ND - Cumulative Volume