Appendix B-5: Alternative 3

Agricultural Flooding

HEC-ResSim Initial Alternative Assessment

Table of Contents

1. Alternative Description & Objective 4
1.1 Alternative Development 4
1.2 Alternative Fine Tuning 4
1.3 HEC-ResSim Nomenclature 4
2. Operational Rules 5
3. Alternative vs Baseline Condition Results 7
4. Summary of Results 8
4.1 Performance Indicators 8
4.1.1 Reservoirs 8
4.1.2 Riverine Reaches 8
5. Suggested Further Alternative Fine Tuning 8
6. Path Forward 9
7. References 9

Figures

Figure 1. Rule Tree with new downstream maximum constraint at Bantry 6
Figure 2. Downstream constraint setup 7

Tables

Table 1. Seasonal flow constraints for Bantry, ND 4
Table 2. Model nomenclature 5
Table 3. Rules specific to alternative 5

Plates

Plate 01 – 1969: Baseline vs Alternative Reservoir Operations
Plate 02 – 1969: Baseline vs Alternative Flows at Critical Locations
Plate 03 – 1974: Baseline vs Alternative Reservoir Operations
Plate 04 – 1974: Baseline vs Alternative Flows at Critical Locations
Plate 05 – 1975: Baseline vs Alternative Reservoir Operations
Plate 06 – 1975: Baseline vs Alternative Flows at Critical Locations
Plate 07 – 1976: Baseline vs Alternative Reservoir Operations
Plate 08 – 1976: Baseline vs Alternative Flows at Critical Locations

Plate 09 – 2011: Baseline vs Alternative Reservoir Operations
Plate 10 – 2011: Baseline vs Alternative Flows at Critical Locations
Plate 11 – 1930-2017: Baseline vs Alternative Performance Indicators

1. Alternative Description & Objective

The purpose of this alternative is to model the reduction in downstream agricultural damages through the implementation of maximum flow constraints at Bantry, ND. Flow constraints were implemented through restrictions on releases from Lake Darling Dam. Results derived to reflect the suggested alternative were compared to baseline model results. Baseline model results reflect present day operations (Annex A & Annex B). The baseline run used the same simulation time window as the alternative (1930-2017).

1.1 Alternative Development

Releases from Lake Darling Reservoir were restricted as a function of date and can be seen in **Error! Reference source not found.**. The restrictions on the releases from Lake Darling were intended to simulate how downstream flow and agricultural damage would be reduced if Lake Darling Reservoir were operated to limit flow downstream. The flow thresholds shown below were chosen based on feedback received from the Public Advisory Group (PAG) and Resource and Agency Advisory Group (RAAG) at the April 2018 ISRSB workshop in Minot, ND.

Table 1. Seasonal flow constraints for Bantry, ND

Season	Max Flow Limit at Bantry, ND
01 Feb – 01 May	3,000 cfs
02 May – 02June	1,500 cfs
03 June – 01 Oct	350 cfs

1.2 Alternative Fine Tuning

The first runs of this alternative model were done with linear interpolation between the dates determining the seasonal constraints in Table 1. It was decided that step interpolation would be more accurate and the interpolation was changed. In addition, the Bantry downstream control rule had to be added to the MAFL zone to avoid a zone boundary issue in ResSim. Doing this effectively increased the Top of Flood Control for this alternative from 1598 ft during the summer months, as described in the International Agreement, to 1601 ft.

1.3 HEC-ResSim Nomenclature

Within HEC-ResSim, a new network, alternative and simulation run was generated to reflect each proposed alternative. 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 both baseline and alternative operations are listed in **Error! Not a valid bookmark self-reference.**.

Table 2. Model nomenclature

Scenario	Time Window	ResSim Model Name	Network Name	Alternative Name	Simulation Name
Baseline	1930-2017	SourisRiverPoS	Base	BL_Norm	1930-2017_BL-1
Agricultural Flooding	1930-2017	SourisRiverPoS	3a_Bty_Ag	3a_Bty_Ag	03BtyMax_Ag_1930_2017

2. Operational Rules

Error! Reference source not found. presents the operational rules that were included in the base HEC-ResSim model alternative to specifically reflect the changes required in support of the Alternative 3. No other modifications were made in the state variable or otherwise in the model.

Table 3. Rules specific to alternative

Name of Dam	Name of Rule, Outlet or IF Statement or State Variable Element	Rule Description
Rafferty Reservoir	-	-
Boundary Reservoir	-	-
Grant Devine Reservoir	-	-
Lake Darling Reservoir	DS_Bantry_Ag	Seasonal downstream maximum constraint at Bantry, ND

Error! Reference source not found. displays the operations rule tree for Lake Darling Reservoir with the new operating rule implemented, with red boxes indicating the new rule at Bantry. The seasonality of the rule can be seen both in the table and in the graphical display located to the right of the table.

Error! Reference source not found. shows how the rule was set up as a downstream constraint for Lake Darling Reservoir as a whole.

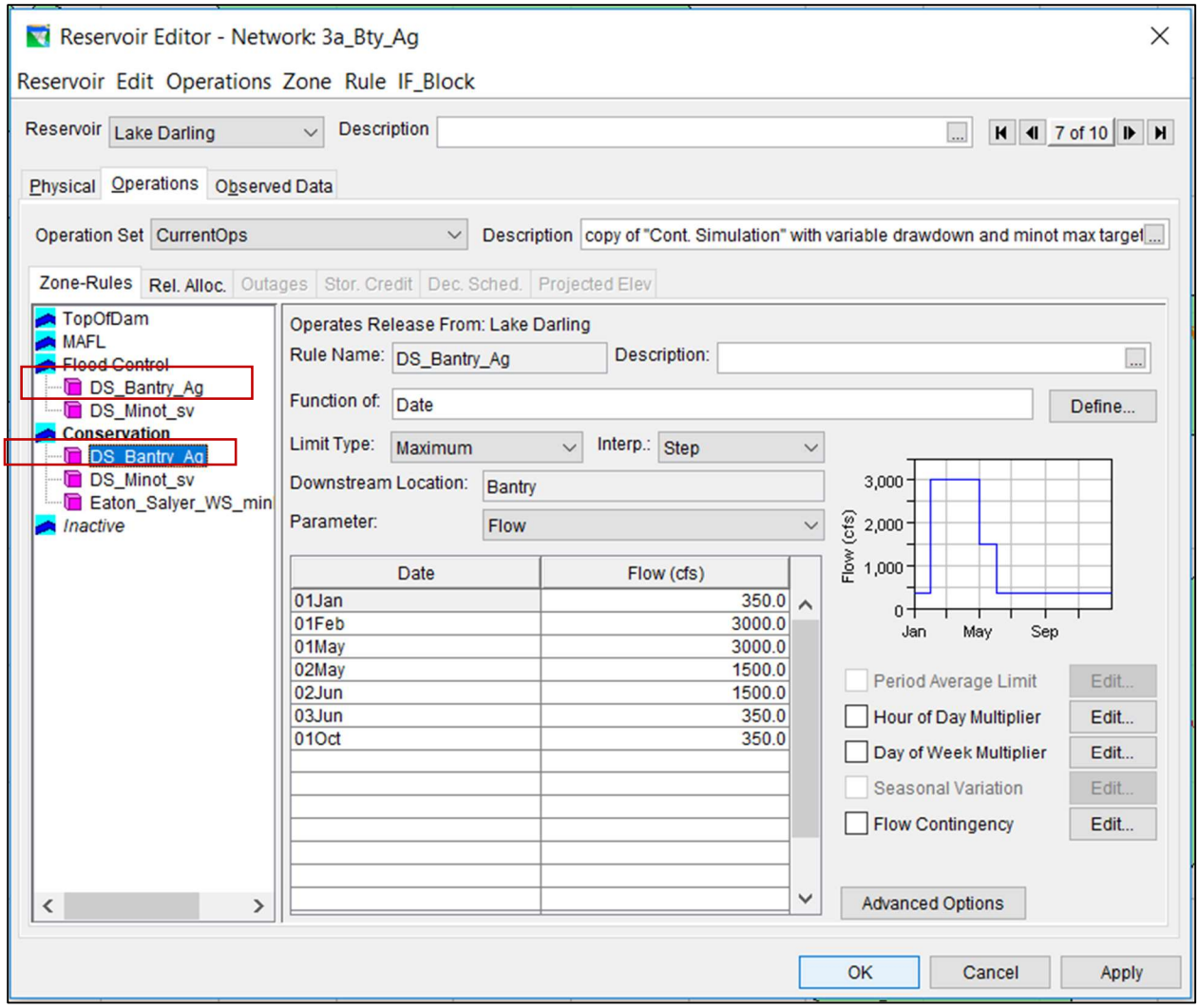


Figure 1. Rule Tree with new downstream maximum constraint at Bantry

IMPORTANT: The DS_Bantry_Ag rule was also added to the MAFL zone, effectively raising the Flood Control zone to 1601 ft. This is not shown in the figure above.

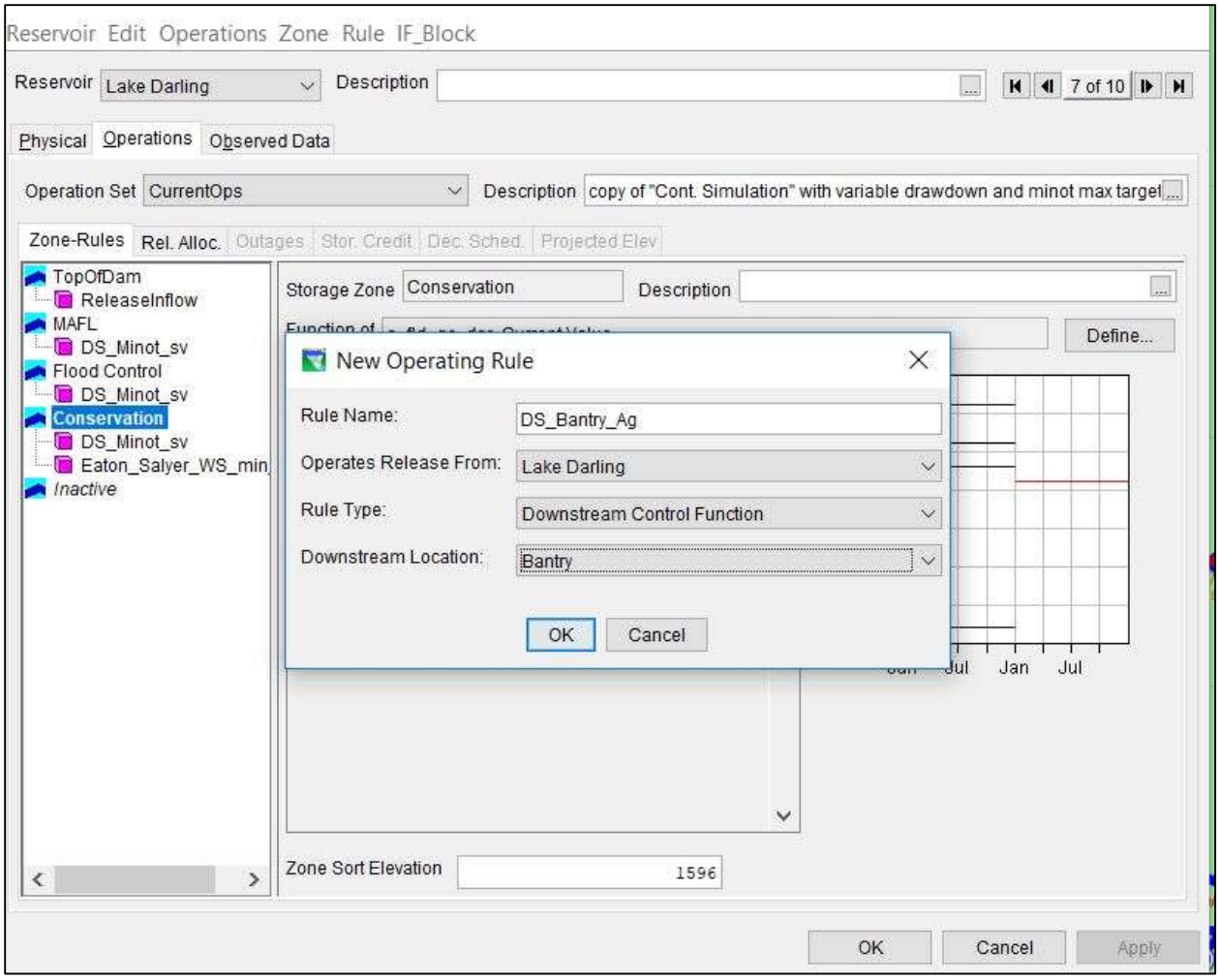


Figure 2. Downstream constraint setup

3. Alternative vs Baseline Condition Results

Plates 01-10 show hydrographs detailing the results of Alternative 3 relative to the baseline scenario at Rafferty, Boundary, Grant Devine, and Lake Darling reservoirs, as well as seven critical mainstem flow locations, for select “index” years. Index years were selected to be representative of high, medium, and low flow years in the basin. High flow years include 2011, 1976, 1975, and 1969, medium flow years include 1987, 1952, and 1946, and low flow years include 1937, 1988, and two extended drought sequences: 1931-1937 and 1988-1991. For Alternative 3, the four flood index years (1969, 1975, 1976 and 2011) were plotted, as well as one non-index year (1974). 1974 is included to better show the effects of this alternative on small floods.

Plate 11 displays performance indicator results for all study reaches over the entire simulation (1930-2017). 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

Since no changes were made to Rafferty, Boundary or Grant Devine reservoirs in Alternative 3, there are no changes relative to the baseline results at any location above Lake Darling. Therefore, the only changes from the baseline simulation are at and below Lake Darling. In addition, there are no changes from baseline during low to moderate flow years.

Generally, Lake Darling pool elevations rise more quickly in this alternative compared to baseline conditions and remain higher for longer, minimizing flood storage in the reservoir. During large flood events, such as 1975, 1976 and 2011, the reservoir reaches MAFL prior to end of the flood event, losing the ability to control flows downstream. In 1974, Lake Darling's pool reaches MAFL in late May, and the reservoir is unable to reduce releases to stay under the 350 cfs maximum at Bantry after June 1st. In 1969, Lake Darling's pool stays well below MAFL, and the reservoir generally manages to maintain flows at Bantry at or below the seasonal flow restrictions.

4.1 Performance Indicators

4.1.1 Reservoirs

Since there are no operational changes to Rafferty or Grant Devine, there is no change to the performance indicators (PIs) for those reservoirs. At Lake Darling, higher reservoir levels have negative impacts to flood control at Mouse River Park and flooding of archaeological sites. Fish and wildlife habitat and boating access are also negatively impacted. There are significant negative impacts to dam safety, as Lake Darling spends much more time near MAFL during large flood events.

4.1.2 Riverine Reaches

PIs for reaches upstream of Lake Darling do not show measurable changes from baseline. Downstream of Lake Darling, there are neutral or positive impacts to most PIs. Since Lake Darling uses more of its pool for flood storage during the summer relative to the baseline scenario, moderate late season flood peaks tend to be reduced, resulting in benefits to most flood performance indicators. Lower summer flows also contribute to less erosion. As expected, positive impacts to PIs generally decrease in magnitude further downstream of Lake Darling.

The Bankfull Exceedances PI favors the baseline from Towner, ND to Westhope, ND. This is due to Lake Darling being at high pool elevations for long periods after flood events, and therefore making releases that exceed bankfull capacity in these reaches for longer durations. The Fish Mortality PI consistently shows negative change, indicating there is no flow in the river more often. However, the actual magnitude of change to the Fish Mortality PI is negligible.

5. Suggested Further Alternative Fine Tuning

Fine tuning of this alternative will occur in Phase 3 of the modeling effort. Suggested modifications of this alternative include modifying the flow constraints at Bantry, moving the flow constraint from Bantry to an upstream location using an associated flow analysis to reduce model run times, modifying flow constraint dates and combining this downstream constraint with other operating scenarios to develop a more resilient alternative that benefits all stakeholders.

In addition, consultation with the U.S. Fish and Wildlife Service (USFWS) should take place regarding increasing Lake Darling's Top of Flood Control during the summer months. Since historical records

indicate storage above 1598 ft has been used in the past, more discussion needs to occur regarding USFWS's operational flexibility from June to September.

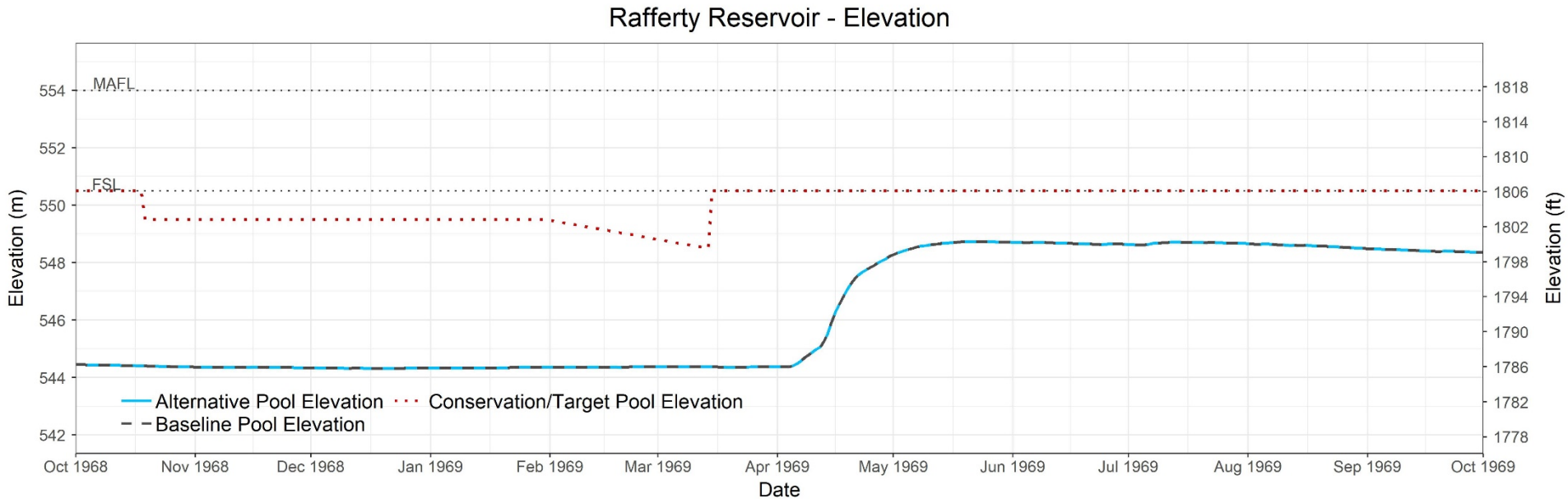
6. Path Forward

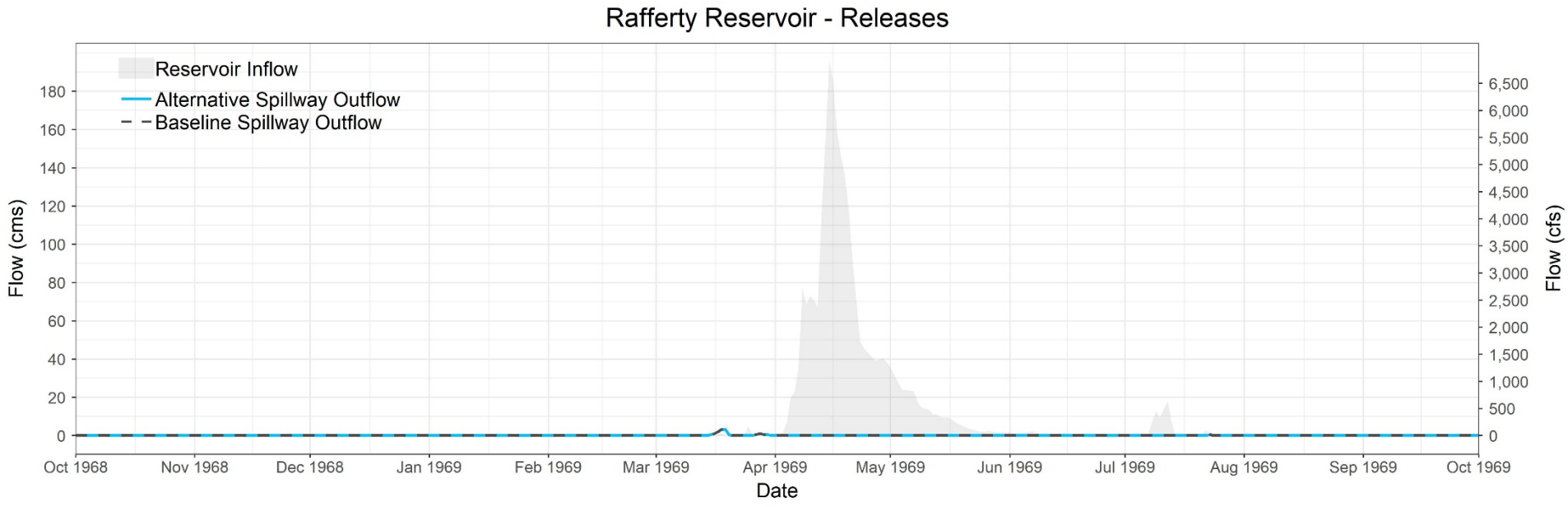
Due to public interest in reducing out of bank flows downstream of Verendrye, ND, and thereby limiting agricultural damages in that reach, this alternative will be carried forward in Phase 3 in alternatives 303 and 304.

7. References

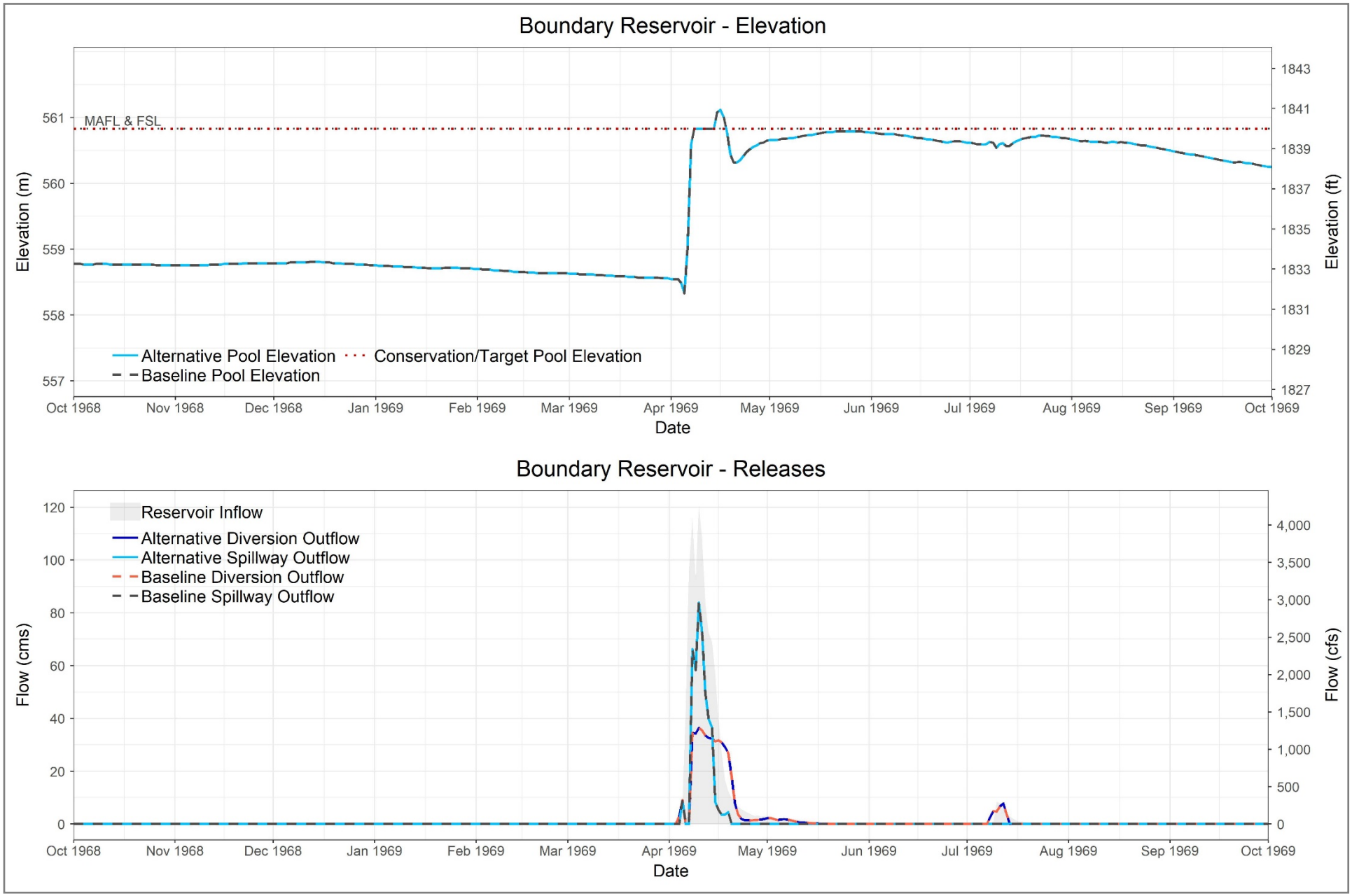
1. "HEC-DSSVue," U.S Army Corps of Engineers, Hydraulic Engineering Center, February 2010.
2. "HEC-ResSim, Reservoir System Simulation, Version 3.3", U.S Army Corps of Engineers, Hydraulic Engineering Center, December 2018.
3. Canada and USA, 1989. Agreement between the Government of Canada and the United 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. There was email communication with the Frank Durbian (U.S.FWS), Elizabeth Nelsen (U.S. Army Corps of Engineers Hydrology and Water Management Section Chief), James Fay, Curtis Hallborg (WSA) during initial modeling stages for this alternative. Frank Durbian offered some insight on changing parts of the alternative and should be included in the fine tuning process as this alternative progresses.

Plate 01	Reservoirs – 1969	Alternative 3 (Phase 2) Souris River Plan of Study

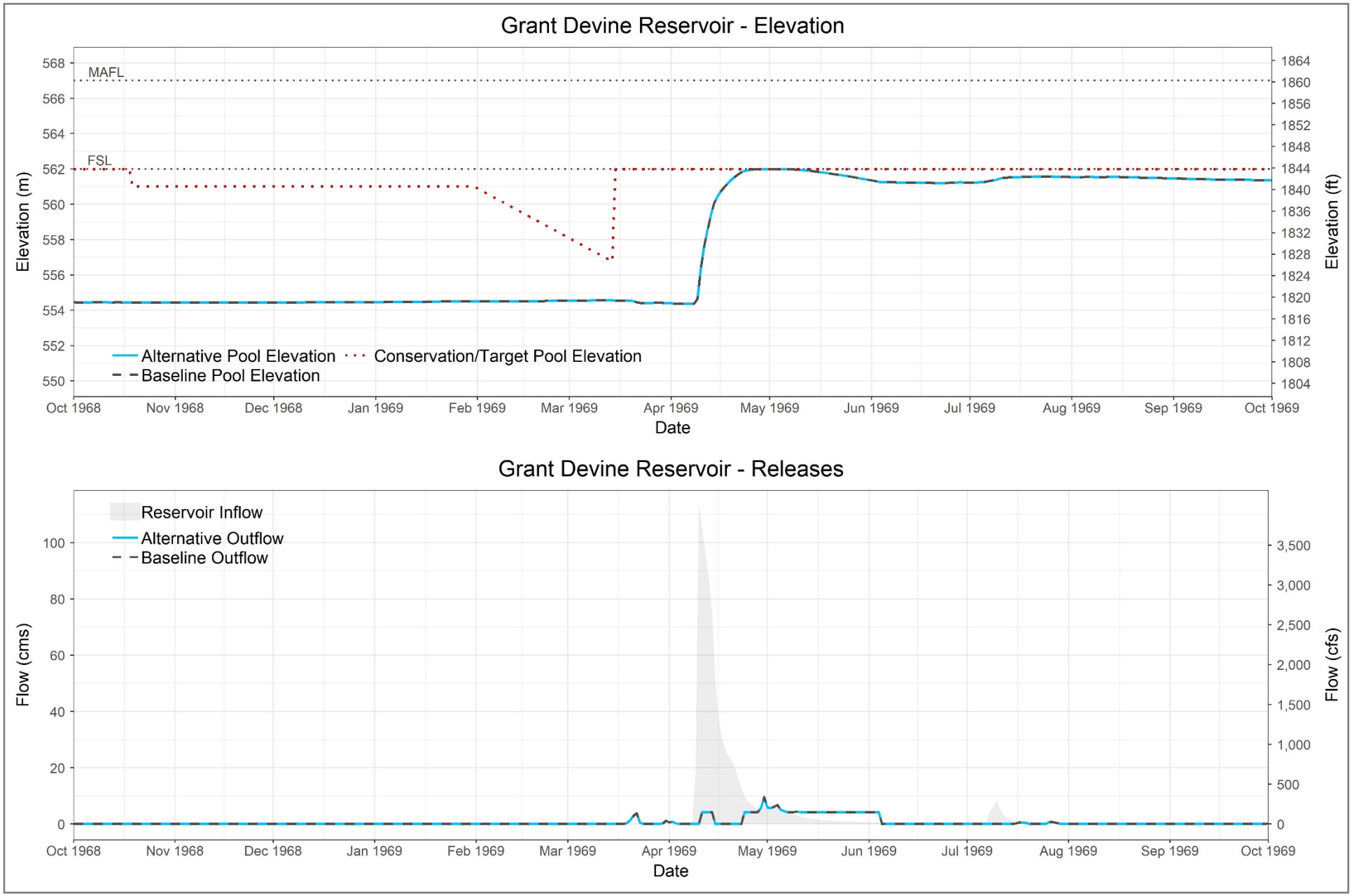




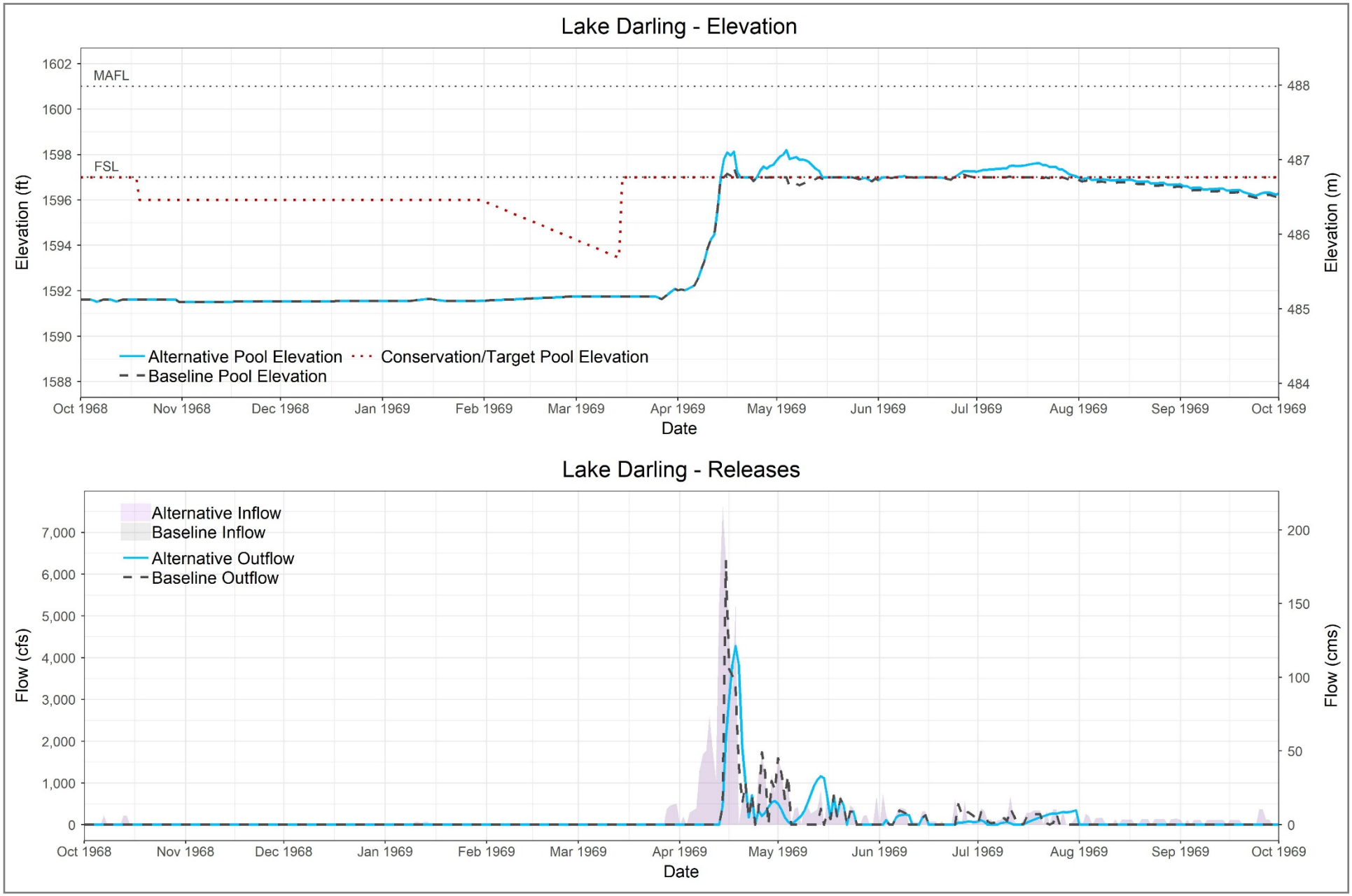
**MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level*



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



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



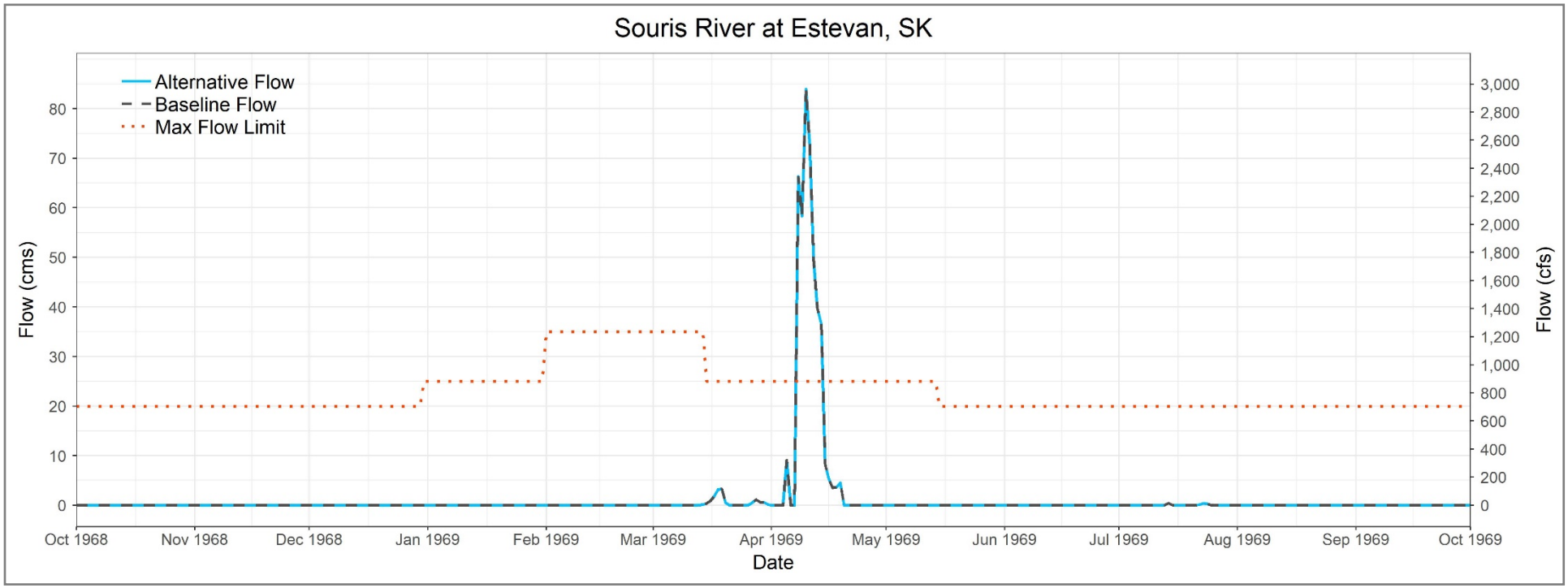
**MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level*

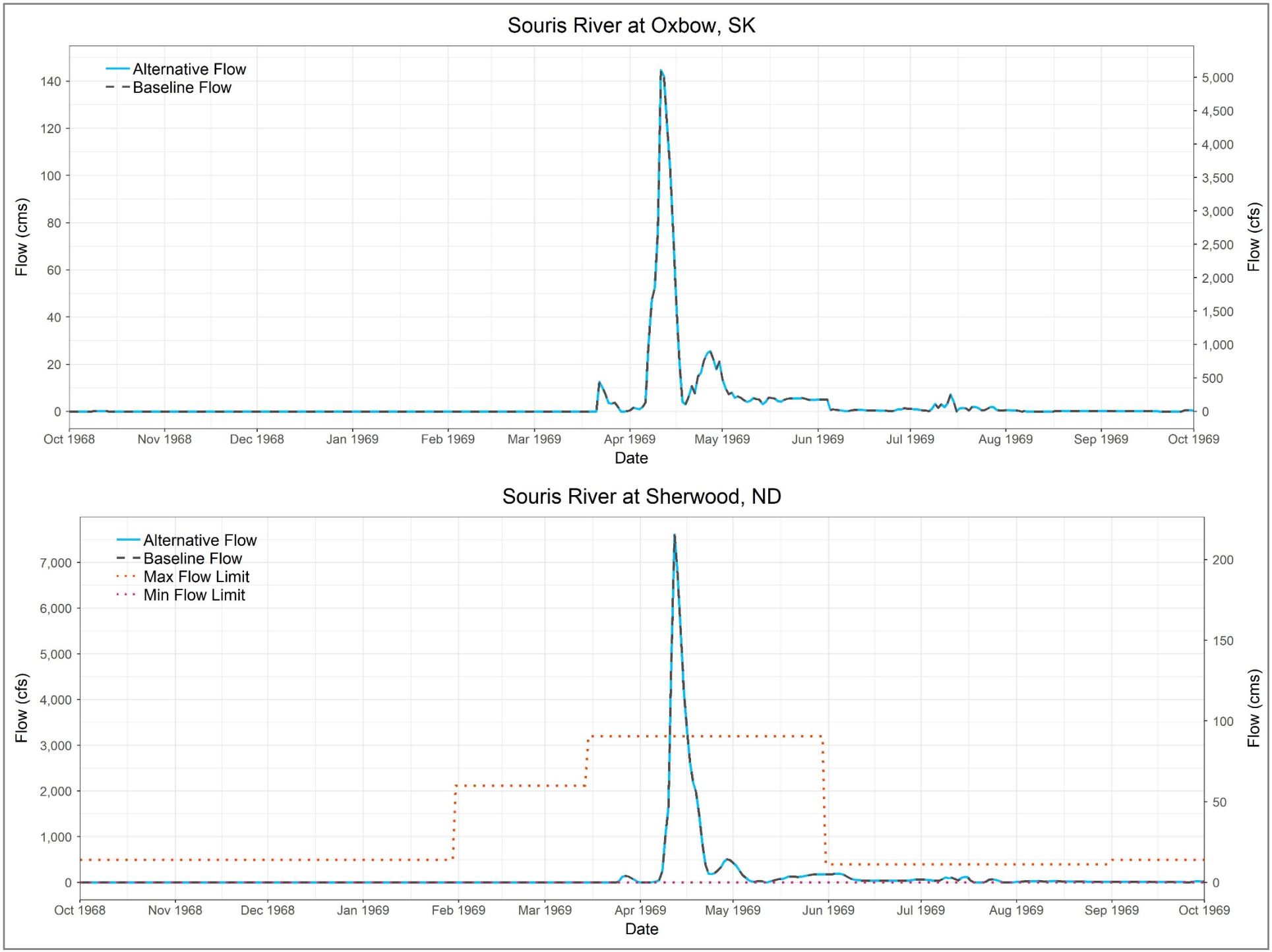
Plate 02

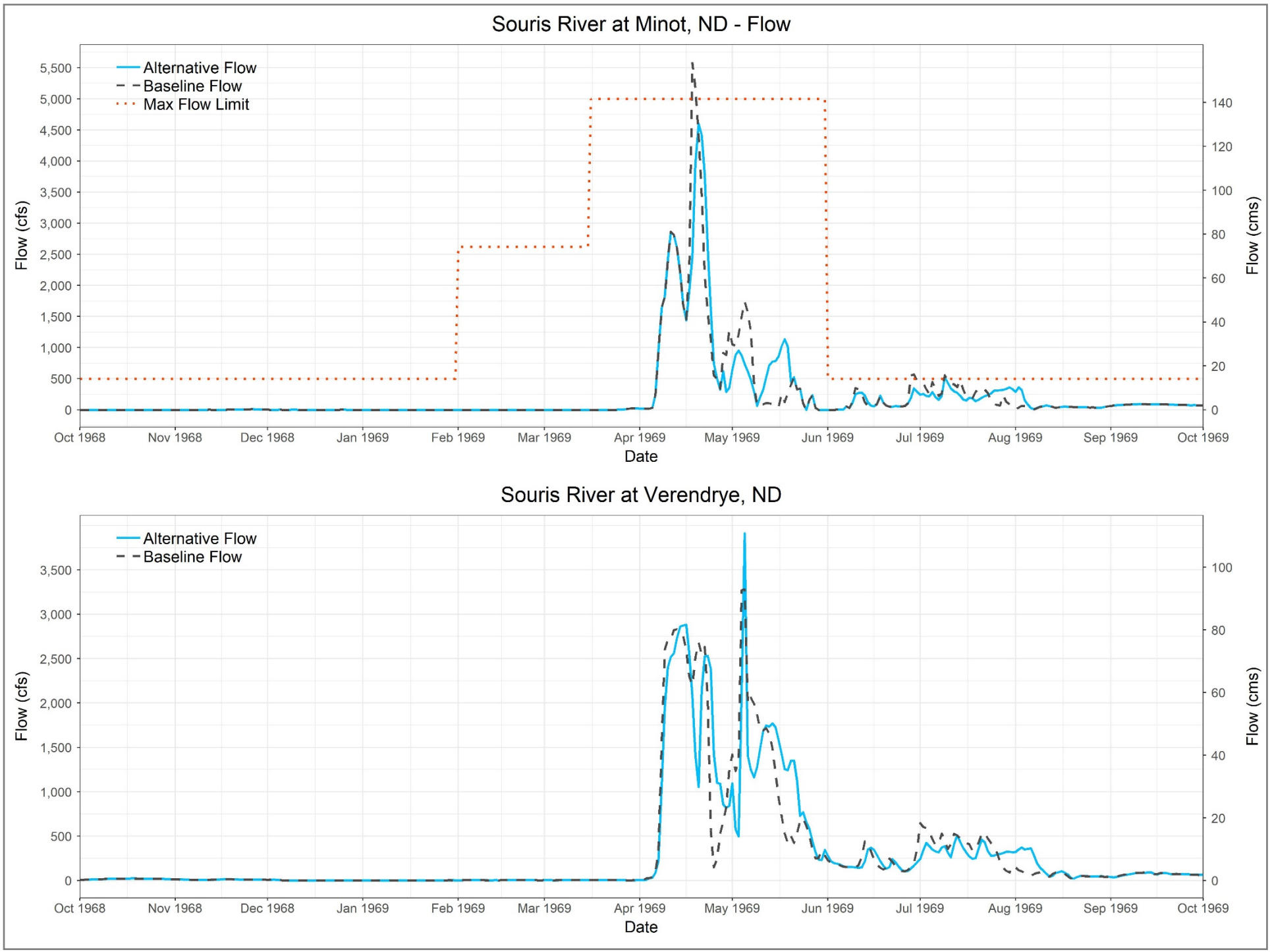
Critical Flow Locations – 1969

Alternative 3 (Phase 2)

Souris River Plan of Study




Souris River at Oxbow, SK
Alternative Flow
Baseline Flow
Flow (cms)
Flow (cfs)
Date
Oct 1968
Nov 1968
Dec 1968
Jan 1969
Feb 1969
Mar 1969
Apr 1969
May 1969
Jun 1969
Jul 1969
Aug 1969
Sep 1969
Oct 1969
Souris River at Sherwood, ND
Alternative Flow
Baseline Flow
Max Flow Limit
Min Flow Limit
Flow (cfs)
Flow (cms)
Date


Souris River at Minot, ND - Flow
Alternative Flow
Baseline Flow
Max Flow Limit
Flow (cfs)
Flow (cms)
5,500
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
140
120
100
80
60
40
20
0
Oct 1968
Nov 1968
Dec 1968
Jan 1969
Feb 1969
Mar 1969
Apr 1969
May 1969
Jun 1969
Jul 1969
Aug 1969
Sep 1969
Oct 1969
Date
Souris River at Verendrye, ND
Alternative Flow
Baseline Flow
Flow (cfs)
Flow (cms)
3,500
3,000
2,500
2,000
1,500
1,000
500
0
100
80
60
40
20
0
Oct 1968
Nov 1968
Dec 1968
Jan 1969
Feb 1969
Mar 1969
Apr 1969
May 1969
Jun 1969
Jul 1969
Aug 1969
Sep 1969
Oct 1969
Date

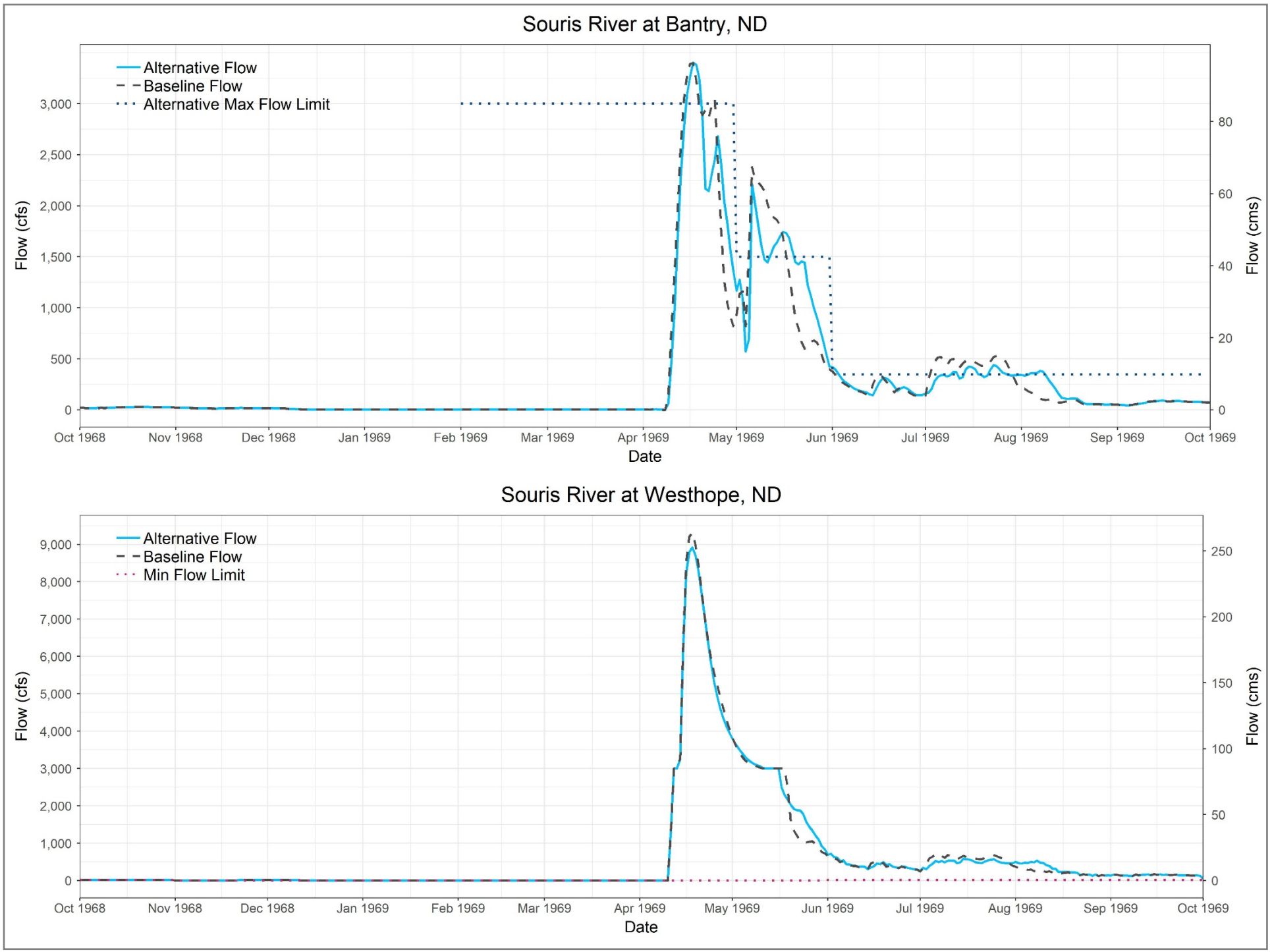
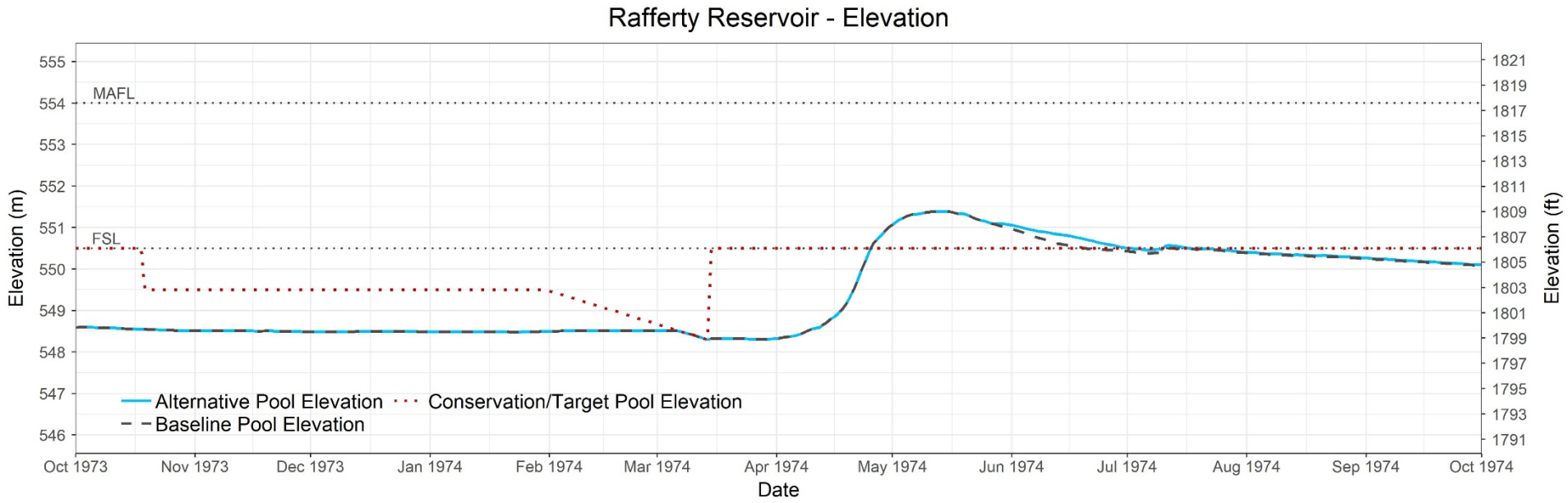
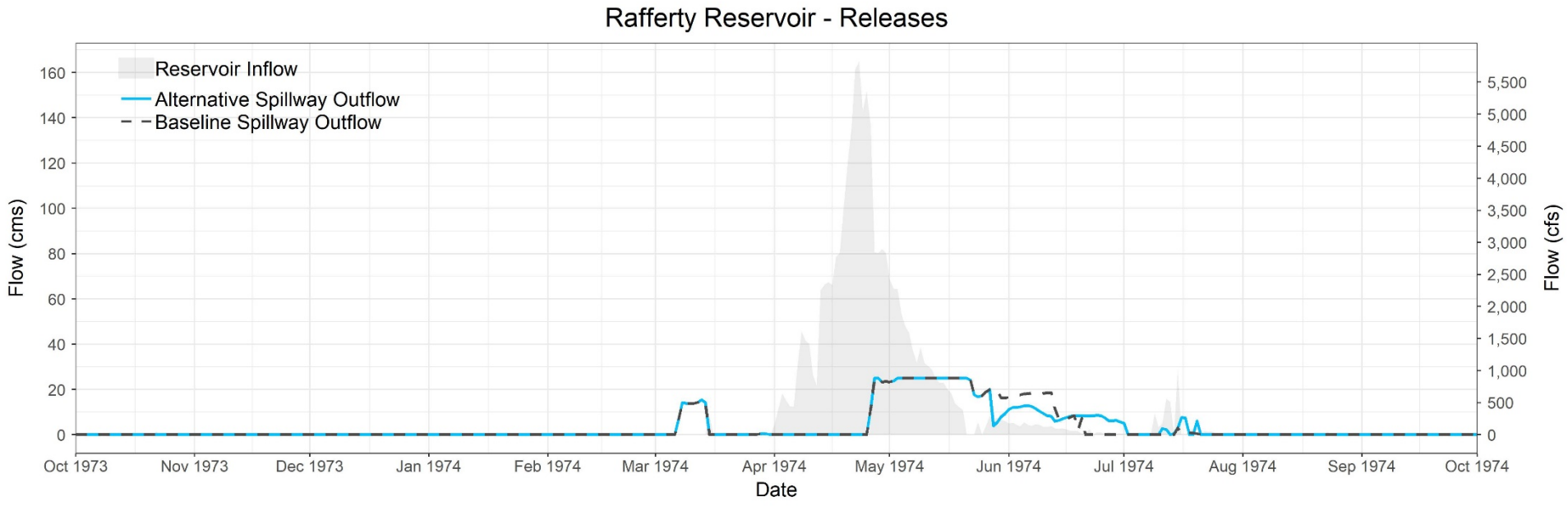
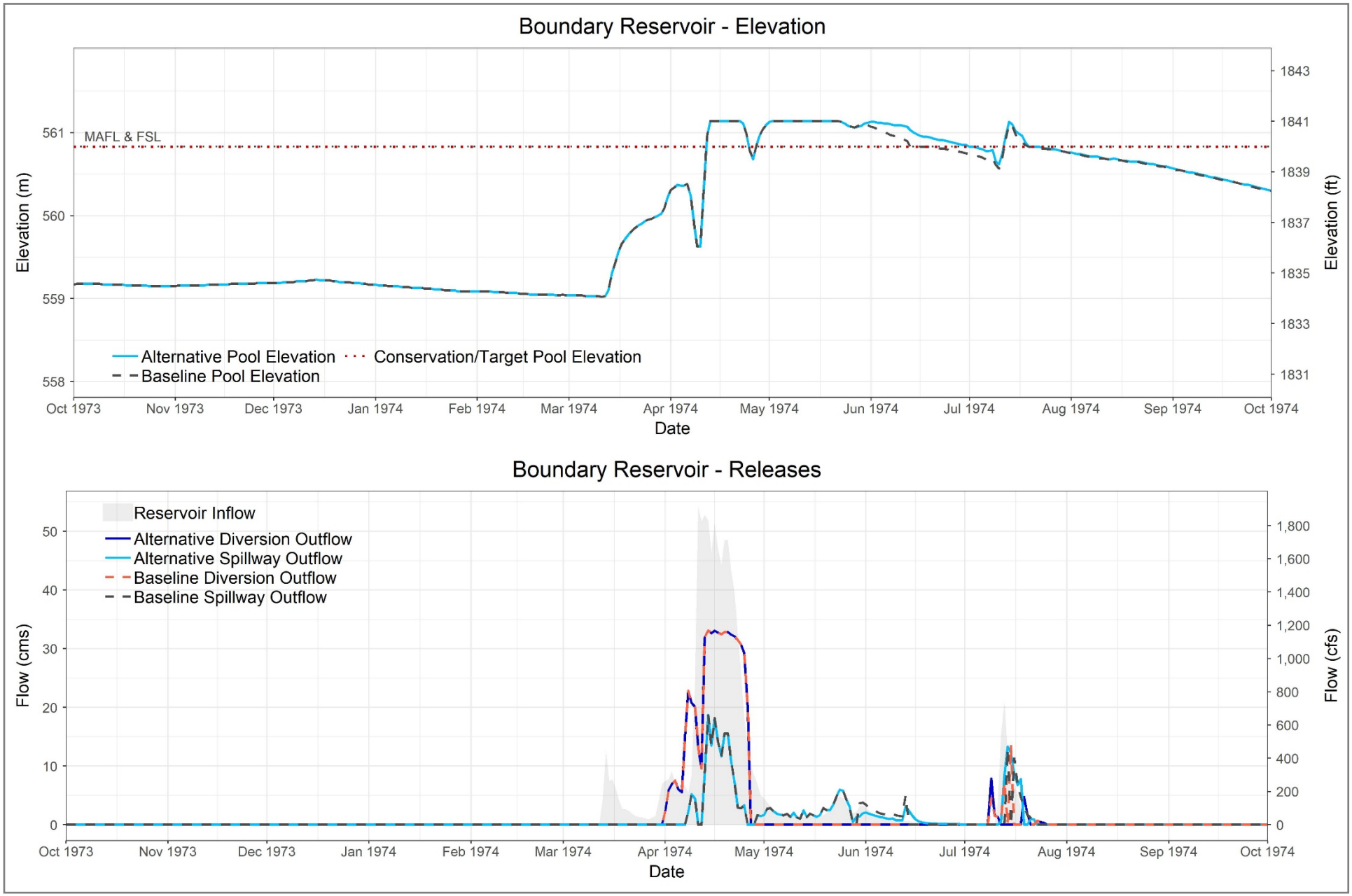

Souris River at Bantry, ND
Alternative Flow
Baseline Flow
Alternative Max Flow Limit
Flow (cfs)
Flow (cms)
Date
Oct 1968
Nov 1968
Dec 1968
Jan 1969
Feb 1969
Mar 1969
Apr 1969
May 1969
Jun 1969
Jul 1969
Aug 1969
Sep 1969
Oct 1969
Souris River at Westhope, ND
Alternative Flow
Baseline Flow
Min Flow Limit
Flow (cfs)
Flow (cms)
Date

Plate 03	Reservoirs – 1974	Alternative 3 (Phase 2) Souris River Plan of Study

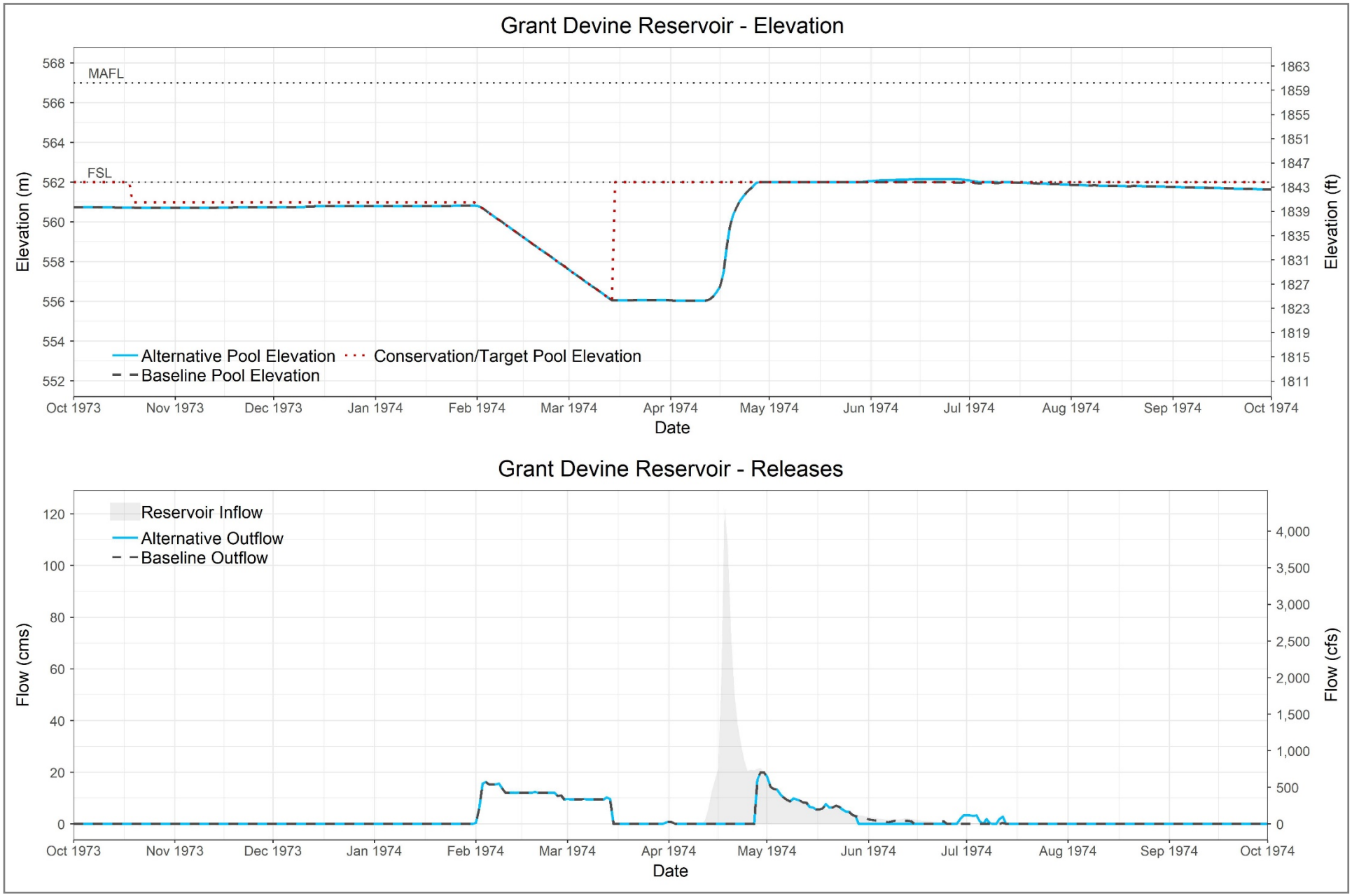




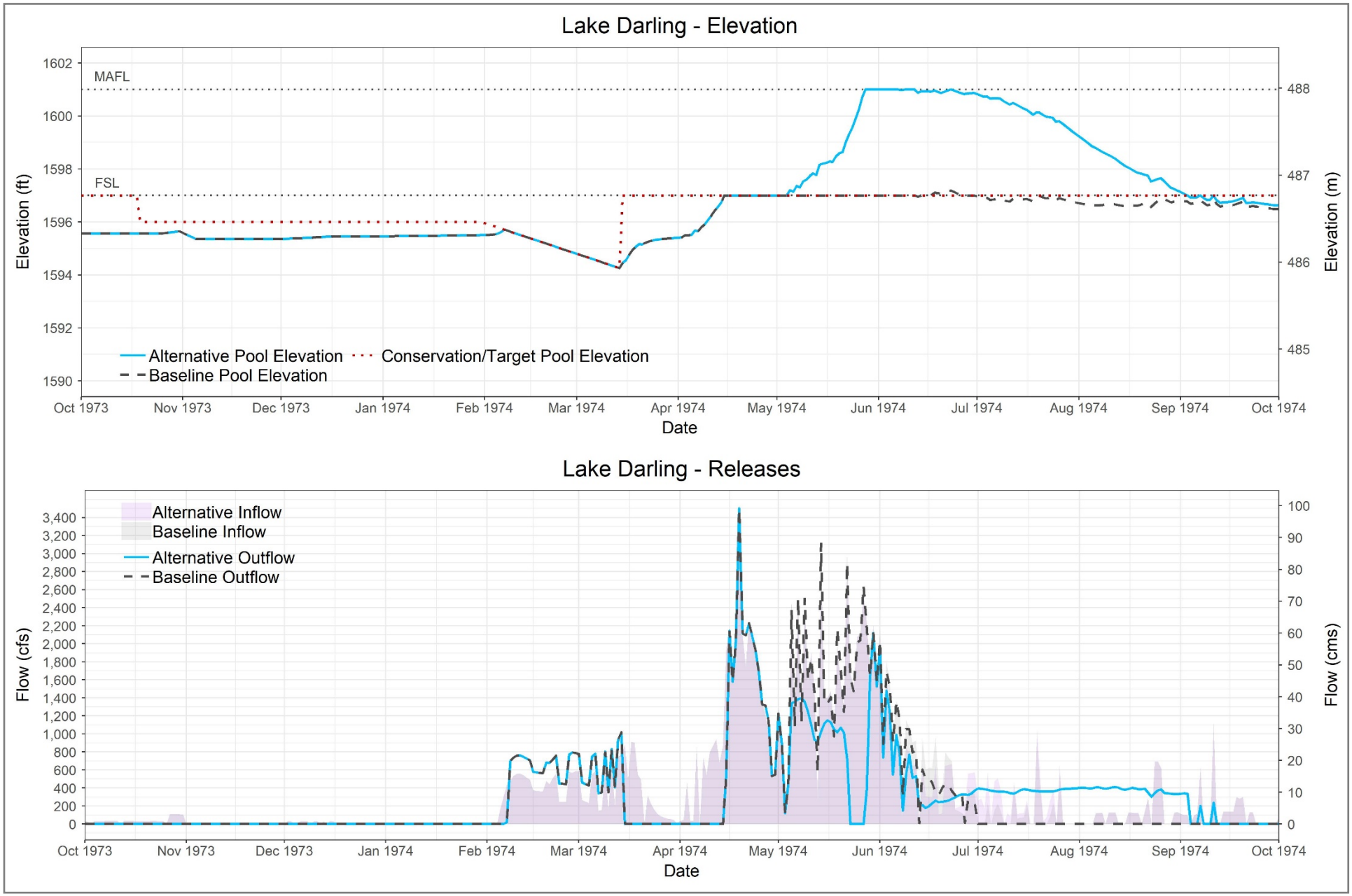
**MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level*



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



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



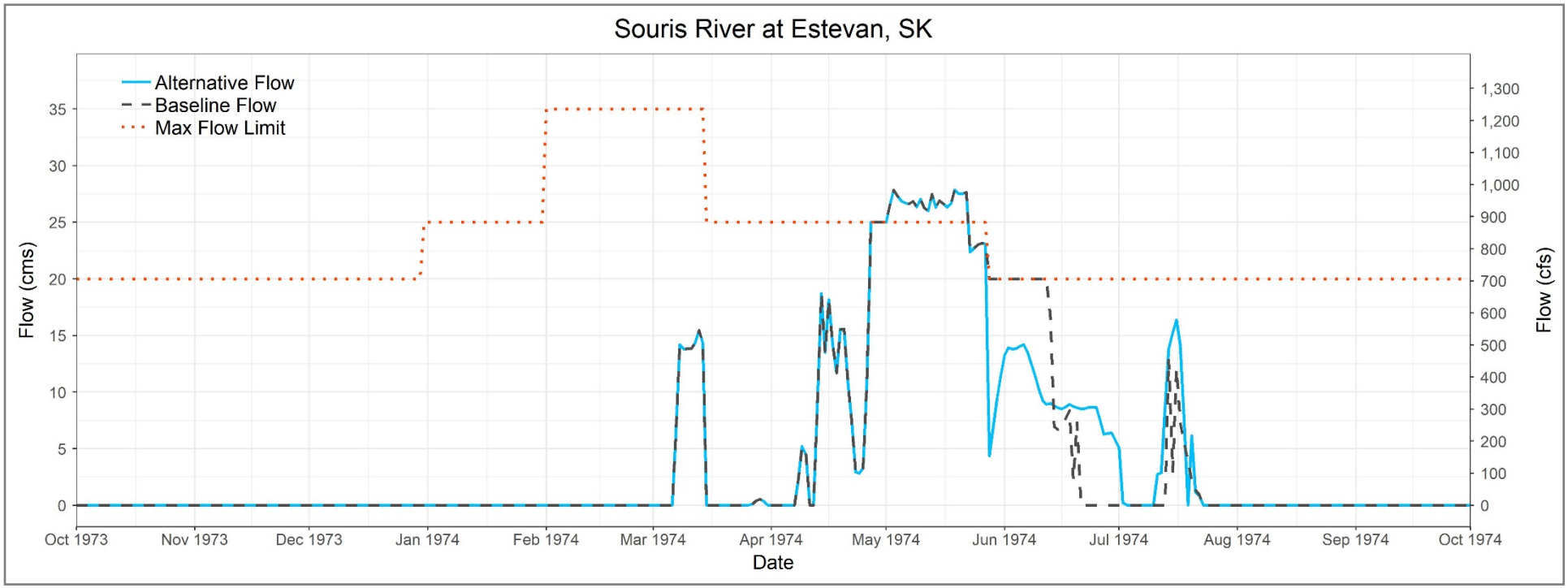
**MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level*

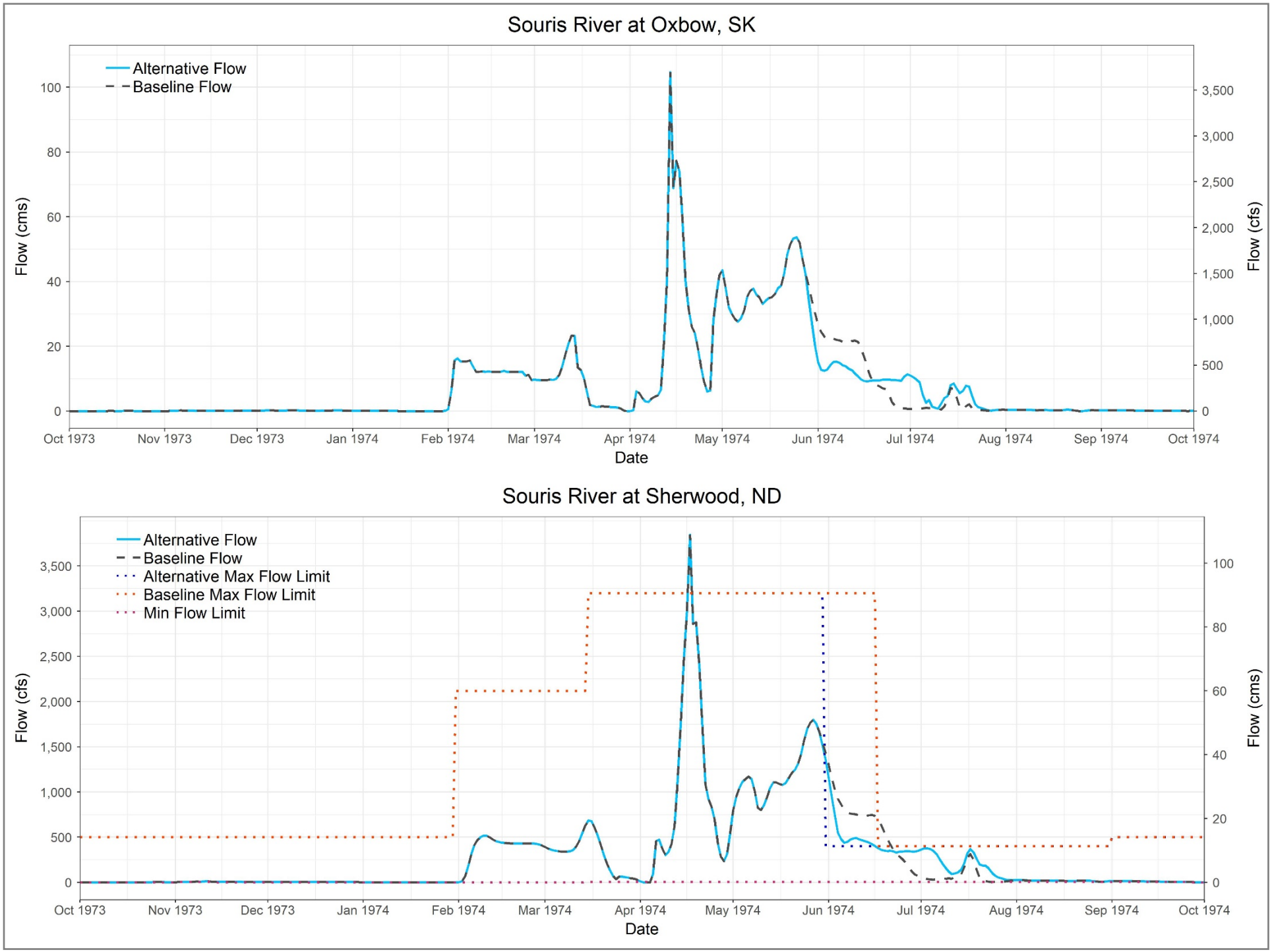
Plate 04

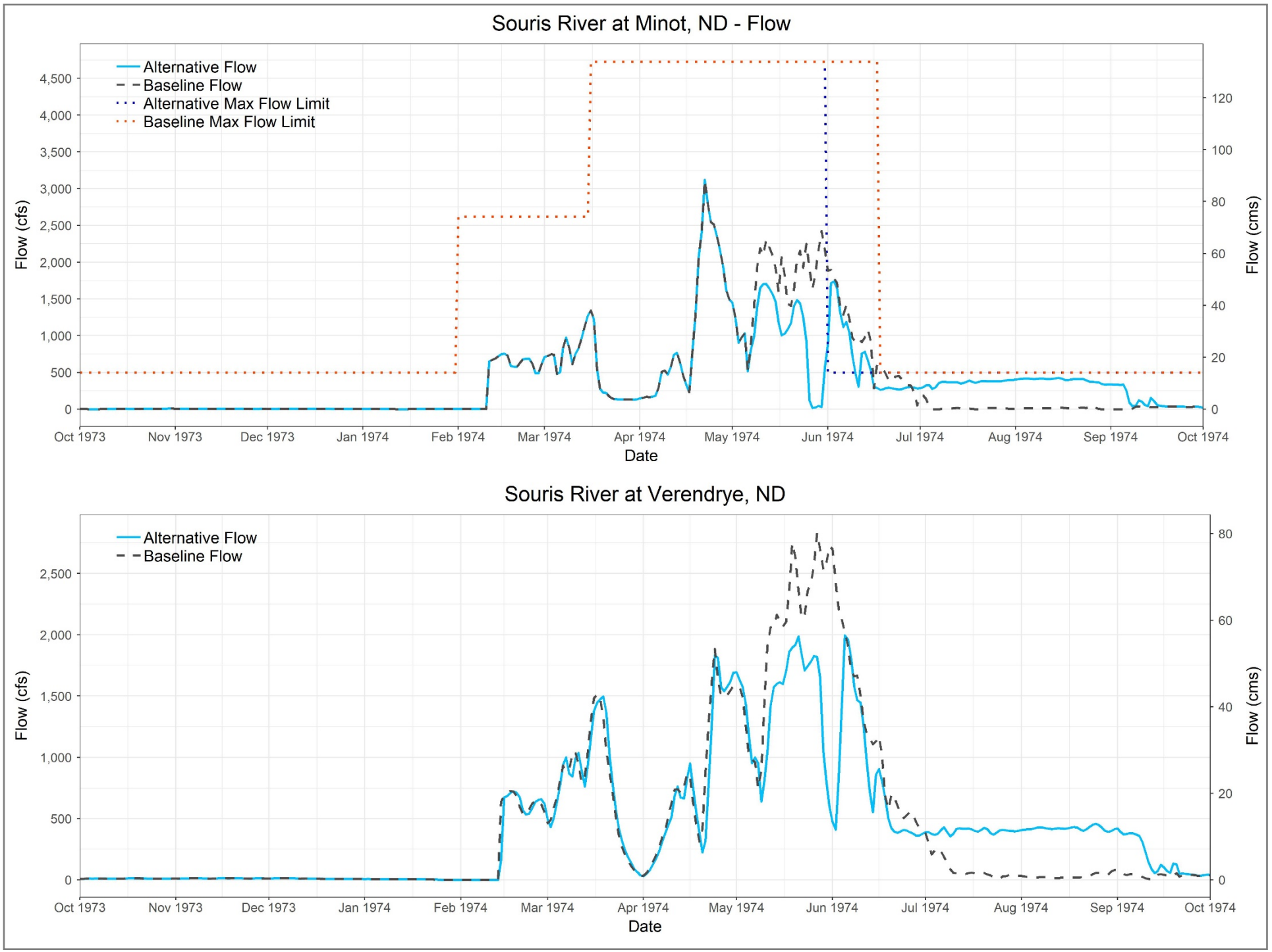
Critical Flow Locations – 1974

Alternative 3 (Phase 2)

Souris River Plan of Study




Souris River at Oxbow, SK
Alternative Flow
Baseline Flow
Flow (cms)
Flow (cfs)
Date
Oct 1973
Nov 1973
Dec 1973
Jan 1974
Feb 1974
Mar 1974
Apr 1974
May 1974
Jun 1974
Jul 1974
Aug 1974
Sep 1974
Oct 1974
Souris River at Sherwood, ND
Alternative Flow
Baseline Flow
Alternative Max Flow Limit
Baseline Max Flow Limit
Min Flow Limit
Flow (cfs)
Flow (cms)
Date


Souris River at Minot, ND - Flow
Alternative Flow
Baseline Flow
Alternative Max Flow Limit
Baseline Max Flow Limit
Flow (cfs)
Flow (cms)
Date
Oct 1973
Nov 1973
Dec 1973
Jan 1974
Feb 1974
Mar 1974
Apr 1974
May 1974
Jun 1974
Jul 1974
Aug 1974
Sep 1974
Oct 1974
Souris River at Verendrye, ND
Alternative Flow
Baseline Flow
Flow (cfs)
Flow (cms)
Date

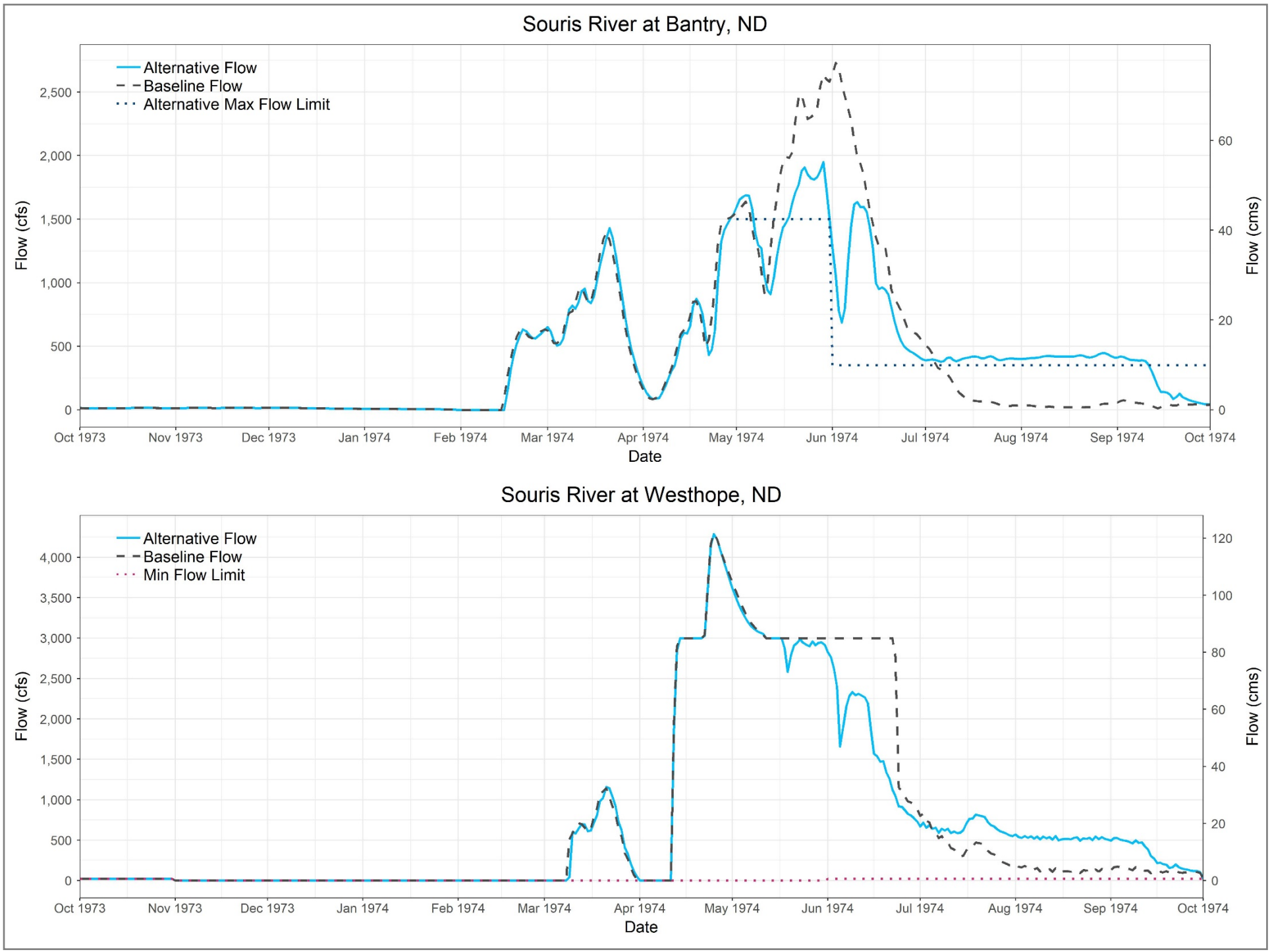
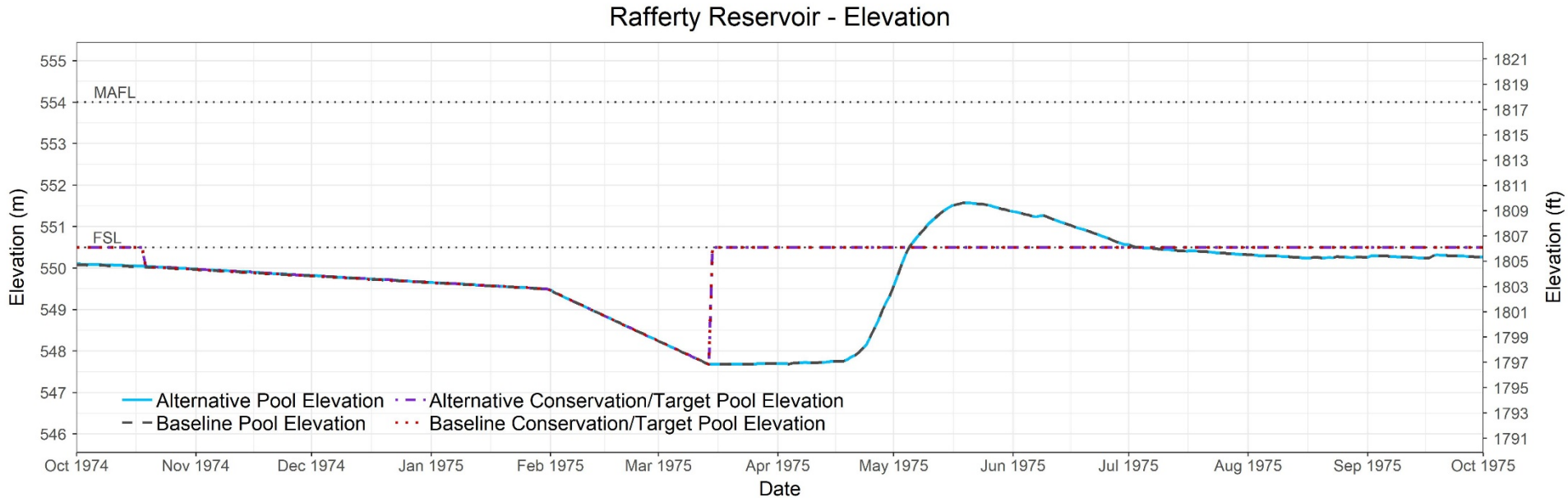
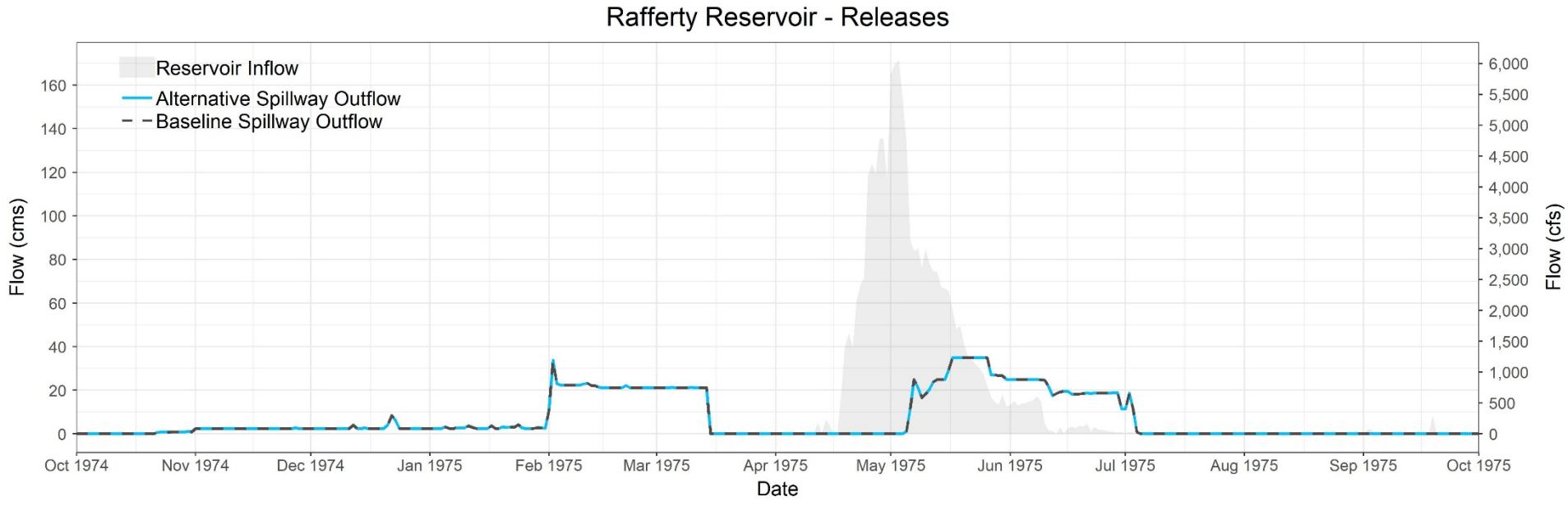
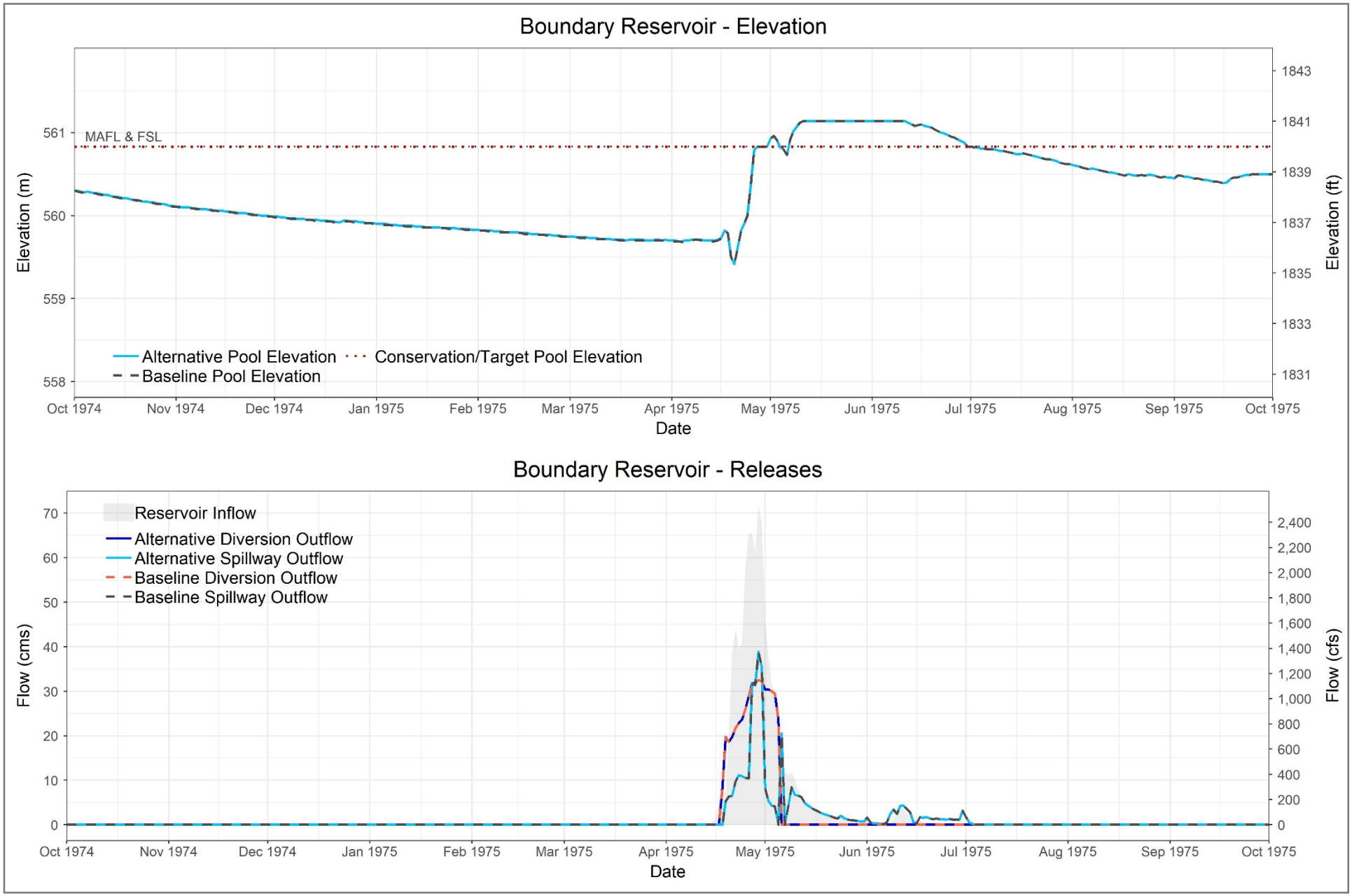

Souris River at Bantry, ND
Alternative Flow
Baseline Flow
Alternative Max Flow Limit
Flow (cfs)
Flow (cms)
Date
Oct 1973
Nov 1973
Dec 1973
Jan 1974
Feb 1974
Mar 1974
Apr 1974
May 1974
Jun 1974
Jul 1974
Aug 1974
Sep 1974
Oct 1974
Souris River at Westhope, ND
Alternative Flow
Baseline Flow
Min Flow Limit
Flow (cfs)
Flow (cms)
Date

Plate 05	Reservoirs – 1975	Alternative 3 (Phase 2) Souris River Plan of Study

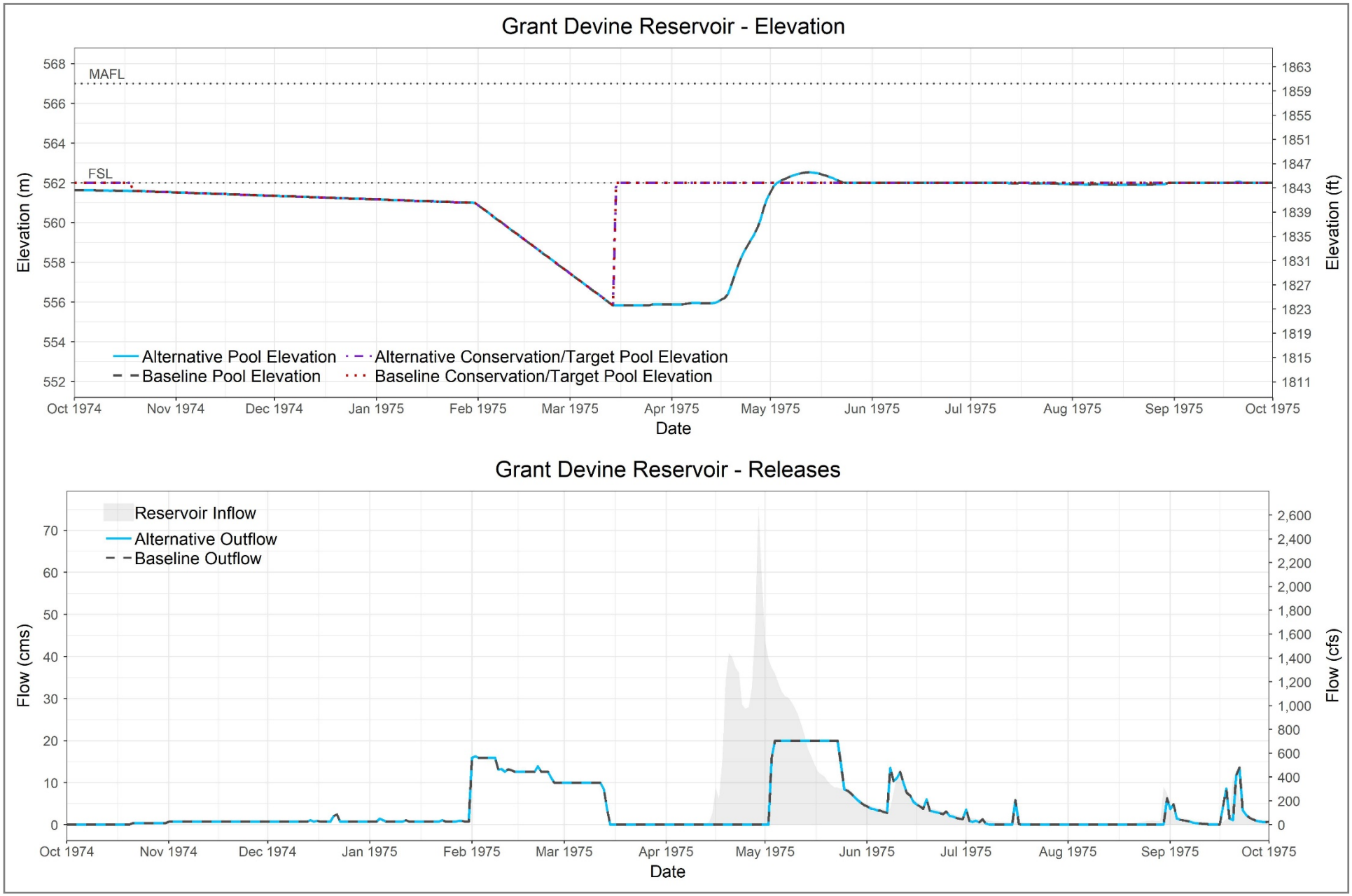




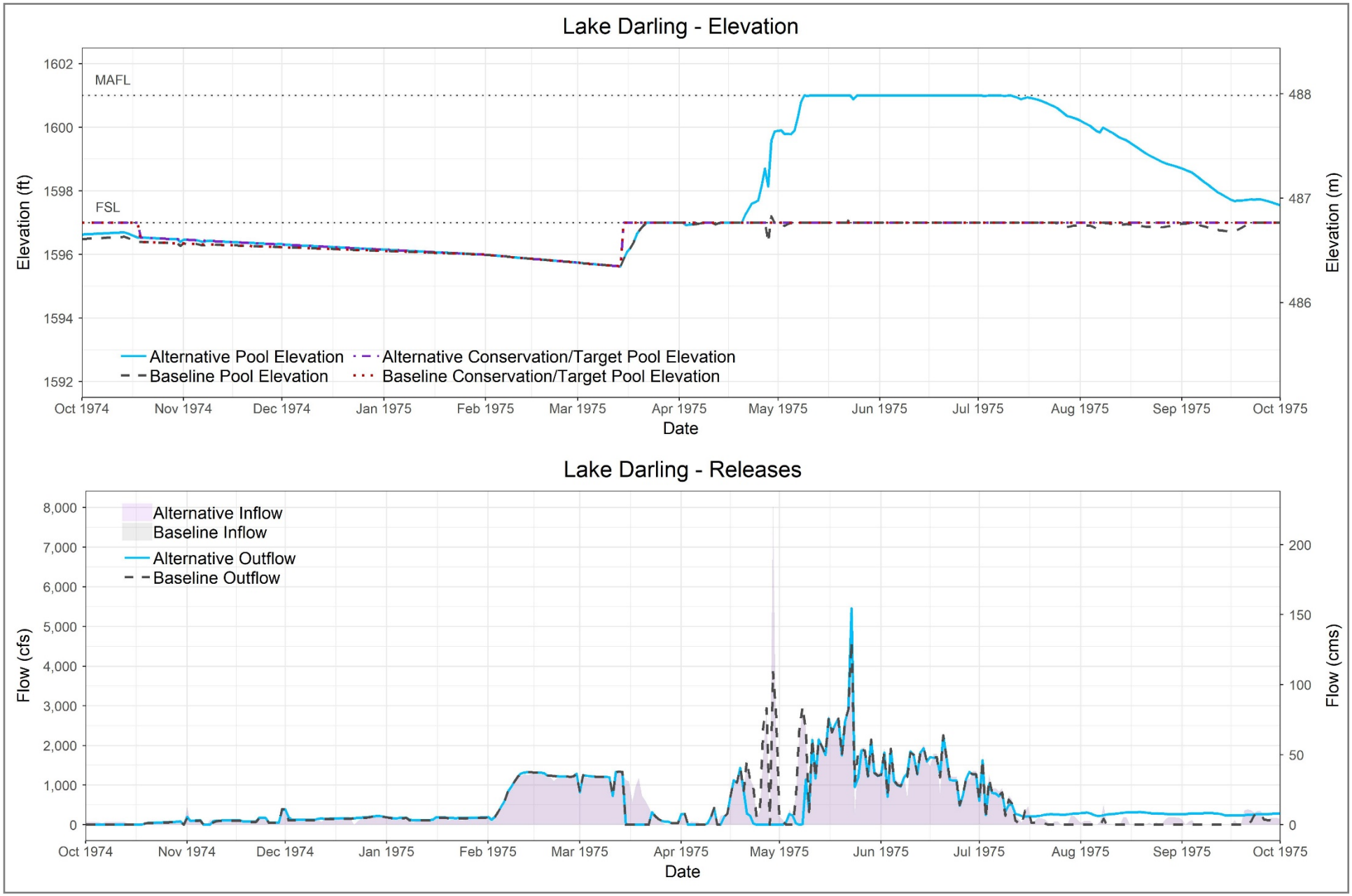
**MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level*



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



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



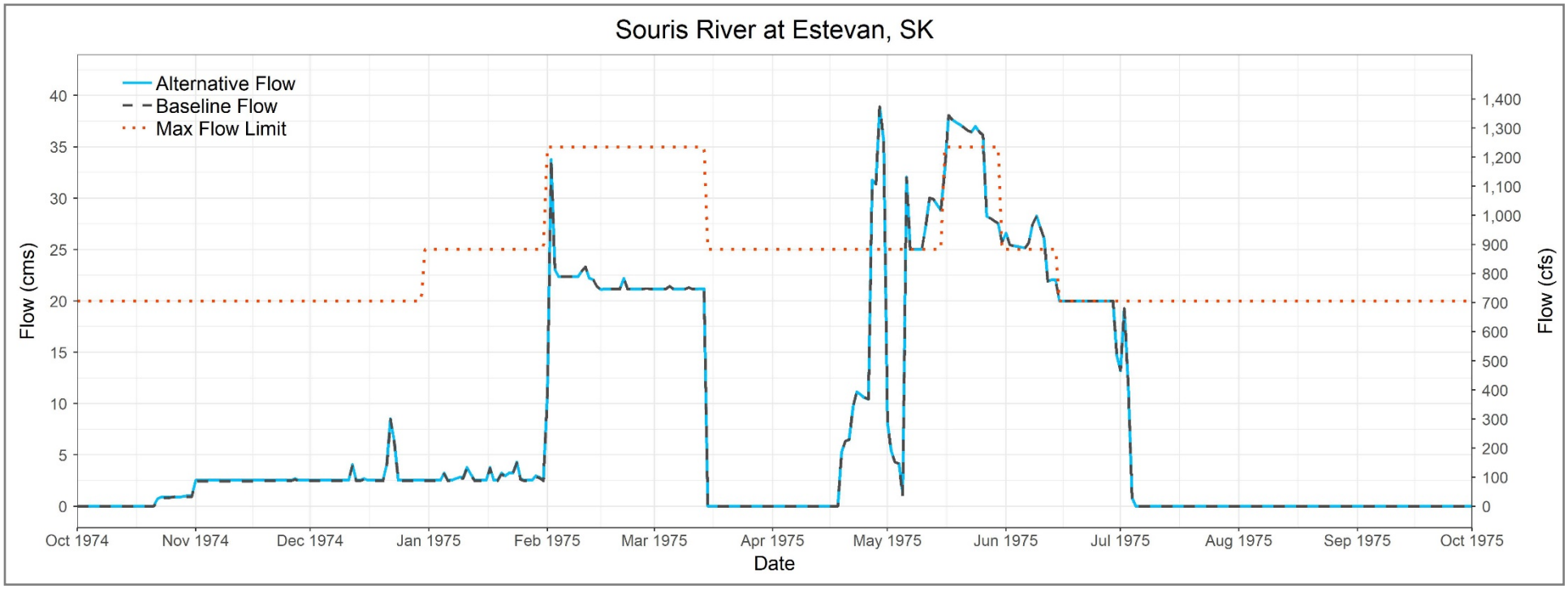
**MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level*

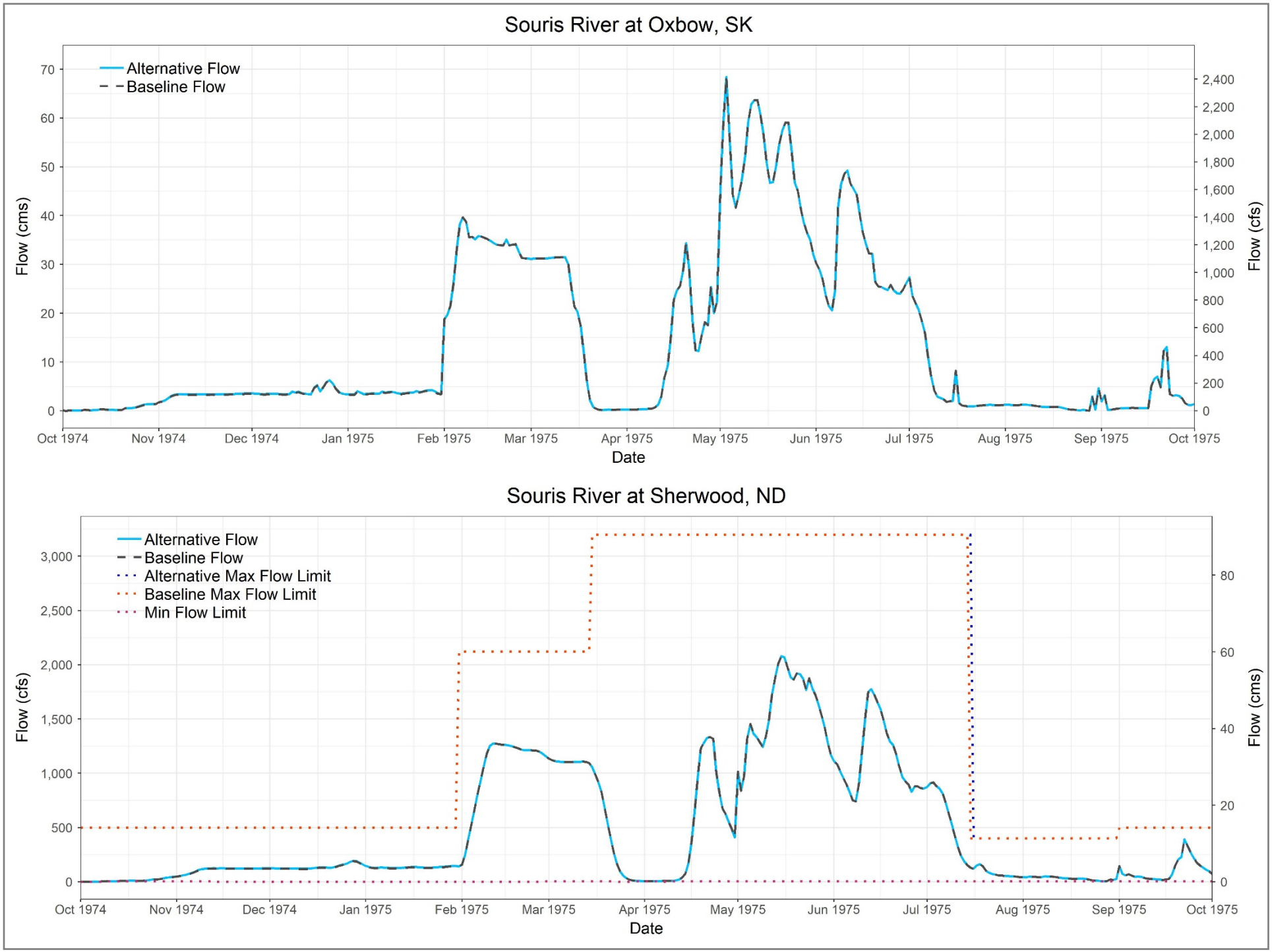
Plate 06

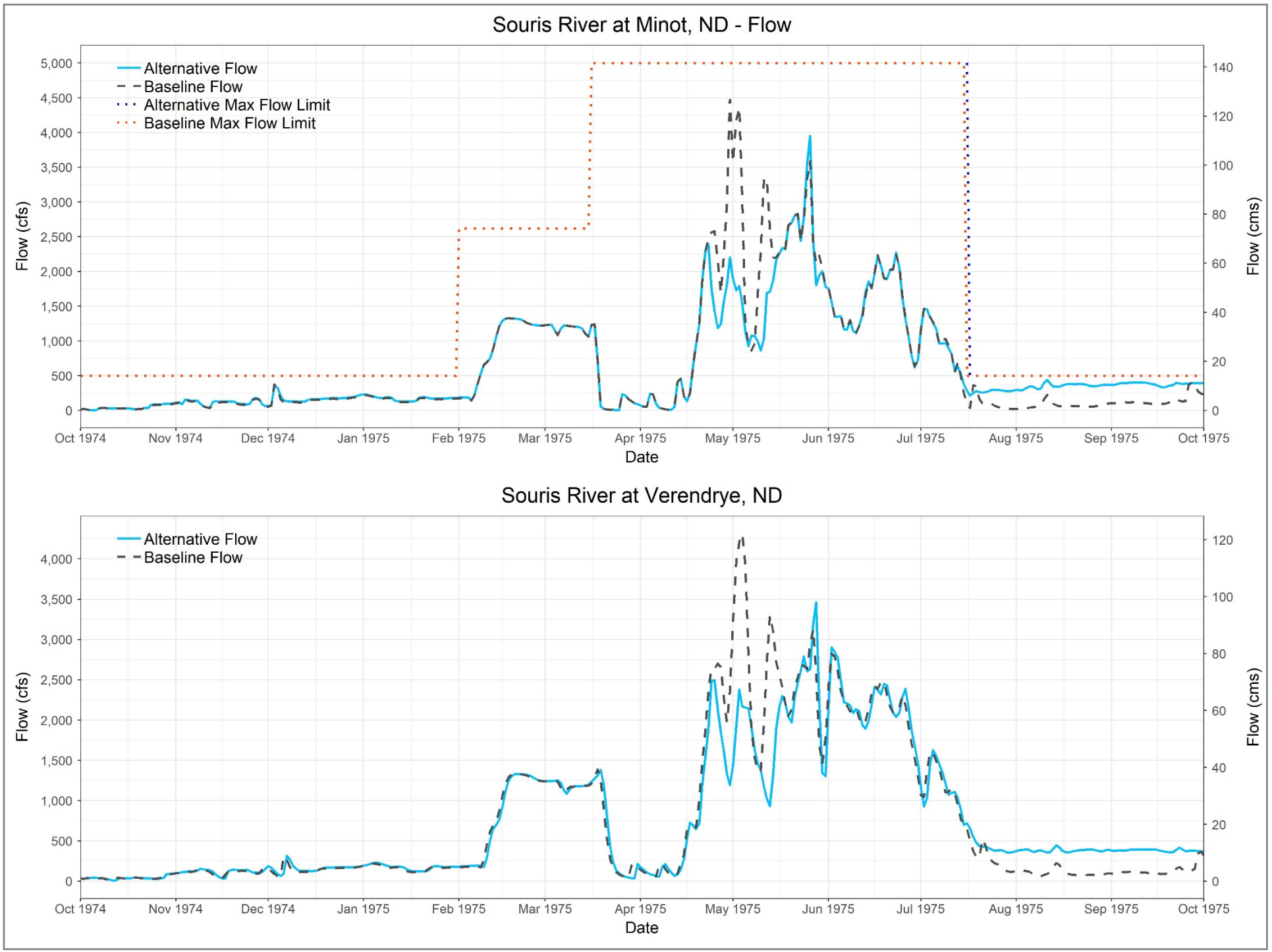
Critical Flow Locations – 1975

Alternative 3 (Phase 2)

Souris River Plan of Study




Souris River at Oxbow, SK
Alternative Flow
Baseline Flow
Flow (cms)
Flow (cfs)
Date
Oct 1974
Nov 1974
Dec 1974
Jan 1975
Feb 1975
Mar 1975
Apr 1975
May 1975
Jun 1975
Jul 1975
Aug 1975
Sep 1975
Oct 1975
Souris River at Sherwood, ND
Alternative Flow
Baseline Flow
Alternative Max Flow Limit
Baseline Max Flow Limit
Min Flow Limit
Flow (cfs)
Flow (cms)
Date


Souris River at Minot, ND - Flow
Alternative Flow
Baseline Flow
Alternative Max Flow Limit
Baseline Max Flow Limit
Flow (cfs)
Flow (cms)
Date
Oct 1974
Nov 1974
Dec 1974
Jan 1975
Feb 1975
Mar 1975
Apr 1975
May 1975
Jun 1975
Jul 1975
Aug 1975
Sep 1975
Oct 1975
Souris River at Verendrye, ND
Alternative Flow
Baseline Flow
Flow (cfs)
Flow (cms)
Date

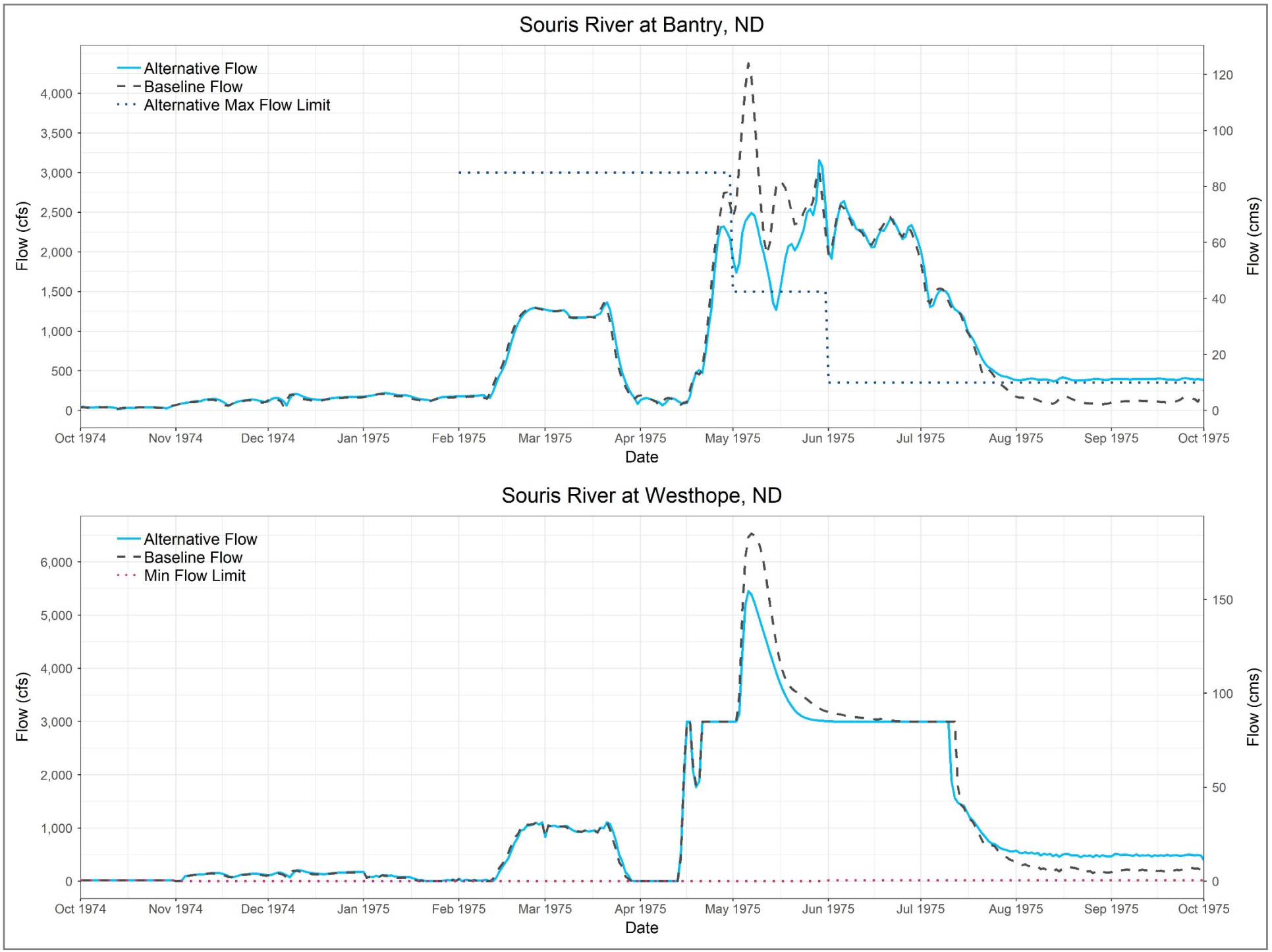
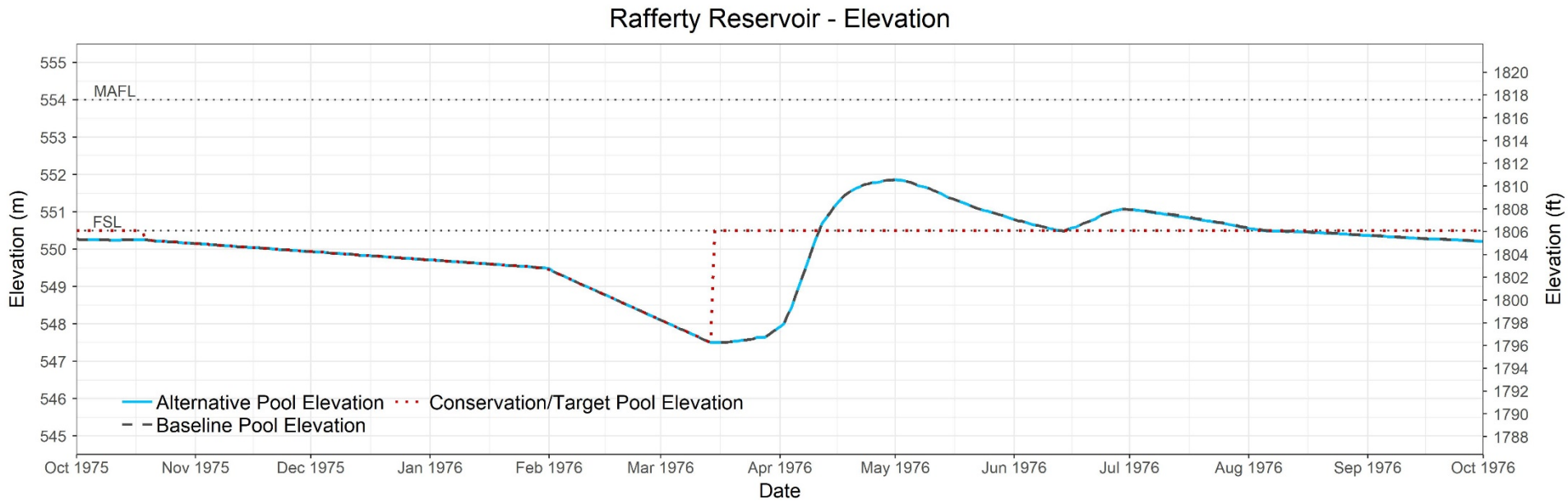
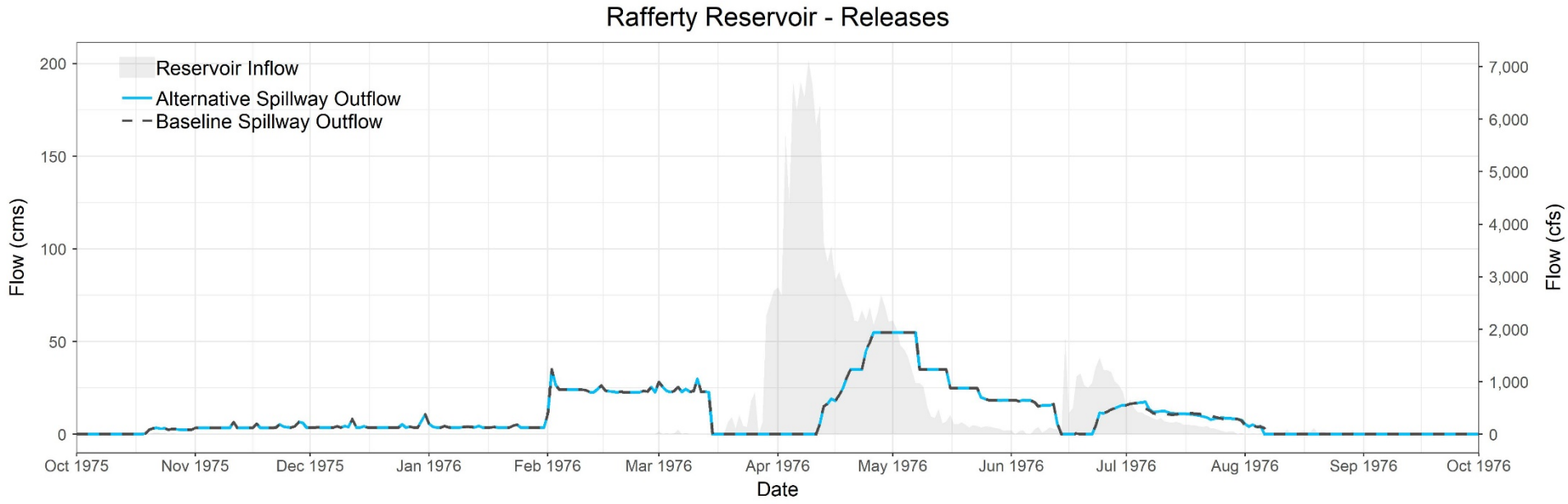
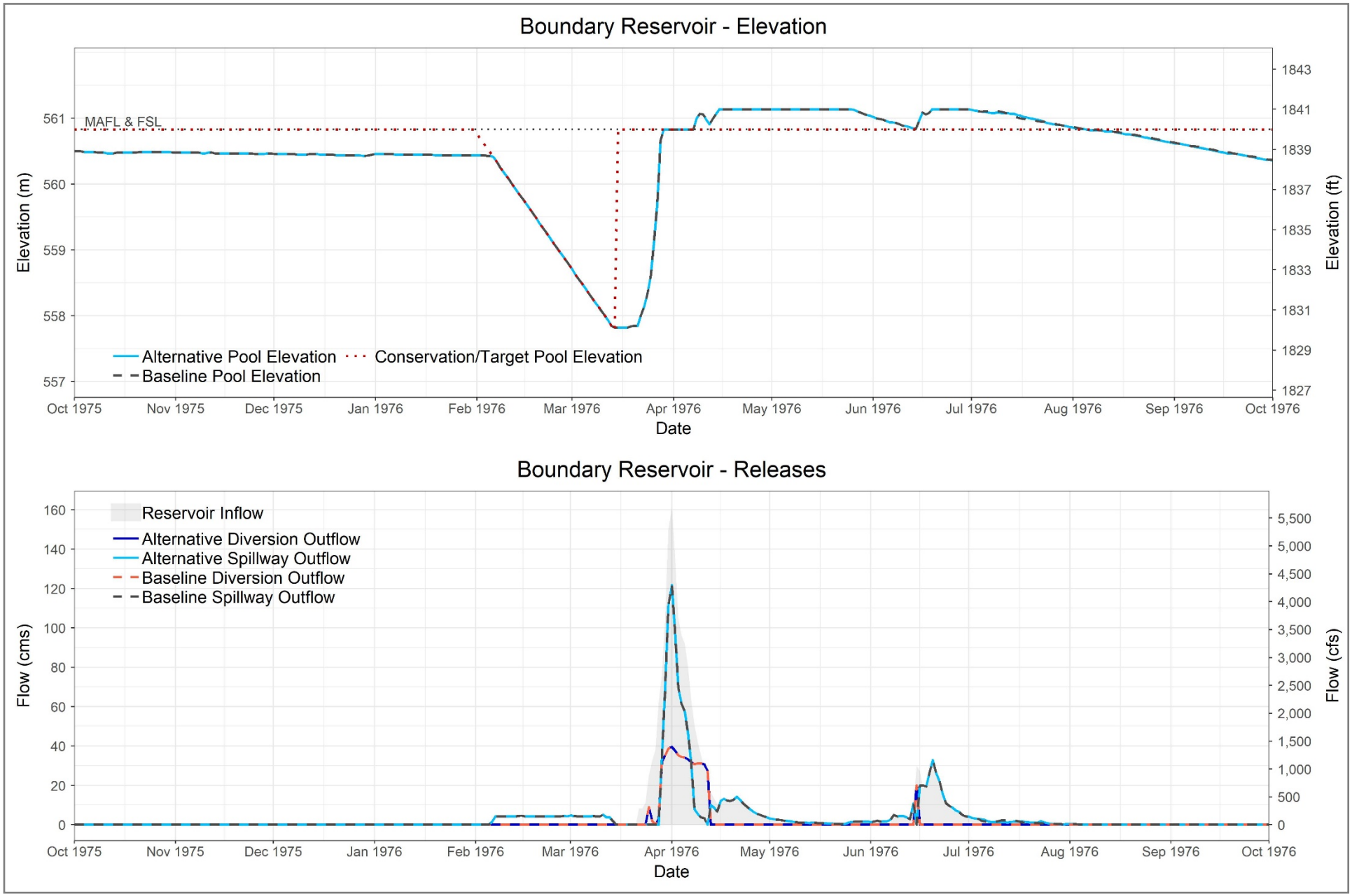

Souris River at Bantry, ND
Alternative Flow
Baseline Flow
Alternative Max Flow Limit
Flow (cfs)
Flow (cms)
Date
Oct 1974
Nov 1974
Dec 1974
Jan 1975
Feb 1975
Mar 1975
Apr 1975
May 1975
Jun 1975
Jul 1975
Aug 1975
Sep 1975
Oct 1975
Souris River at Westhope, ND
Alternative Flow
Baseline Flow
Min Flow Limit
Flow (cfs)
Flow (cms)
Date

Plate 07	Reservoirs – 1976	Alternative 3 (Phase 2) Souris River Plan of Study

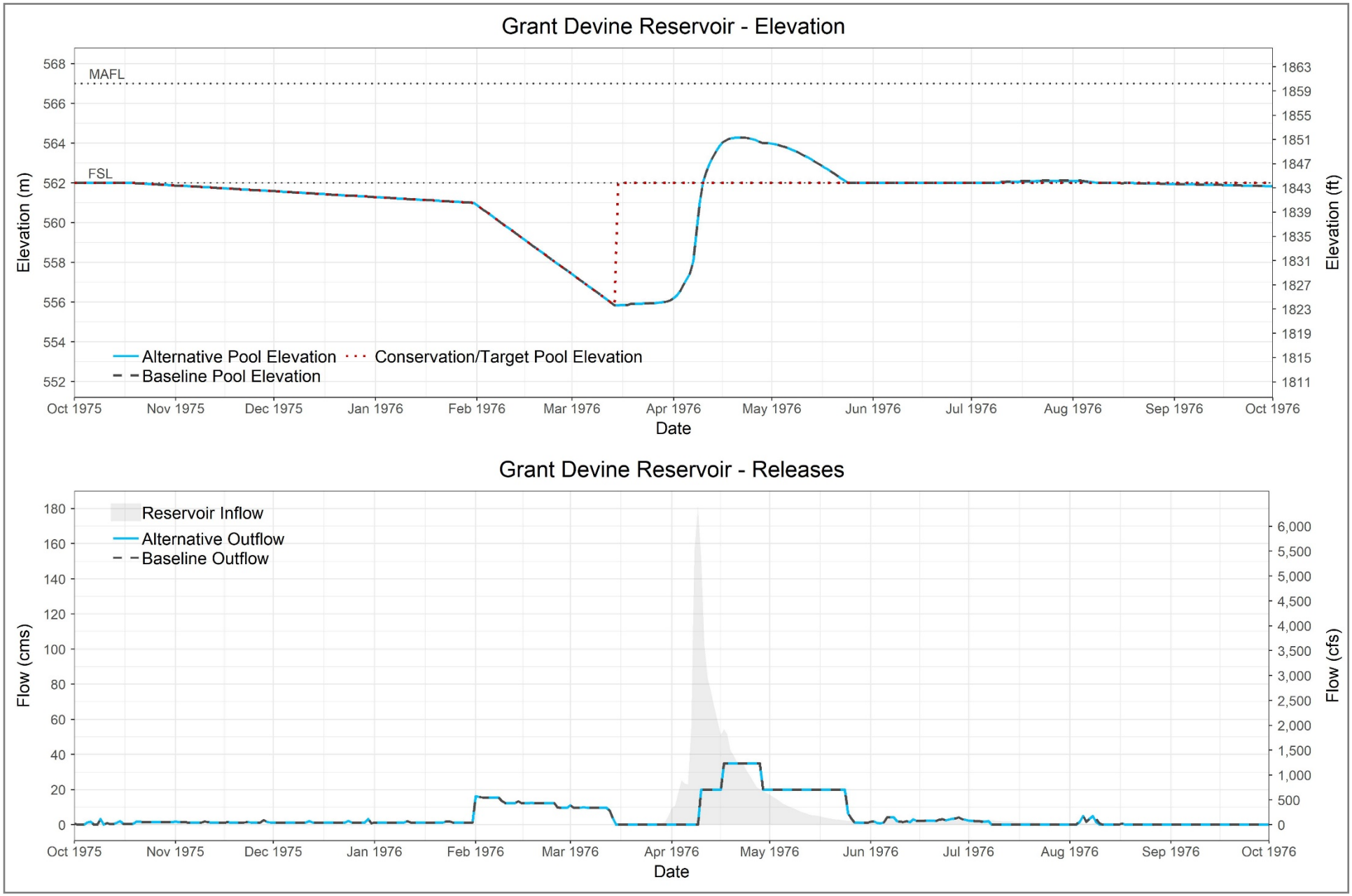




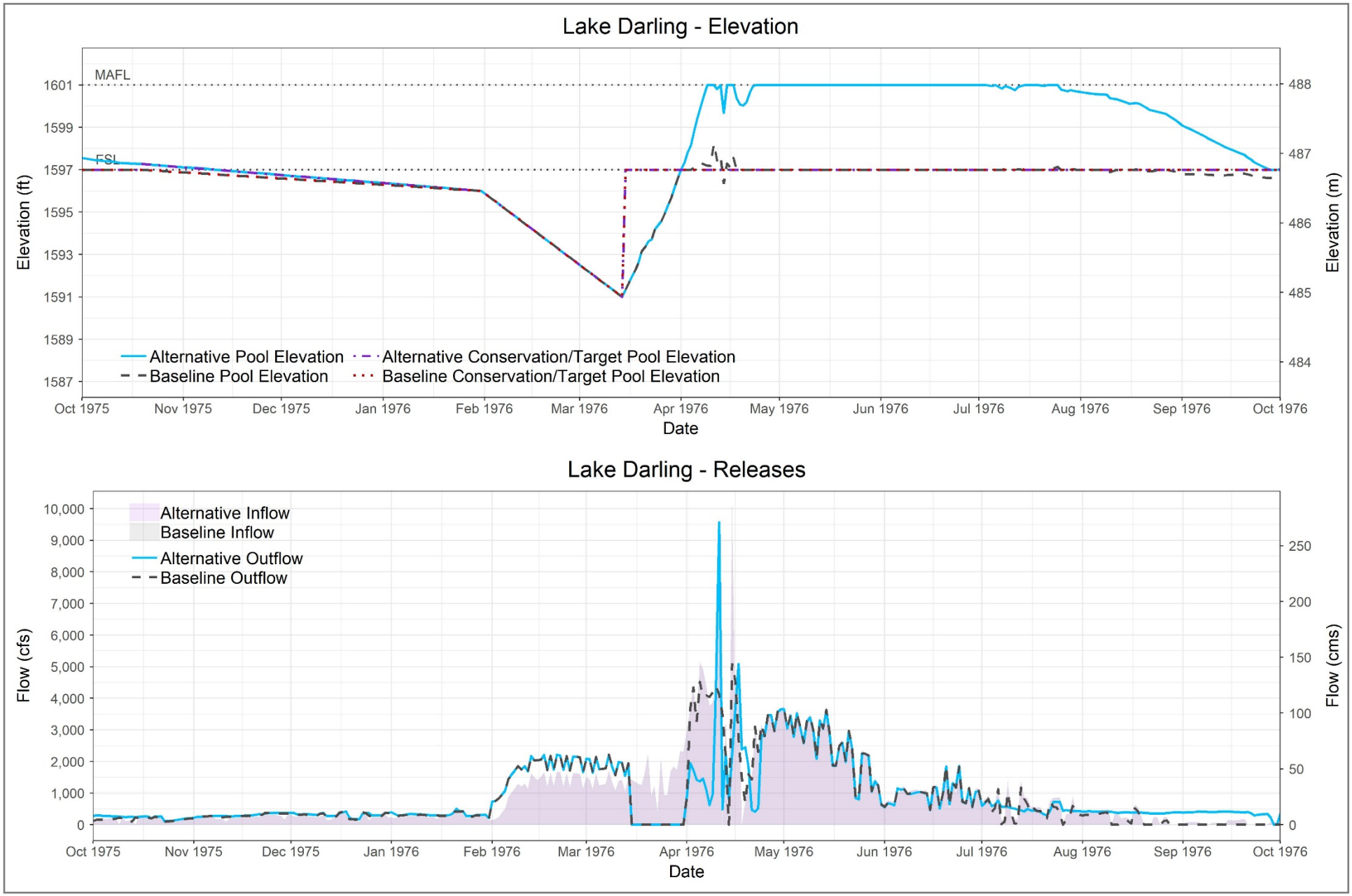
**MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level*



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



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



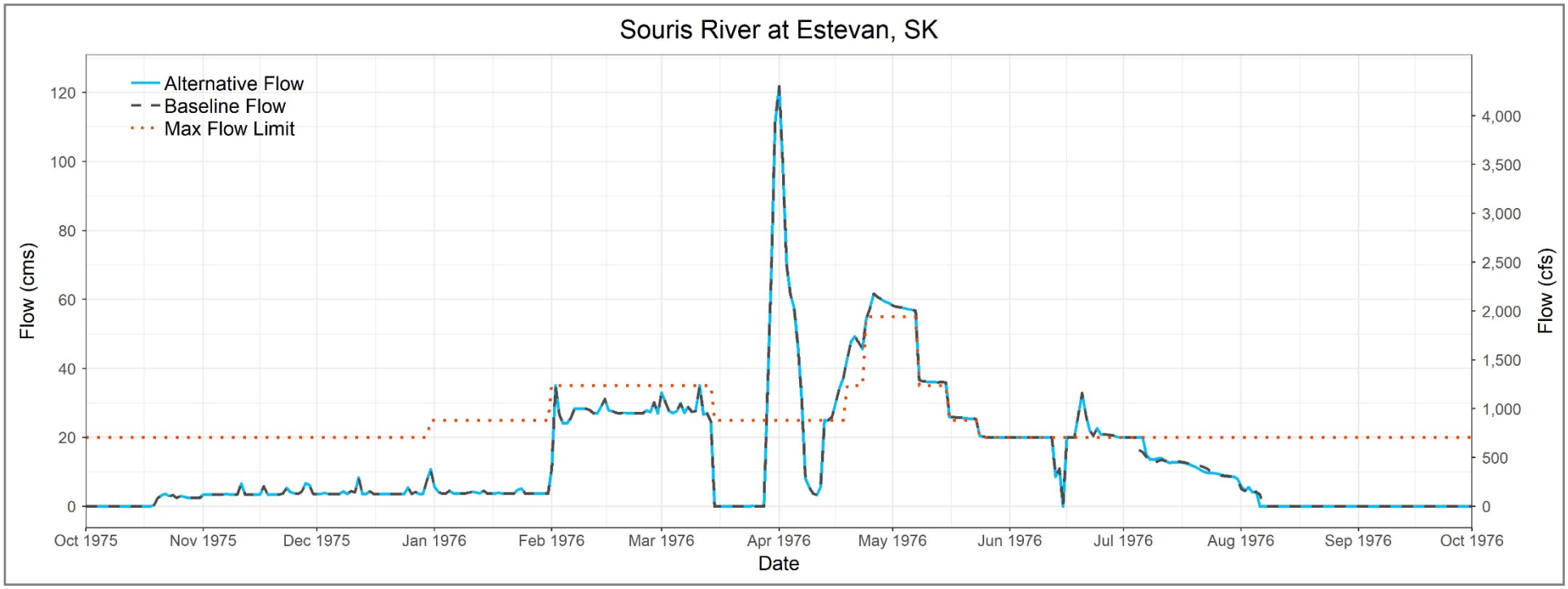
**MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level*

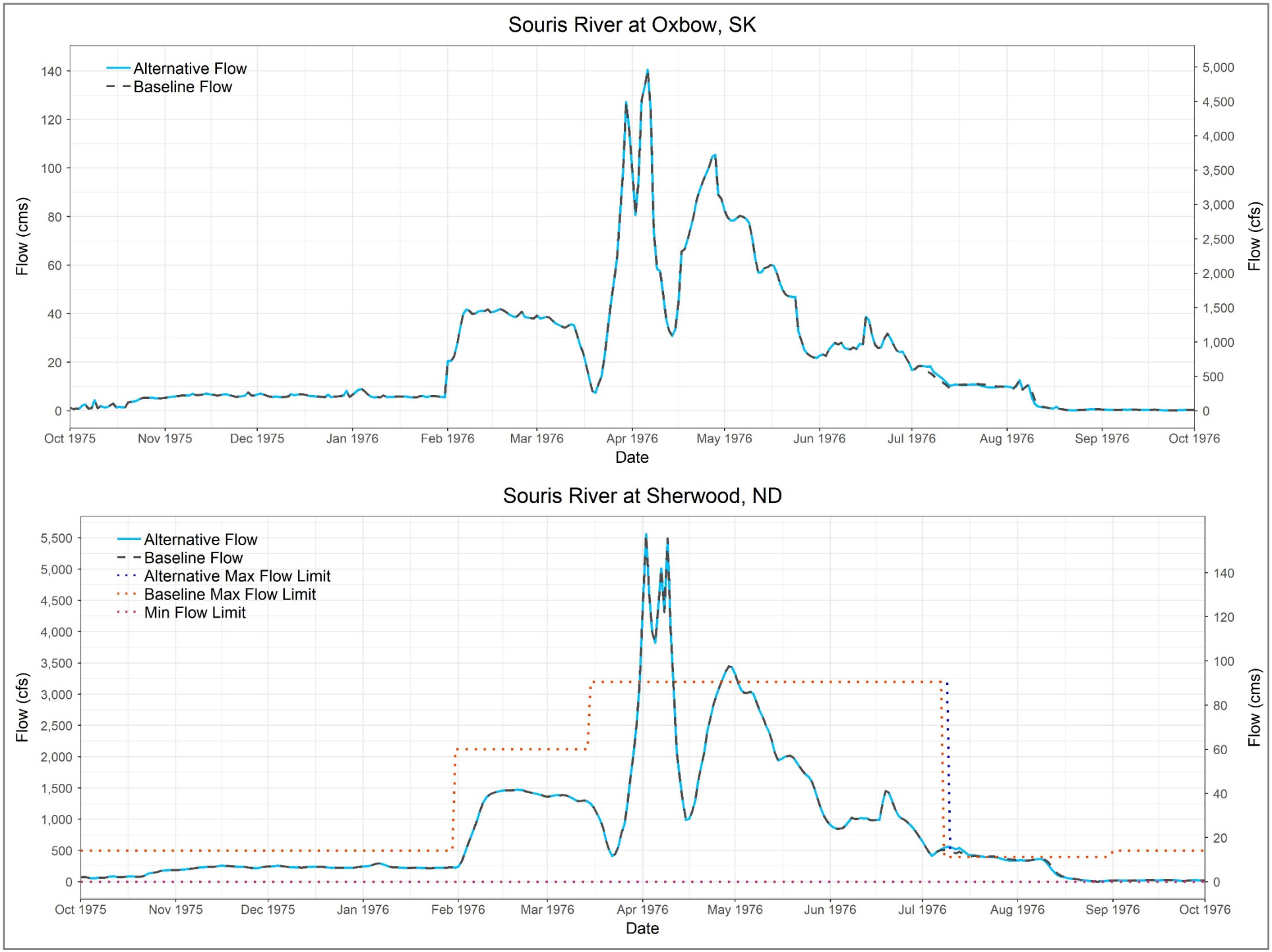
Plate 08

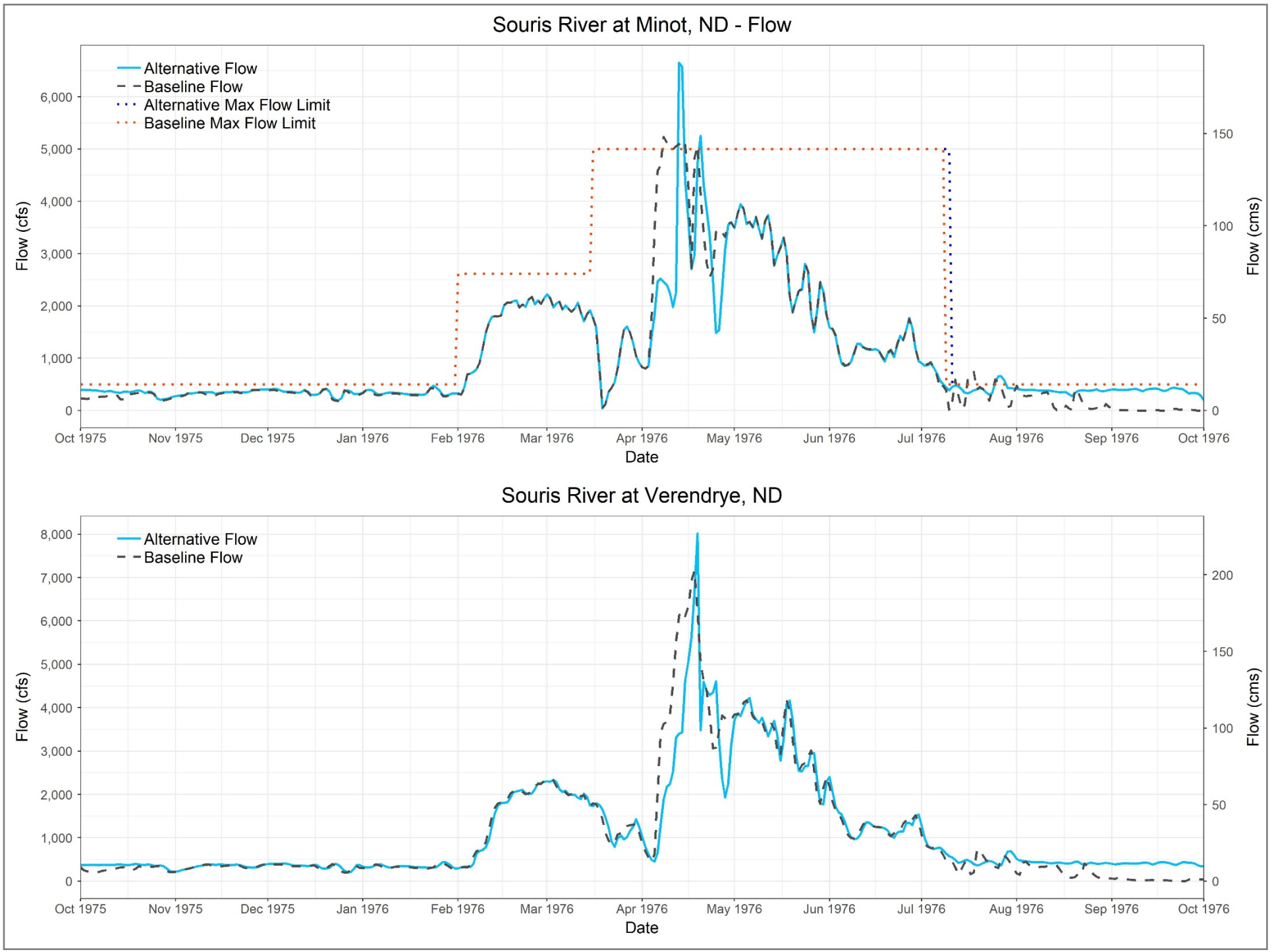
Critical Flow Locations – 1976

Alternative 3 (Phase 2)

Souris River Plan of Study




Souris River at Oxbow, SK
Alternative Flow
Baseline Flow
Flow (cms)
Flow (cfs)
Date
Oct 1975
Nov 1975
Dec 1975
Jan 1976
Feb 1976
Mar 1976
Apr 1976
May 1976
Jun 1976
Jul 1976
Aug 1976
Sep 1976
Oct 1976
Souris River at Sherwood, ND
Alternative Flow
Baseline Flow
Alternative Max Flow Limit
Baseline Max Flow Limit
Min Flow Limit
Flow (cfs)
Flow (cms)
Date


Souris River at Minot, ND - Flow
Alternative Flow
Baseline Flow
Alternative Max Flow Limit
Baseline Max Flow Limit
Flow (cfs)
Flow (cms)
Date
Oct 1975
Nov 1975
Dec 1975
Jan 1976
Feb 1976
Mar 1976
Apr 1976
May 1976
Jun 1976
Jul 1976
Aug 1976
Sep 1976
Oct 1976
Souris River at Verendrye, ND
Alternative Flow
Baseline Flow
Flow (cfs)
Flow (cms)
Date

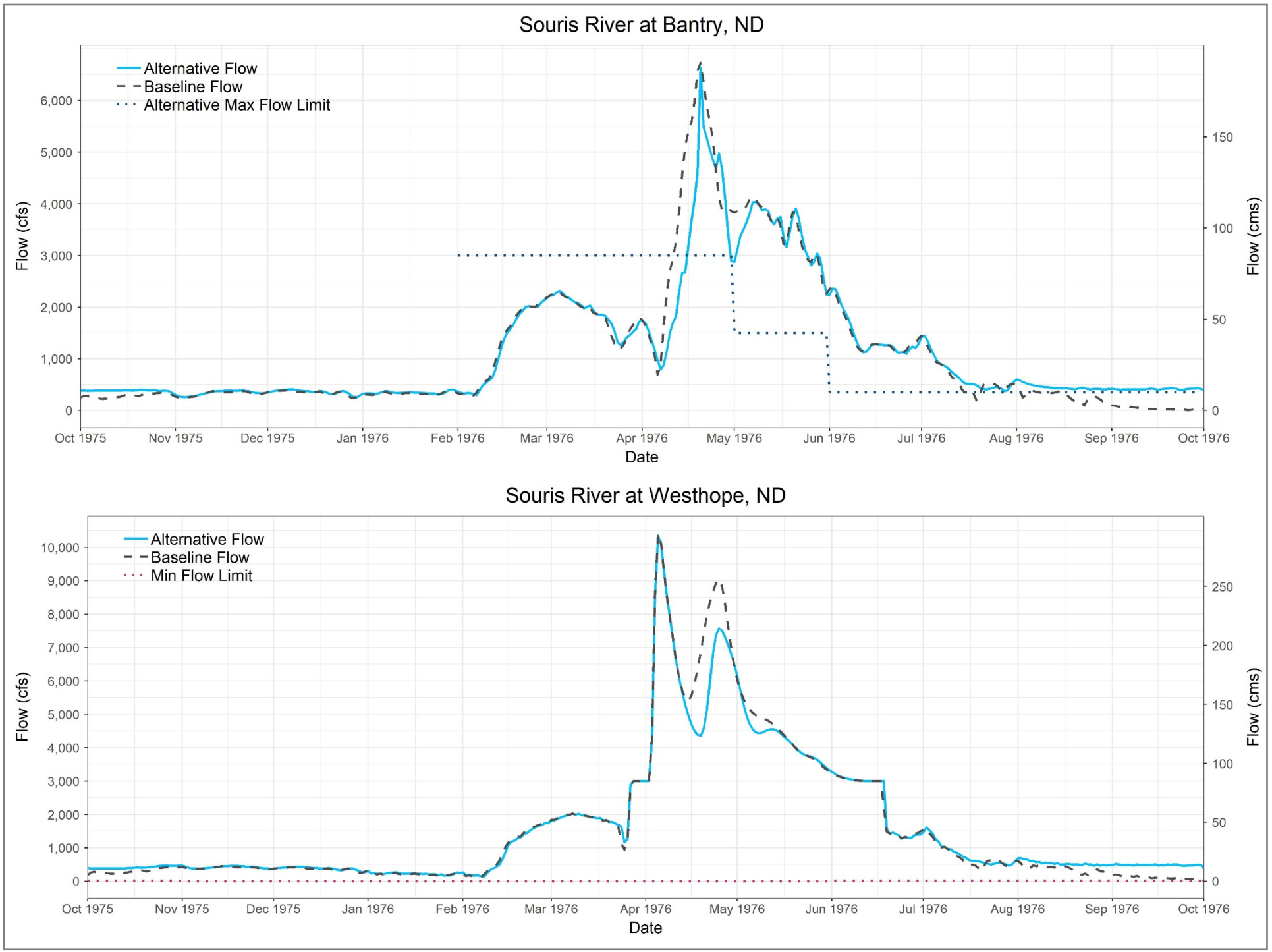
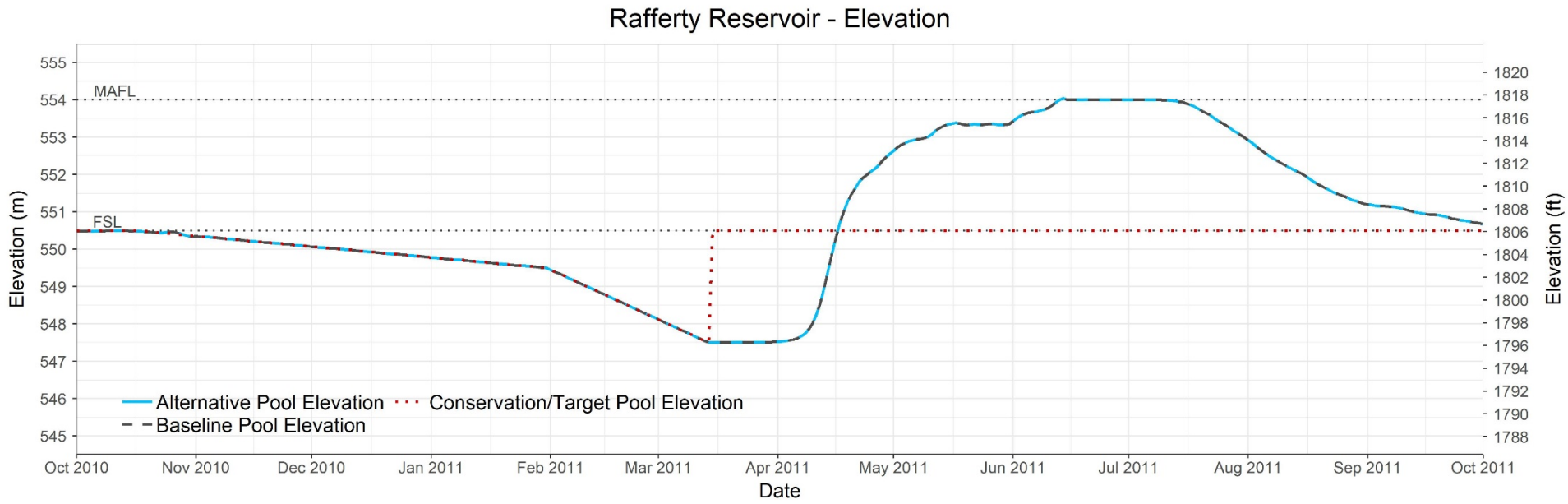
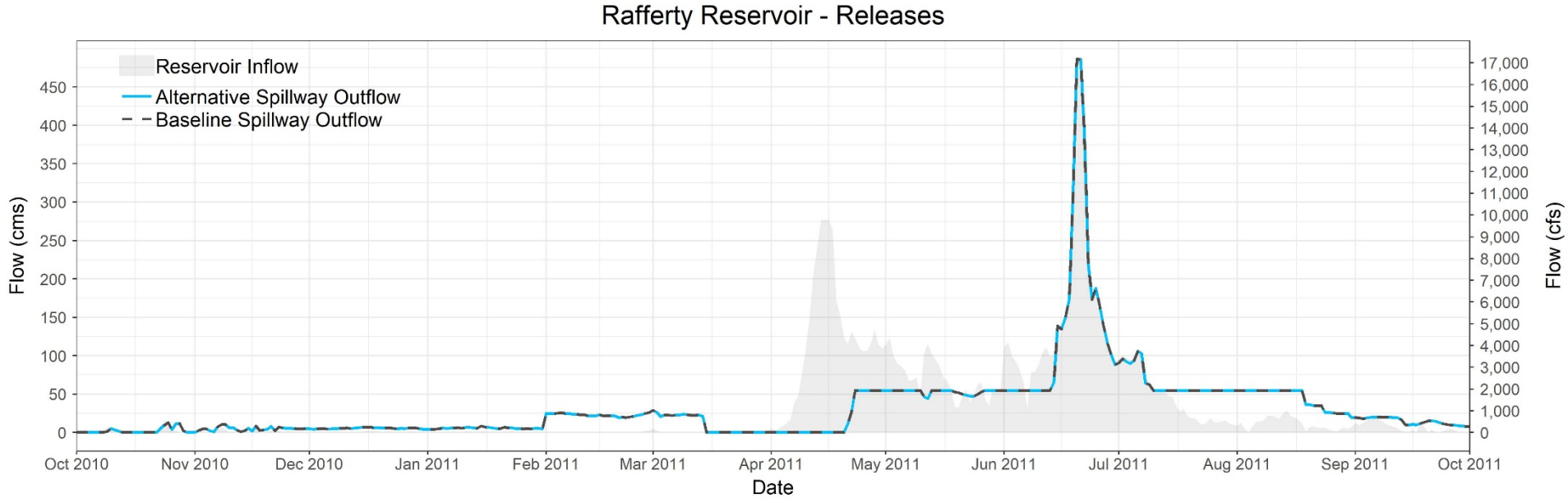
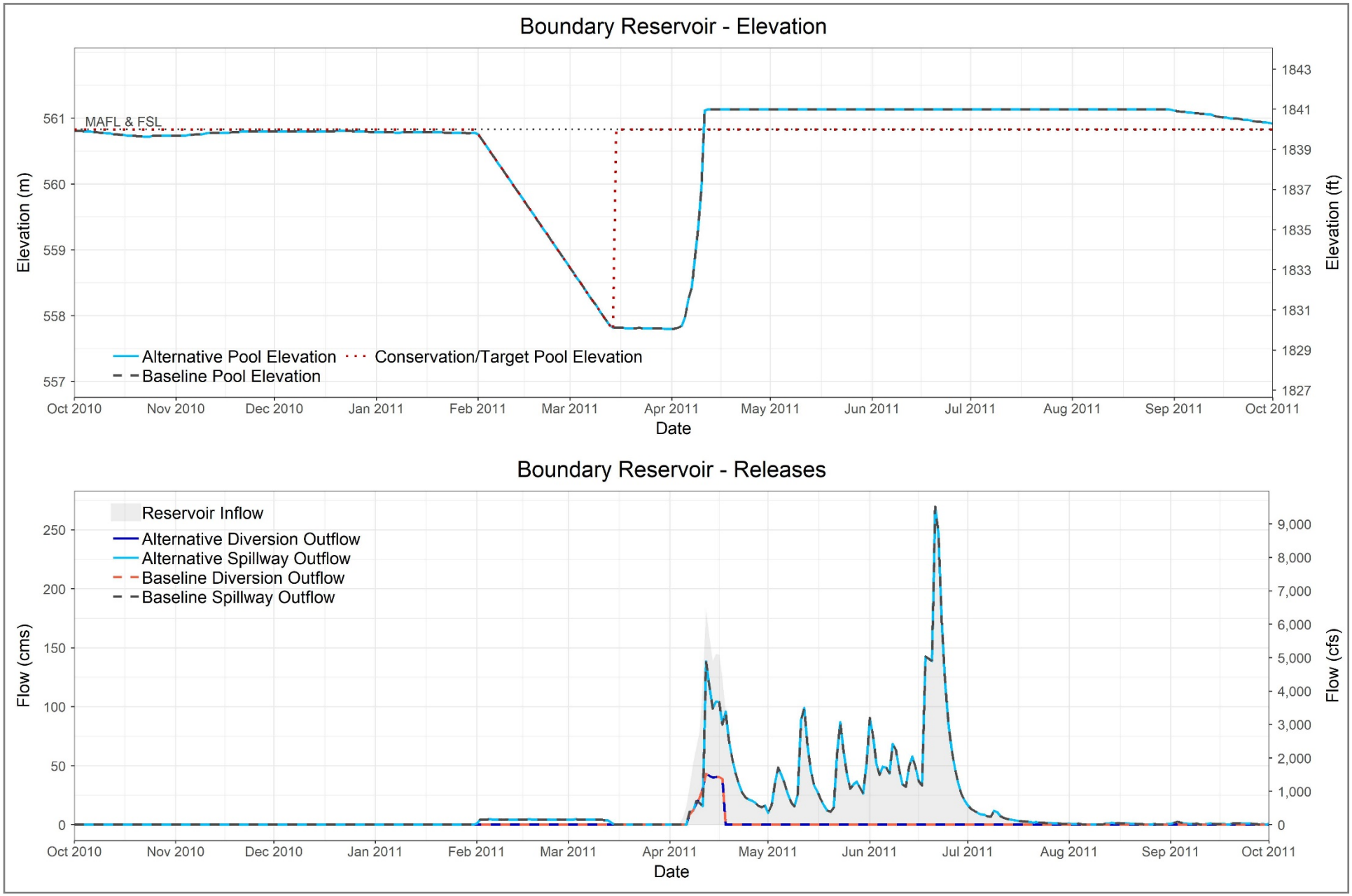

Souris River at Bantry, ND
Alternative Flow
Baseline Flow
Alternative Max Flow Limit
Flow (cfs)
Flow (cms)
Date
Oct 1975
Nov 1975
Dec 1975
Jan 1976
Feb 1976
Mar 1976
Apr 1976
May 1976
Jun 1976
Jul 1976
Aug 1976
Sep 1976
Oct 1976
Souris River at Westhope, ND
Alternative Flow
Baseline Flow
Min Flow Limit
Flow (cfs)
Flow (cms)
Date

Plate 09	Reservoirs – 2011	Alternative 3 (Phase 2) Souris River Plan of Study

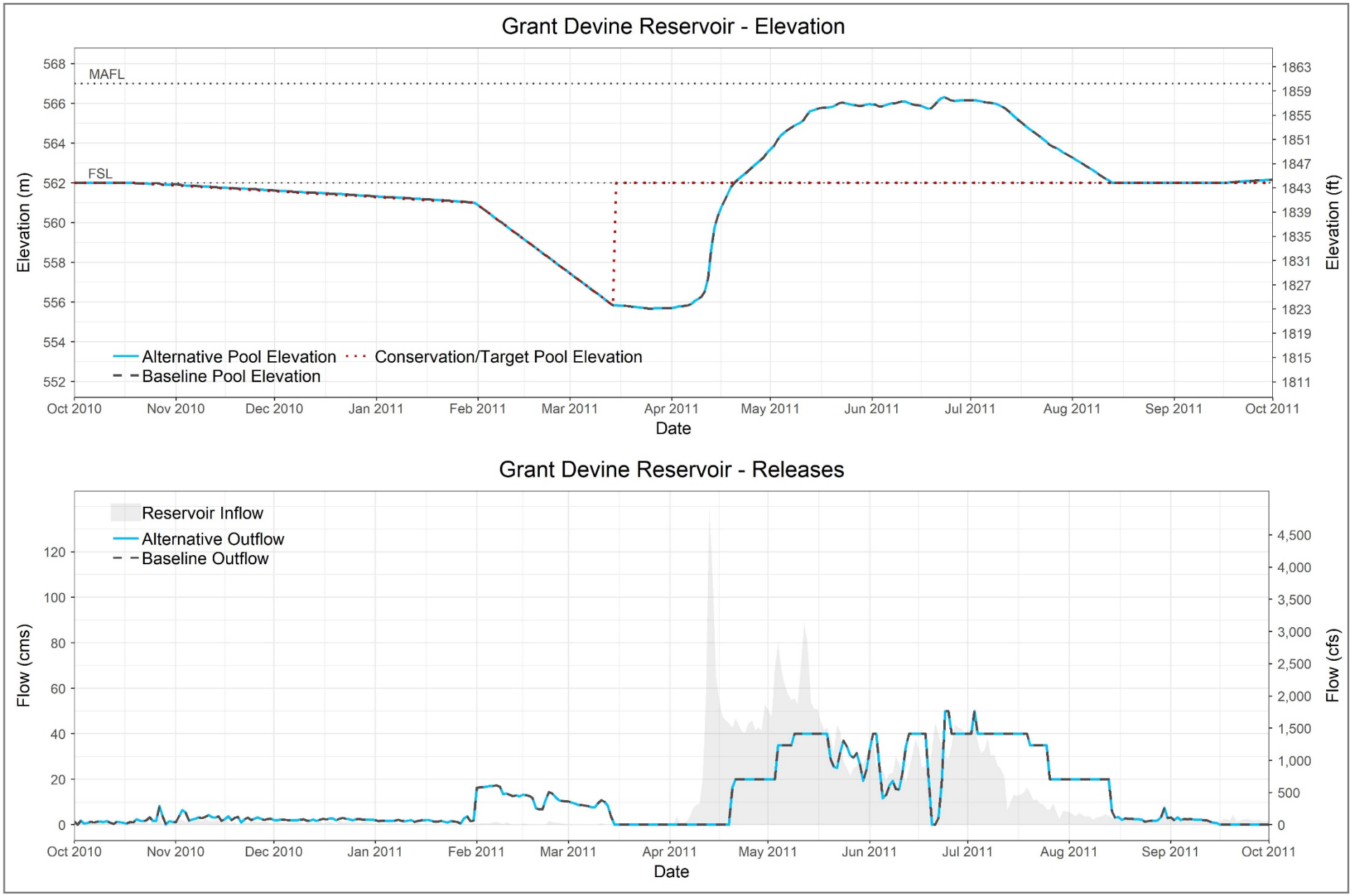




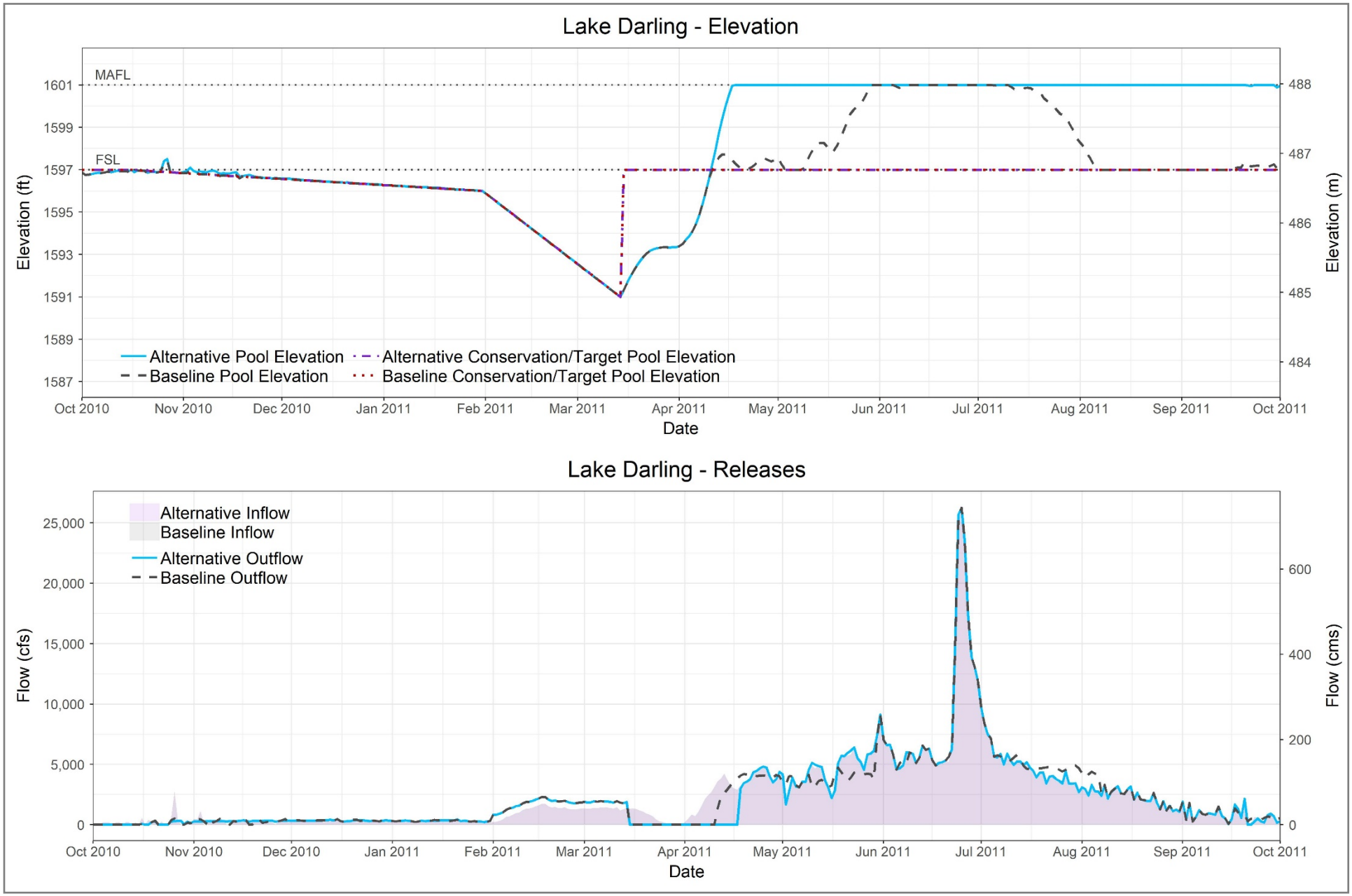
**MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level*



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



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



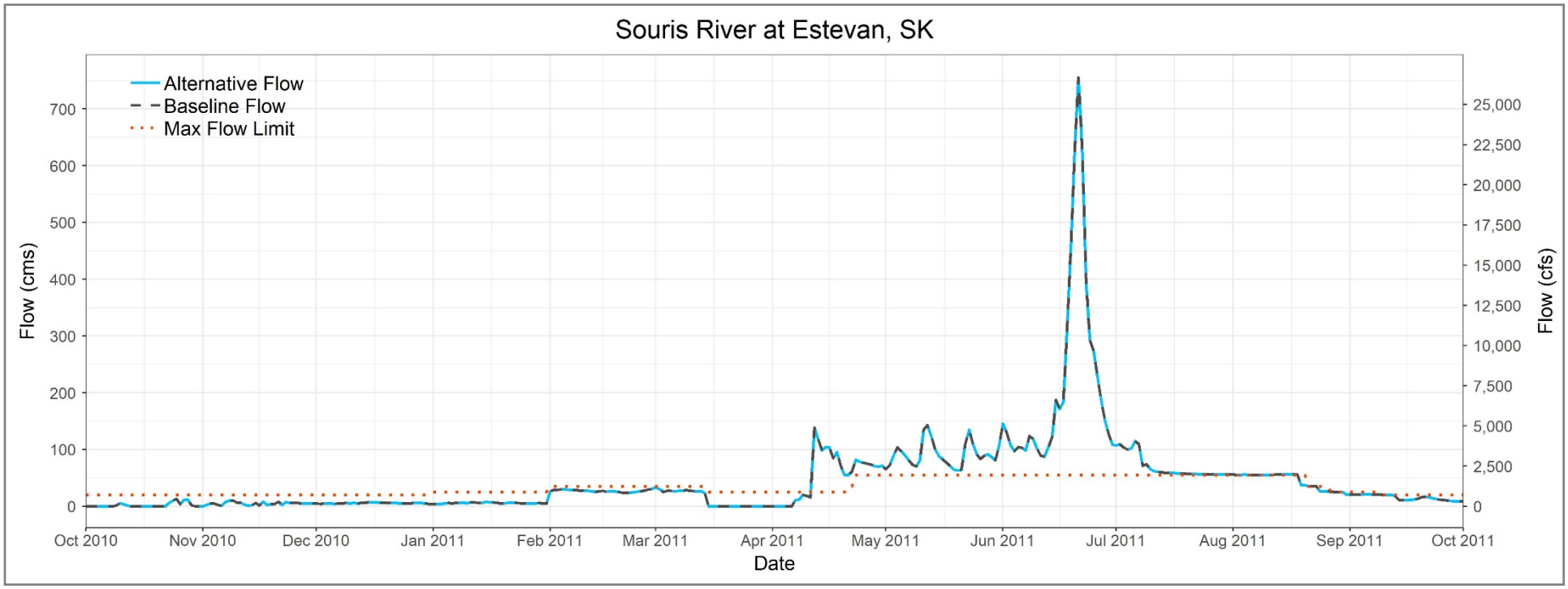
**MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level*

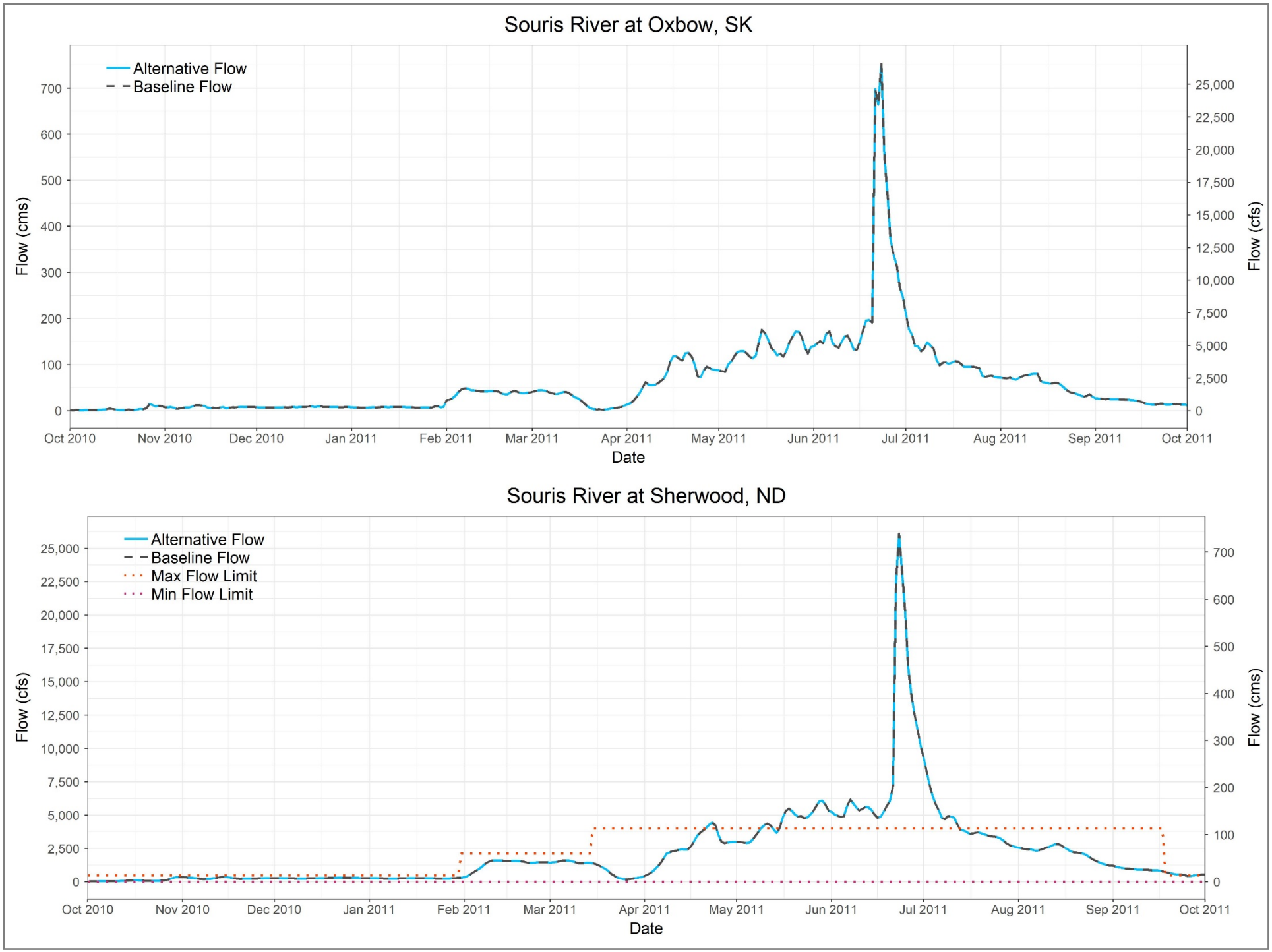
Plate 10

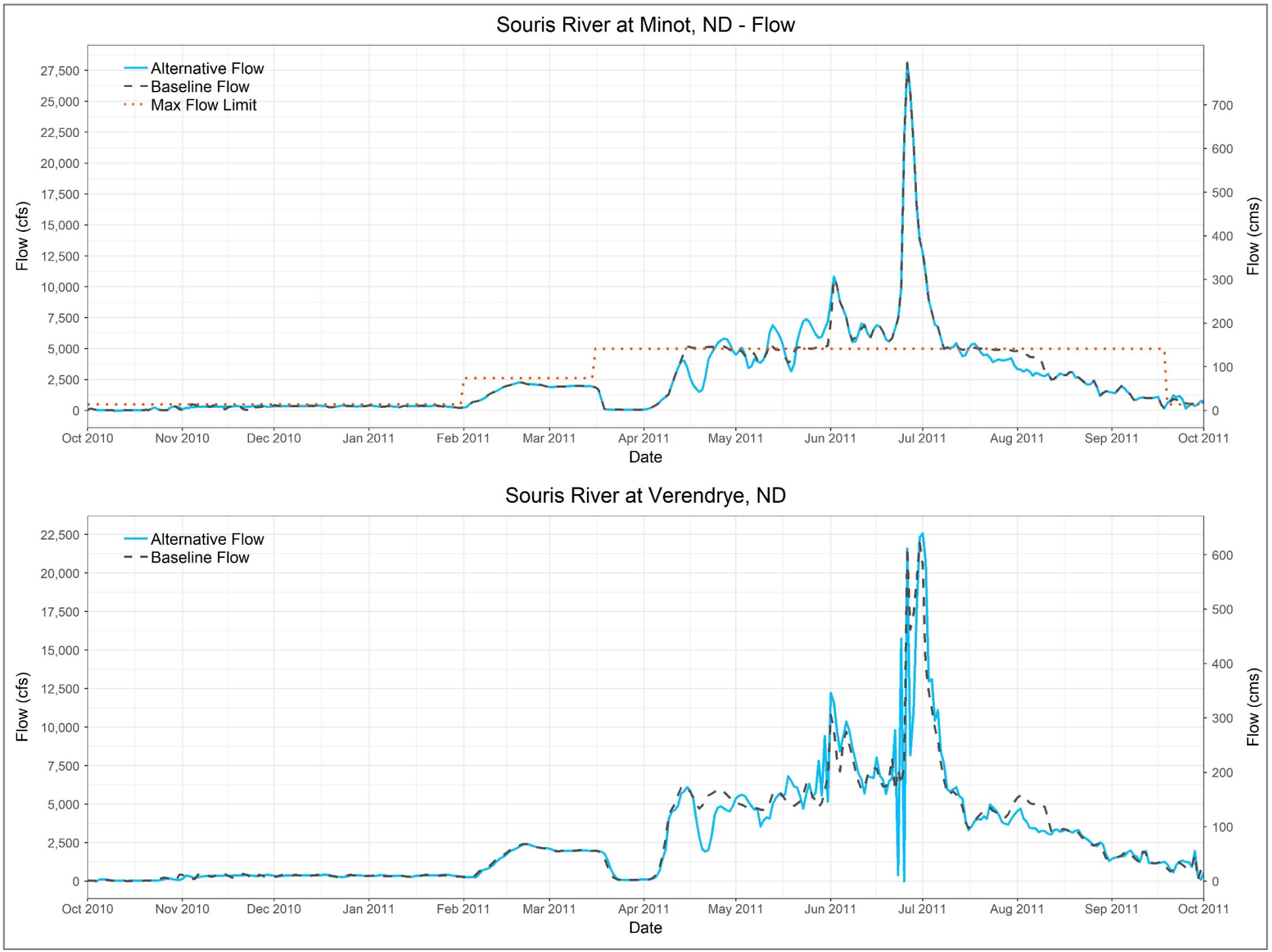
Critical Flow Locations – 2011

Alternative 3 (Phase 2)

Souris River Plan of Study




Souris River at Oxbow, SK
Alternative Flow
Baseline Flow
Flow (cms)
Flow (cfs)
Date
Oct 2010
Nov 2010
Dec 2010
Jan 2011
Feb 2011
Mar 2011
Apr 2011
May 2011
Jun 2011
Jul 2011
Aug 2011
Sep 2011
Oct 2011
Souris River at Sherwood, ND
Alternative Flow
Baseline Flow
Max Flow Limit
Min Flow Limit
Flow (cfs)
Flow (cms)
Date


Souris River at Minot, ND - Flow
Alternative Flow
Baseline Flow
Max Flow Limit
Flow (cfs)
Flow (cms)
Date
Oct 2010
Nov 2010
Dec 2010
Jan 2011
Feb 2011
Mar 2011
Apr 2011
May 2011
Jun 2011
Jul 2011
Aug 2011
Sep 2011
Oct 2011
Souris River at Verendrye, ND
Alternative Flow
Baseline Flow
Flow (cfs)
Flow (cms)
Date

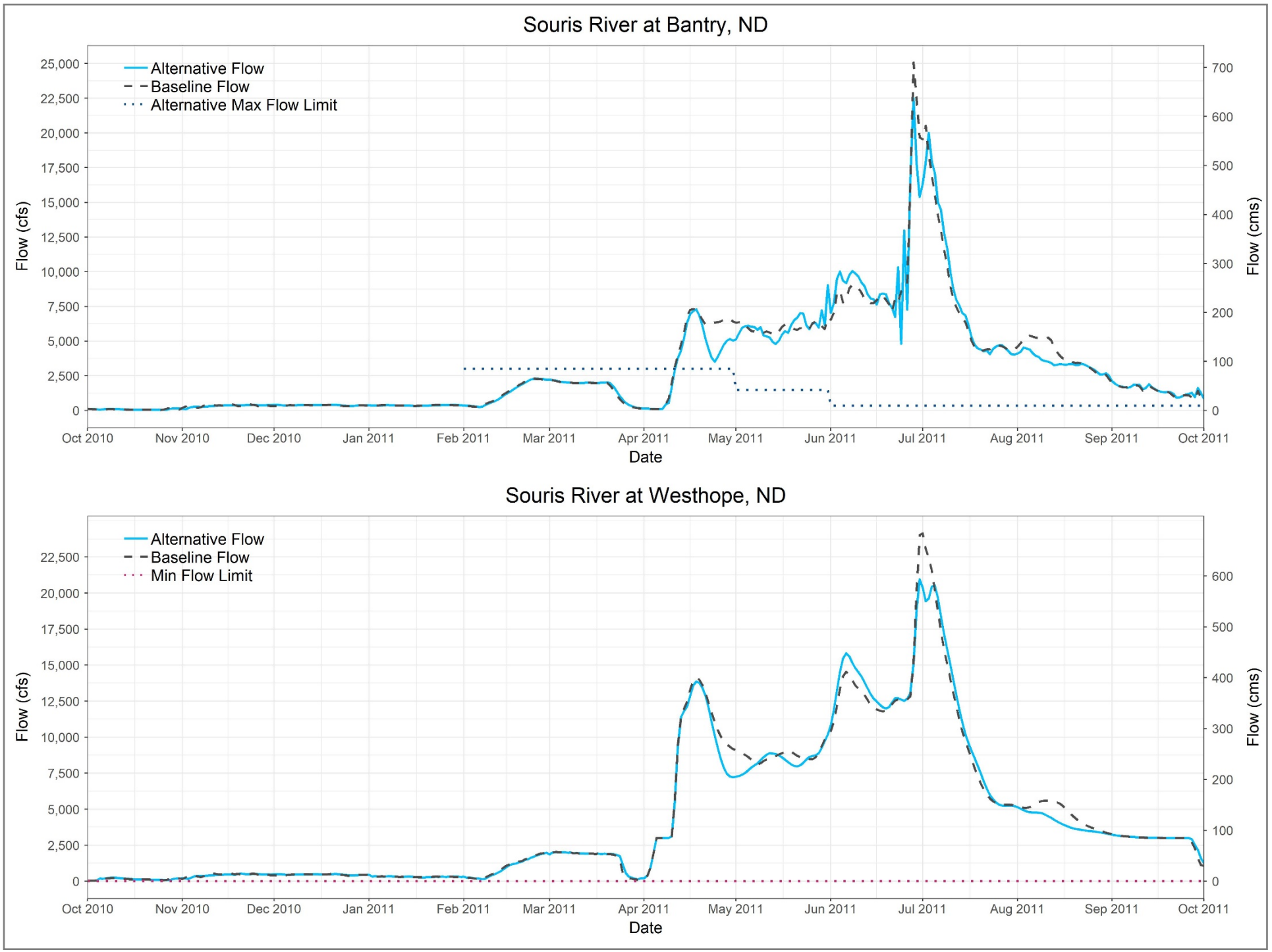
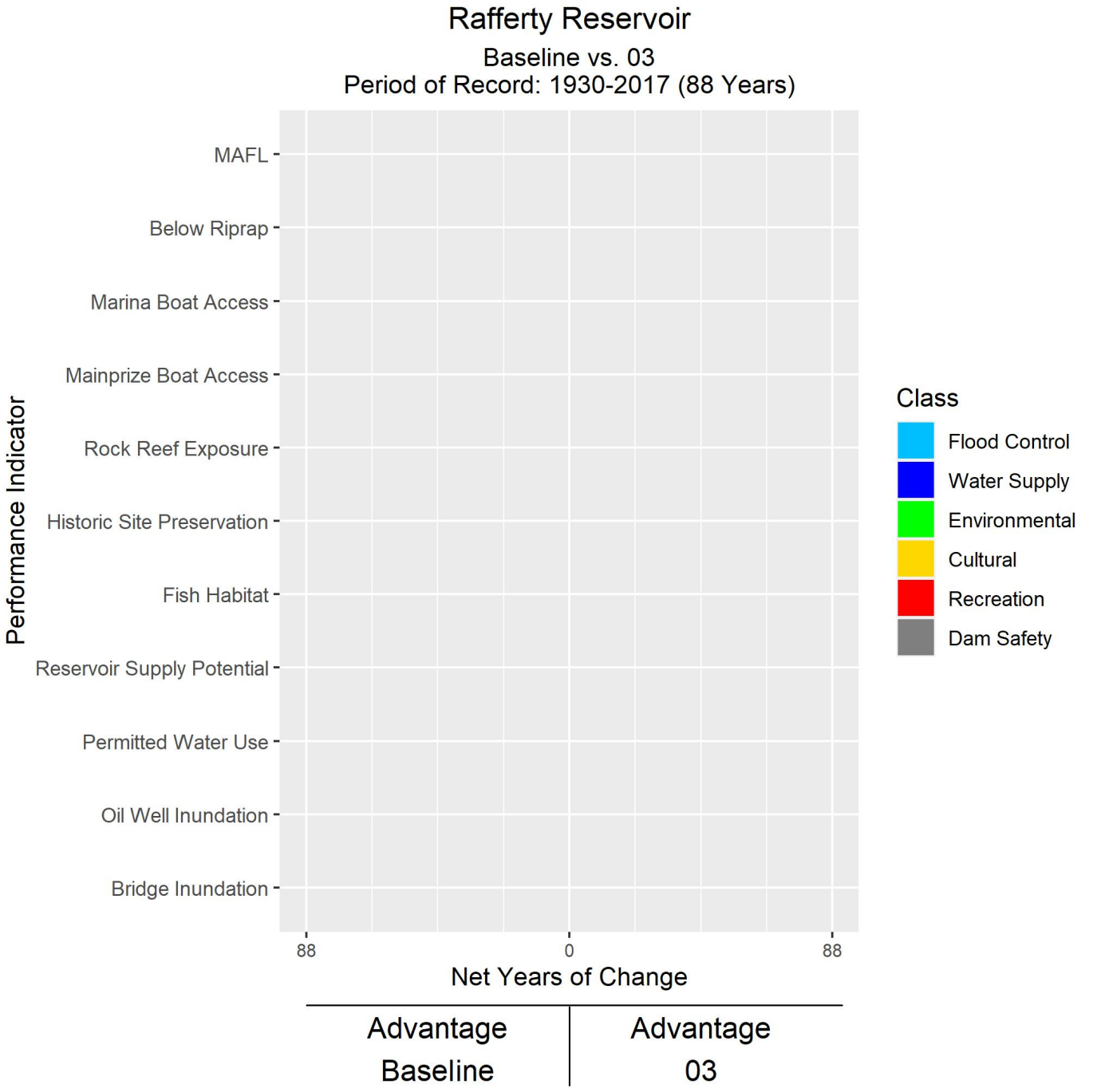
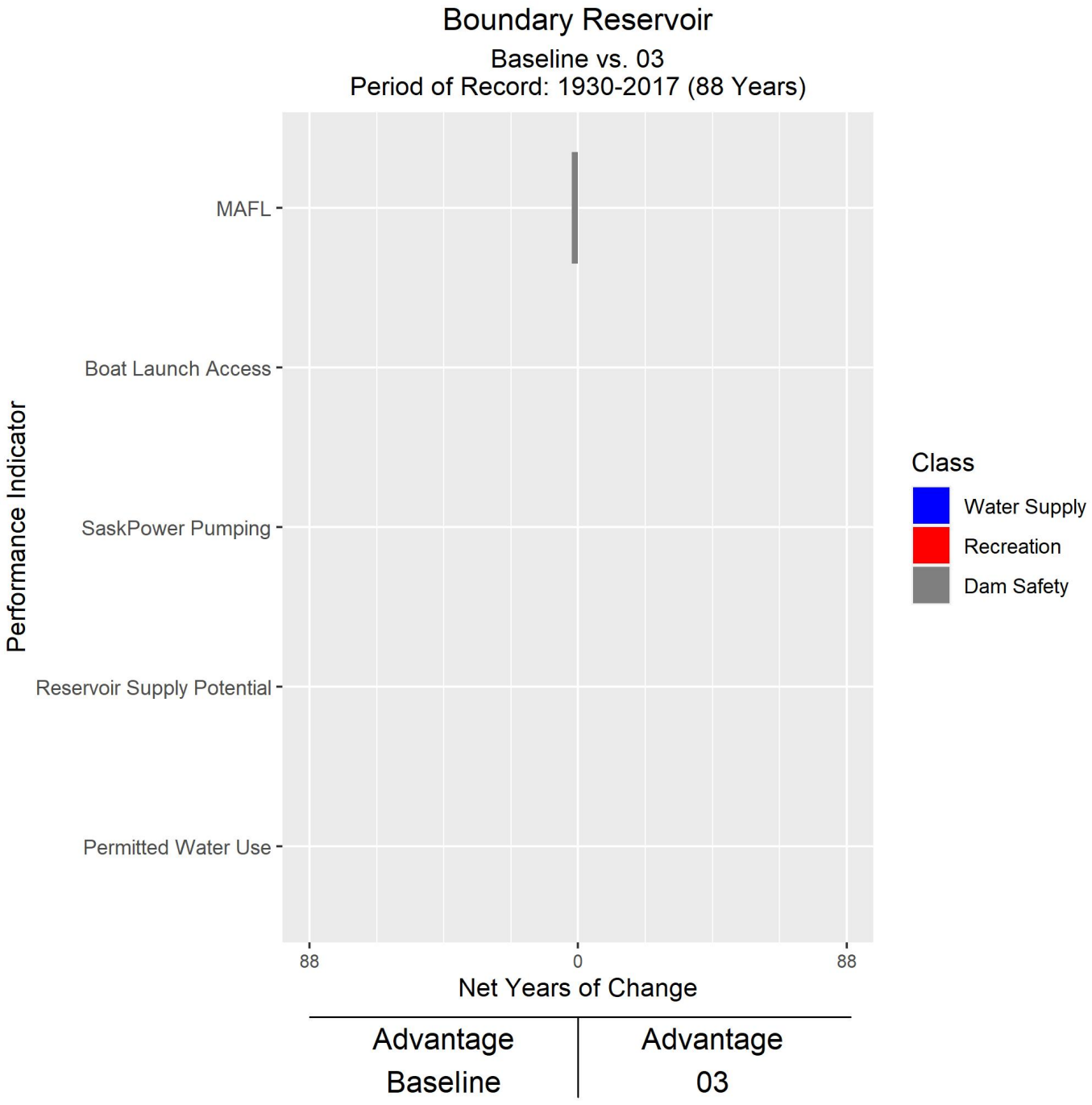
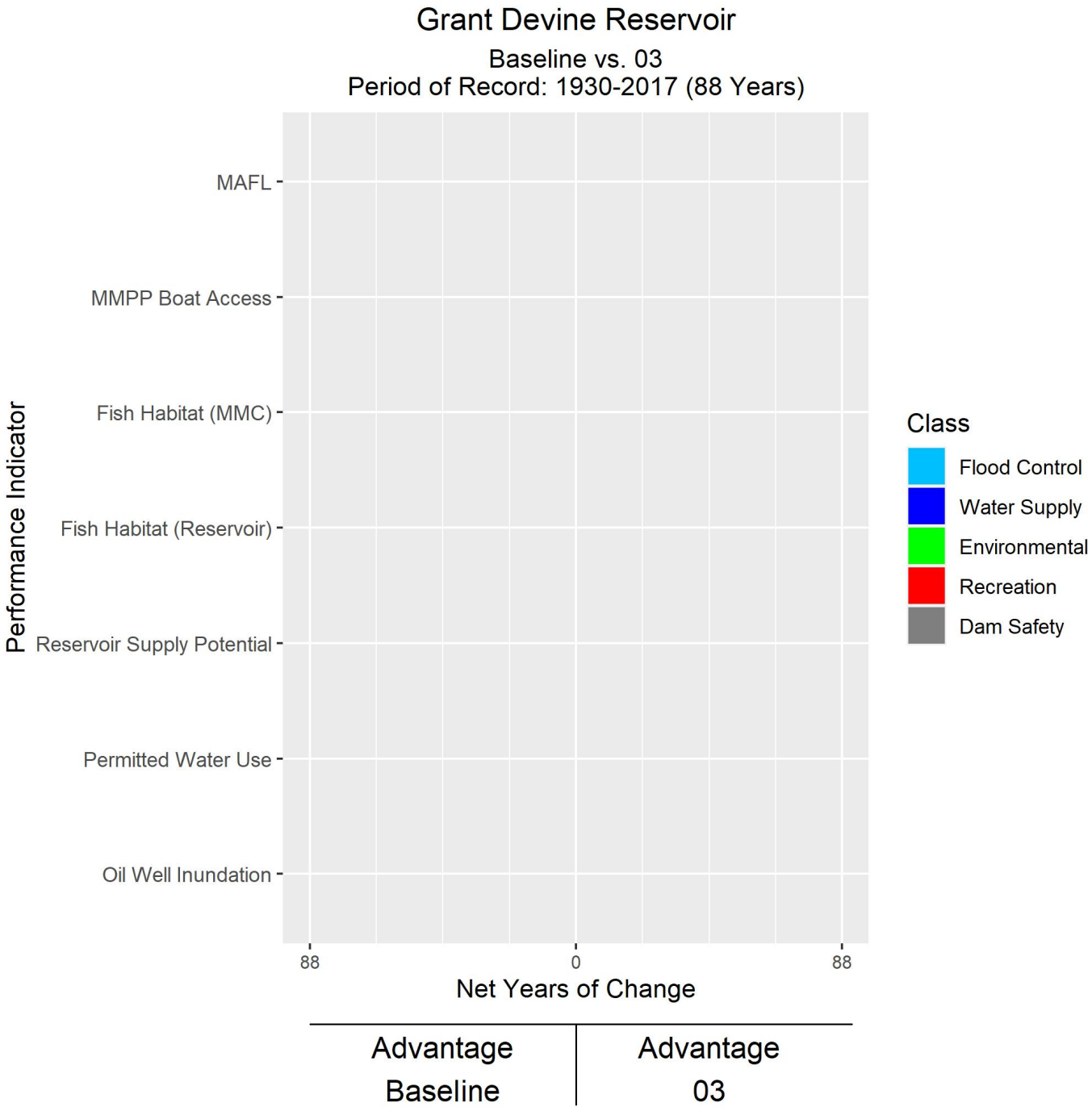
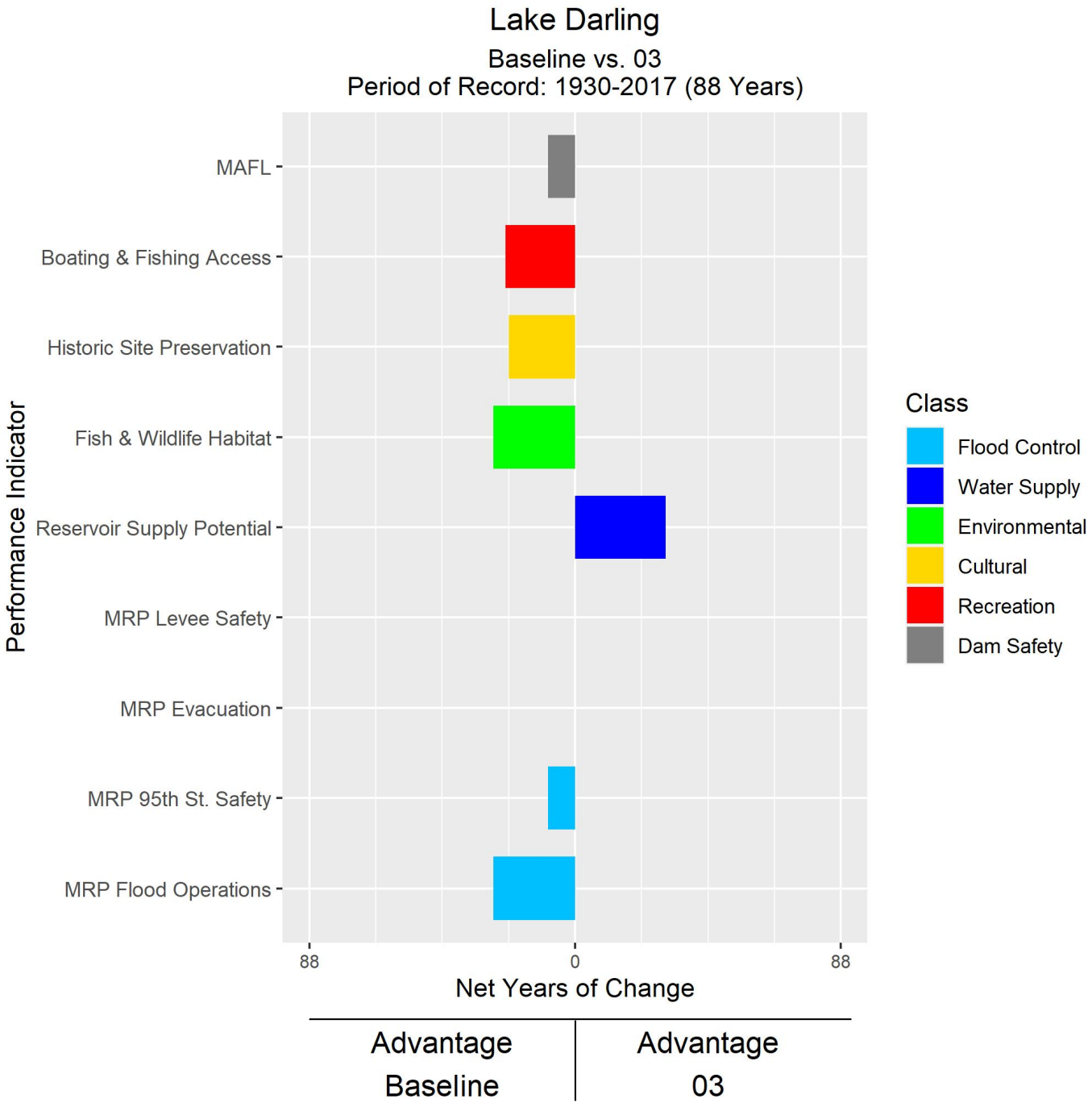

Souris River at Bantry, ND
Alternative Flow
Baseline Flow
Alternative Max Flow Limit
Flow (cfs)
Flow (cms)
25,000
22,500
20,000
17,500
15,000
12,500
10,000
7,500
5,000
2,500
0
700
600
500
400
300
200
100
0
Oct 2010
Nov 2010
Dec 2010
Jan 2011
Feb 2011
Mar 2011
Apr 2011
May 2011
Jun 2011
Jul 2011
Aug 2011
Sep 2011
Oct 2011
Date
Souris River at Westhope, ND
Alternative Flow
Baseline Flow
Min Flow Limit
Flow (cfs)
Flow (cms)
22,500
20,000
17,500
15,000
12,500
10,000
7,500
5,000
2,500
0
600
500
400
300
200
100
0
Oct 2010
Nov 2010
Dec 2010
Jan 2011
Feb 2011
Mar 2011
Apr 2011
May 2011
Jun 2011
Jul 2011
Aug 2011
Sep 2011
Oct 2011
Date

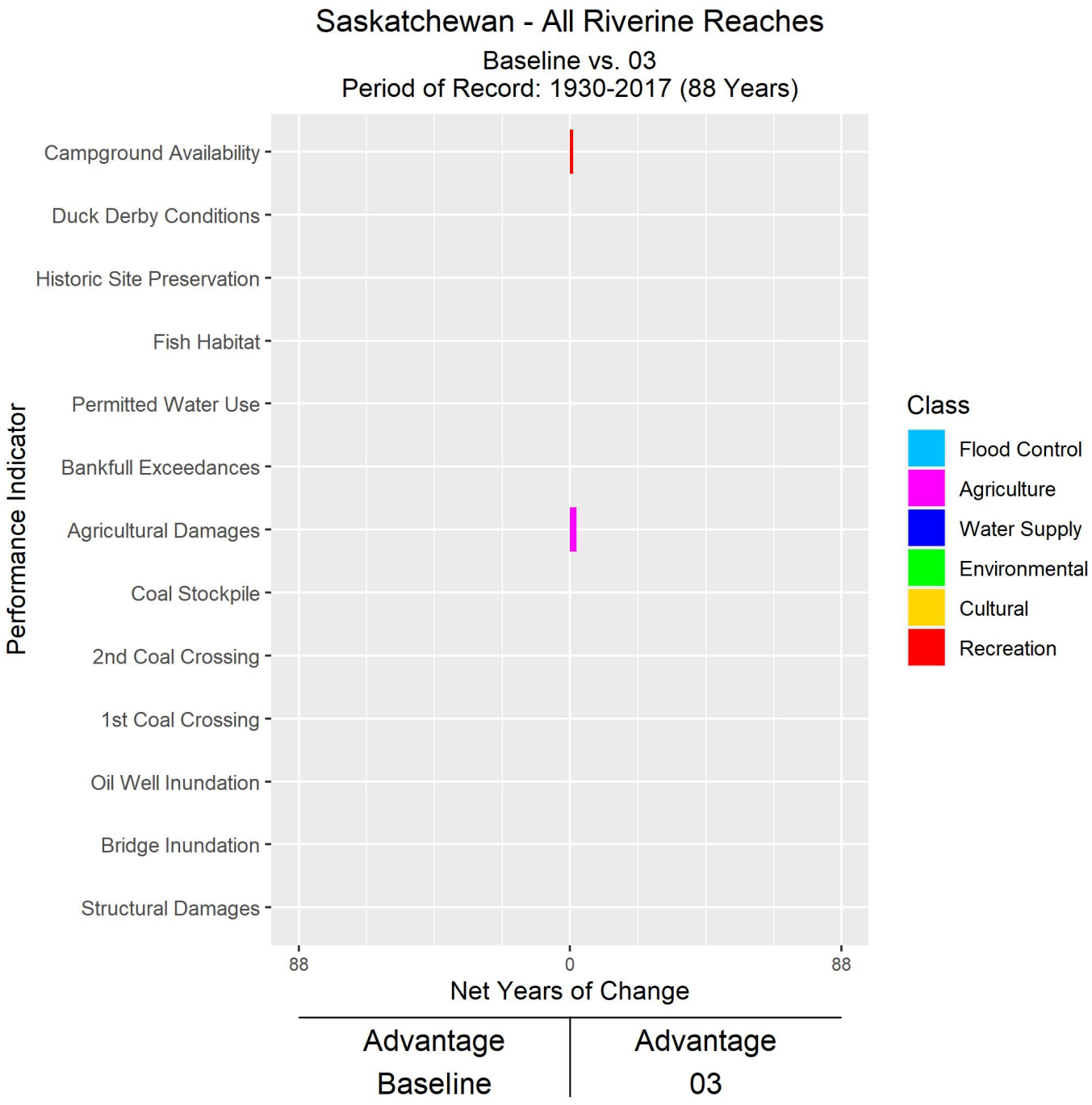
Plate 11	Performance Indicators 1930-2017 (88 years)	Alternative 03 vs. Baseline (Phase 2)

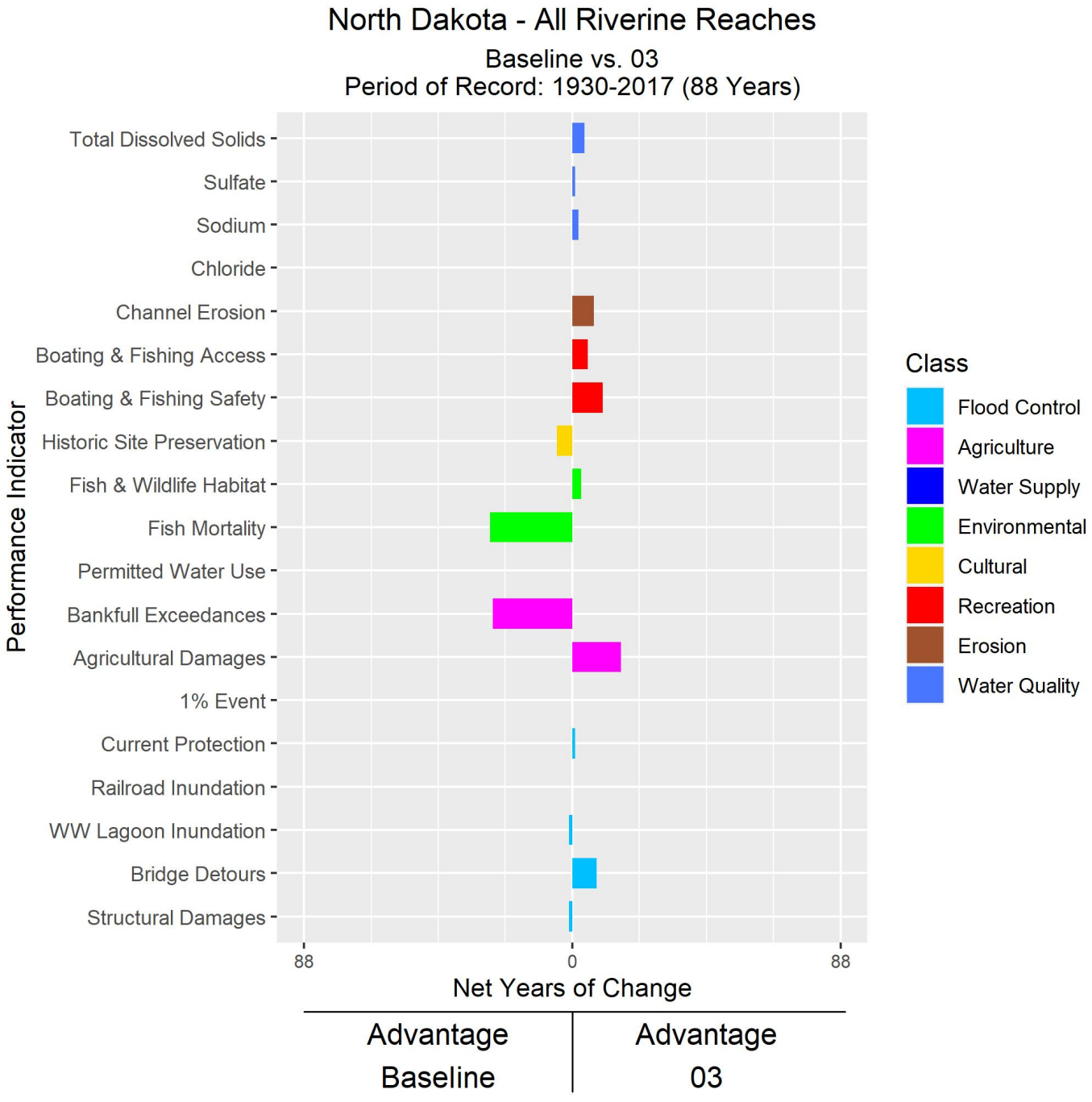


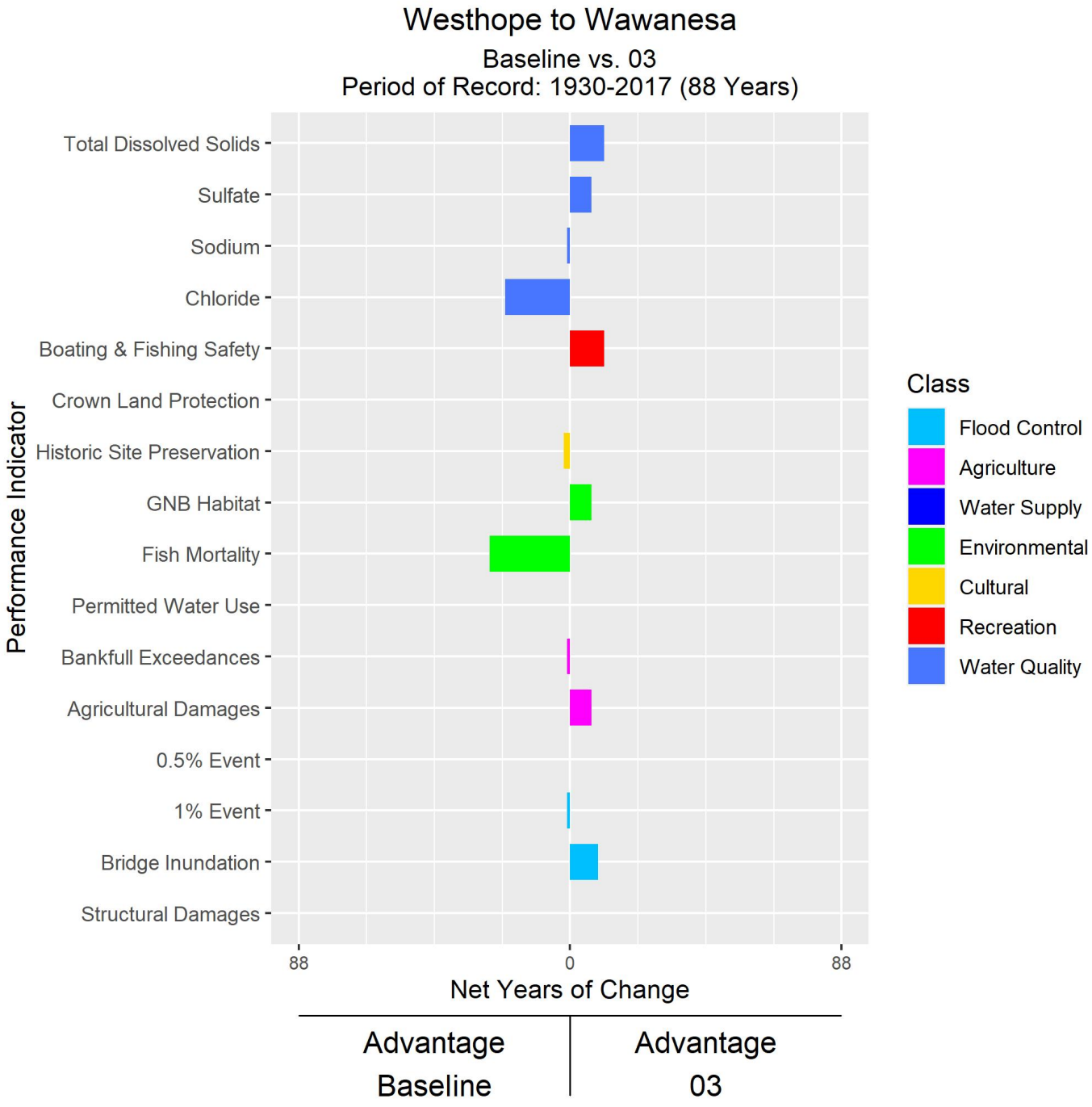

Boundary Reservoir
Baseline vs. 03
Period of Record: 1930-2017 (88 Years)
Performance Indicator
MAFL
Boat Launch Access
SaskPower Pumping
Reservoir Supply Potential
Permitted Water Use
88
0
88
Net Years of Change
Advantage Baseline
Advantage 03
Class
Water Supply
Recreation
Dam Safety

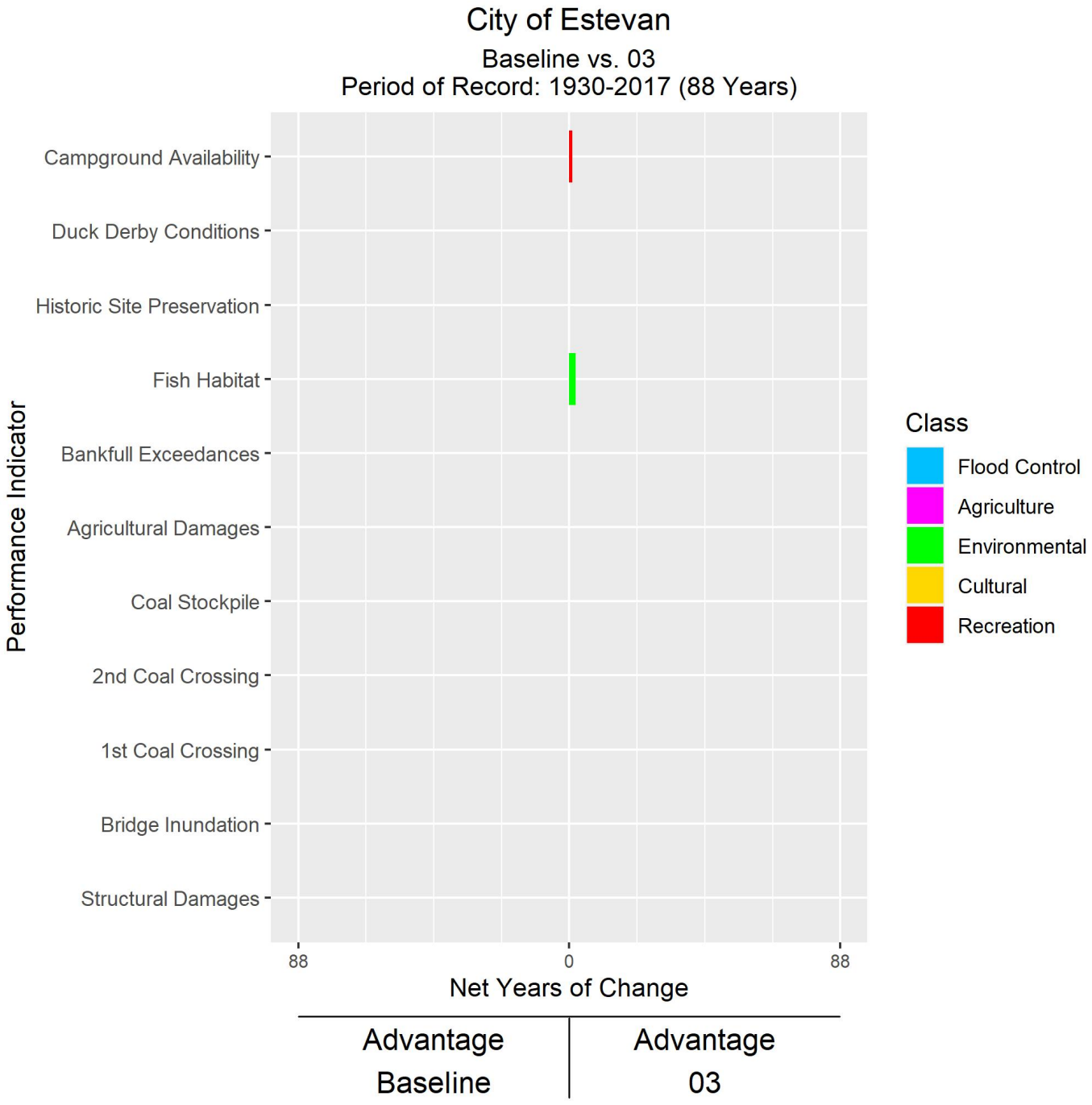

Grant Devine Reservoir
Baseline vs. 03
Period of Record: 1930-2017 (88 Years)
Performance Indicator
MAFL
MMPP Boat Access
Fish Habitat (MMC)
Fish Habitat (Reservoir)
Reservoir Supply Potential
Permitted Water Use
Oil Well Inundation
88
0
88
Net Years of Change
Advantage Baseline
Advantage 03
Class
Flood Control
Water Supply
Environmental
Recreation
Dam Safety

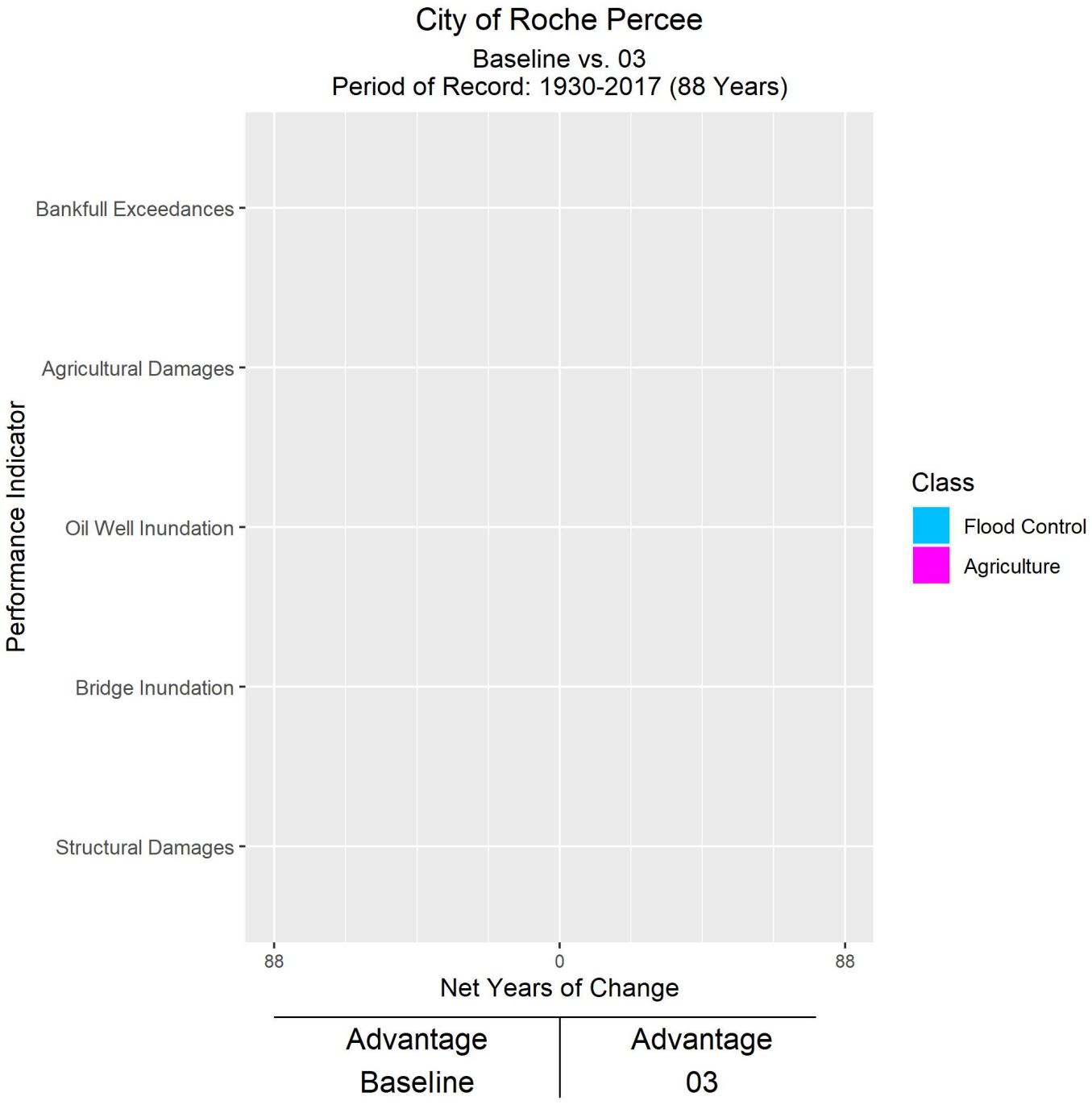

Lake Darling
Baseline vs. 03
Period of Record: 1930-2017 (88 Years)
Performance Indicator
MAFL
Boating & Fishing Access
Historic Site Preservation
Fish & Wildlife Habitat
Reservoir Supply Potential
MRP Levee Safety
MRP Evacuation
MRP 95th St. Safety
MRP Flood Operations
88
0
88
Net Years of Change
Advantage
Baseline
Advantage
03
Class
Flood Control
Water Supply
Environmental
Cultural
Recreation
Dam Safety

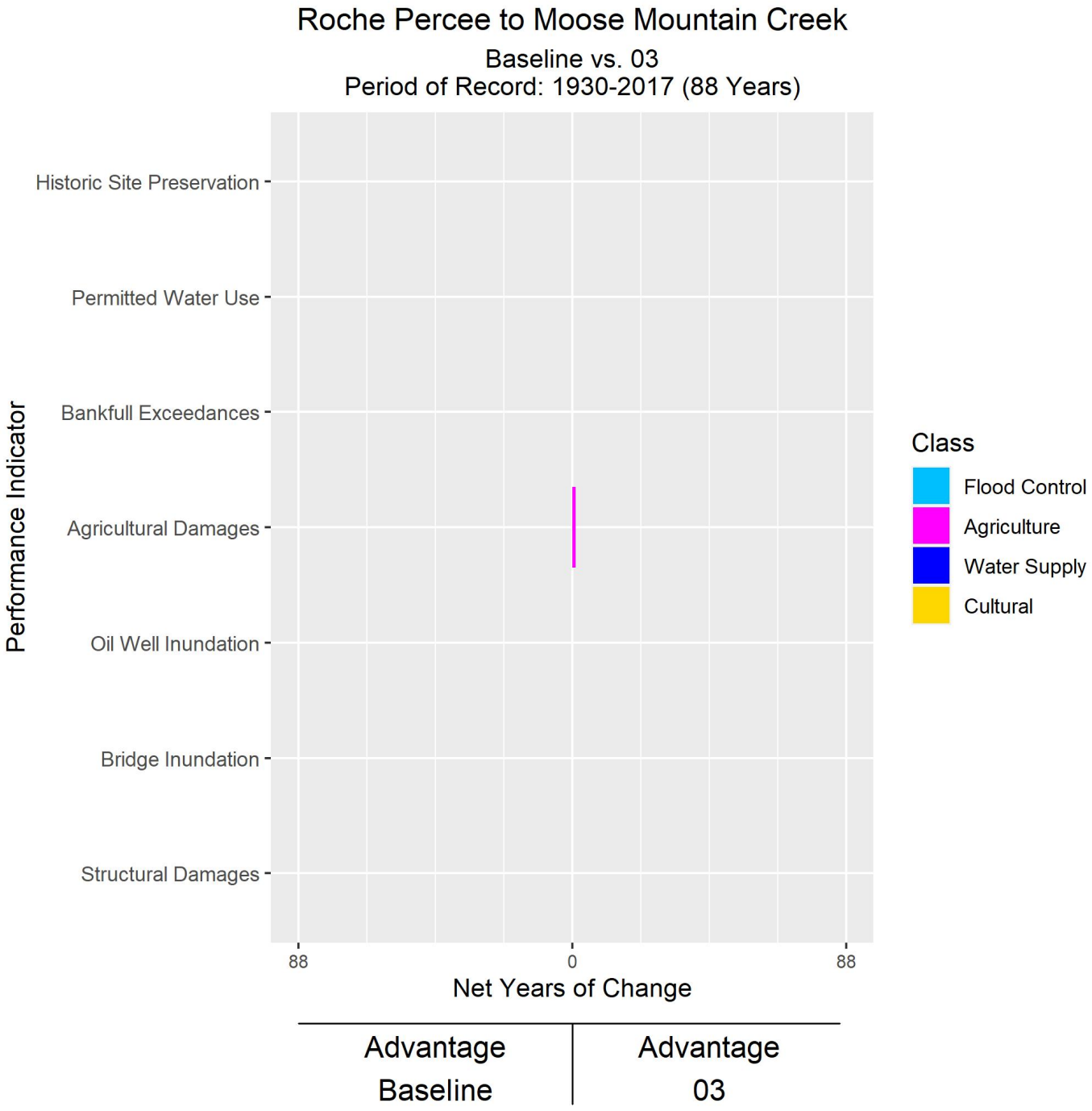

Saskatchewan - All Riverine Reaches
Baseline vs. 03
Period of Record: 1930-2017 (88 Years)
Performance Indicator
Campground Availability
Duck Derby Conditions
Historic Site Preservation
Fish Habitat
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
Coal Stockpile
2nd Coal Crossing
1st Coal Crossing
Oil Well Inundation
Bridge Inundation
Structural Damages
88
0
88
Net Years of Change
Advantage Baseline
Advantage 03
Class
Flood Control
Agriculture
Water Supply
Environmental
Cultural
Recreation

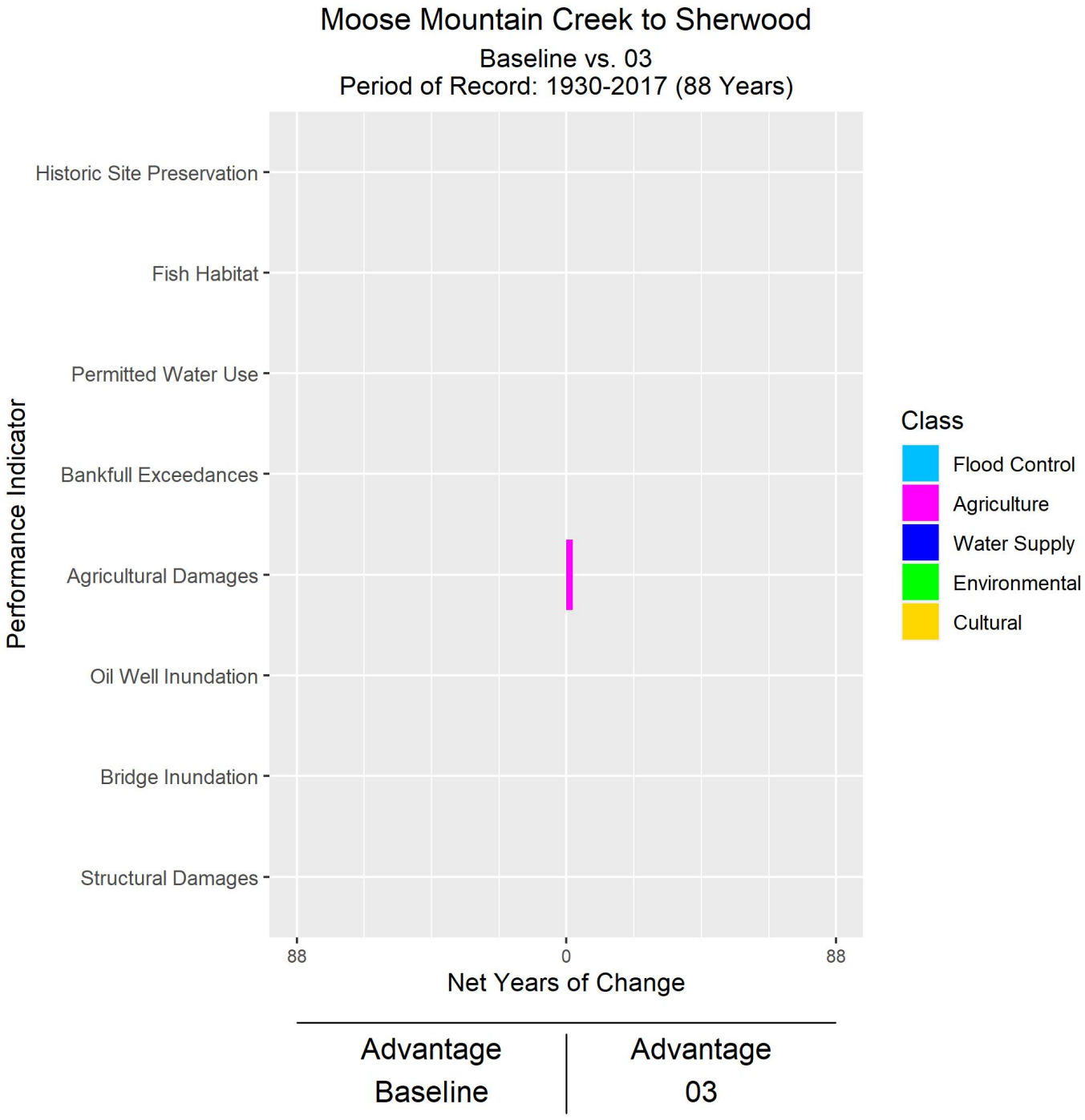

North Dakota - All Riverine Reaches
Baseline vs. 03
Period of Record: 1930-2017 (88 Years)
Performance Indicator
Total Dissolved Solids
Sulfate
Sodium
Chloride
Channel Erosion
Boating & Fishing Access
Boating & Fishing Safety
Historic Site Preservation
Fish & Wildlife Habitat
Fish Mortality
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
1% Event
Current Protection
Railroad Inundation
WW Lagoon Inundation
Bridge Detours
Structural Damages
88
0
88
Net Years of Change
Advantage
Baseline
Advantage
03
Class
Flood Control
Agriculture
Water Supply
Environmental
Cultural
Recreation
Erosion
Water Quality

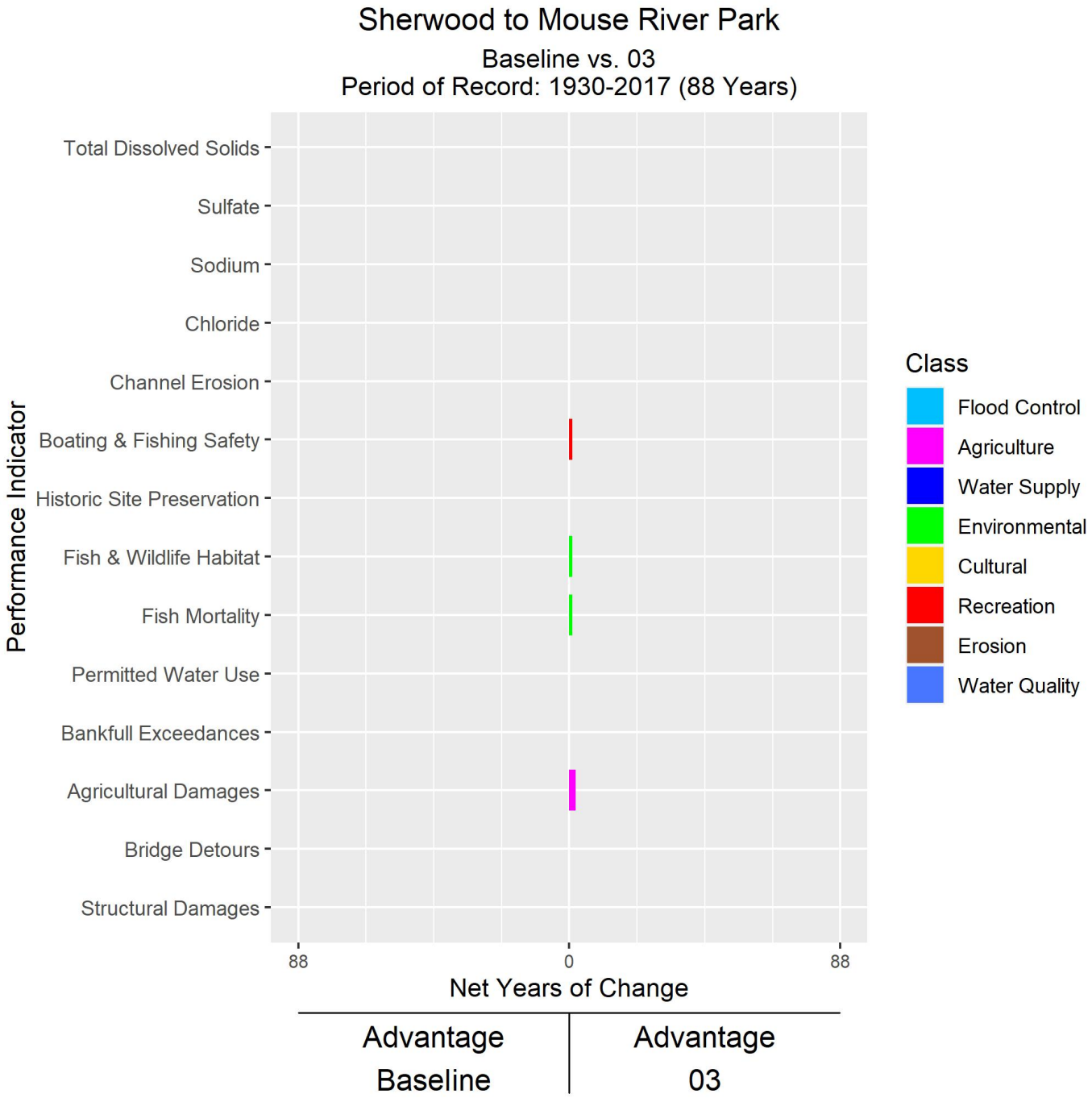

Westhope to Wawanesa
Baseline vs. 03
Period of Record: 1930-2017 (88 Years)
Performance Indicator
Total Dissolved Solids
Sulfate
Sodium
Chloride
Boating & Fishing Safety
Crown Land Protection
Historic Site Preservation
GNB Habitat
Fish Mortality
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
0.5% Event
1% Event
Bridge Inundation
Structural Damages
88
0
88
Net Years of Change
Advantage Baseline
Advantage 03
Class
Flood Control
Agriculture
Water Supply
Environmental
Cultural
Recreation
Water Quality

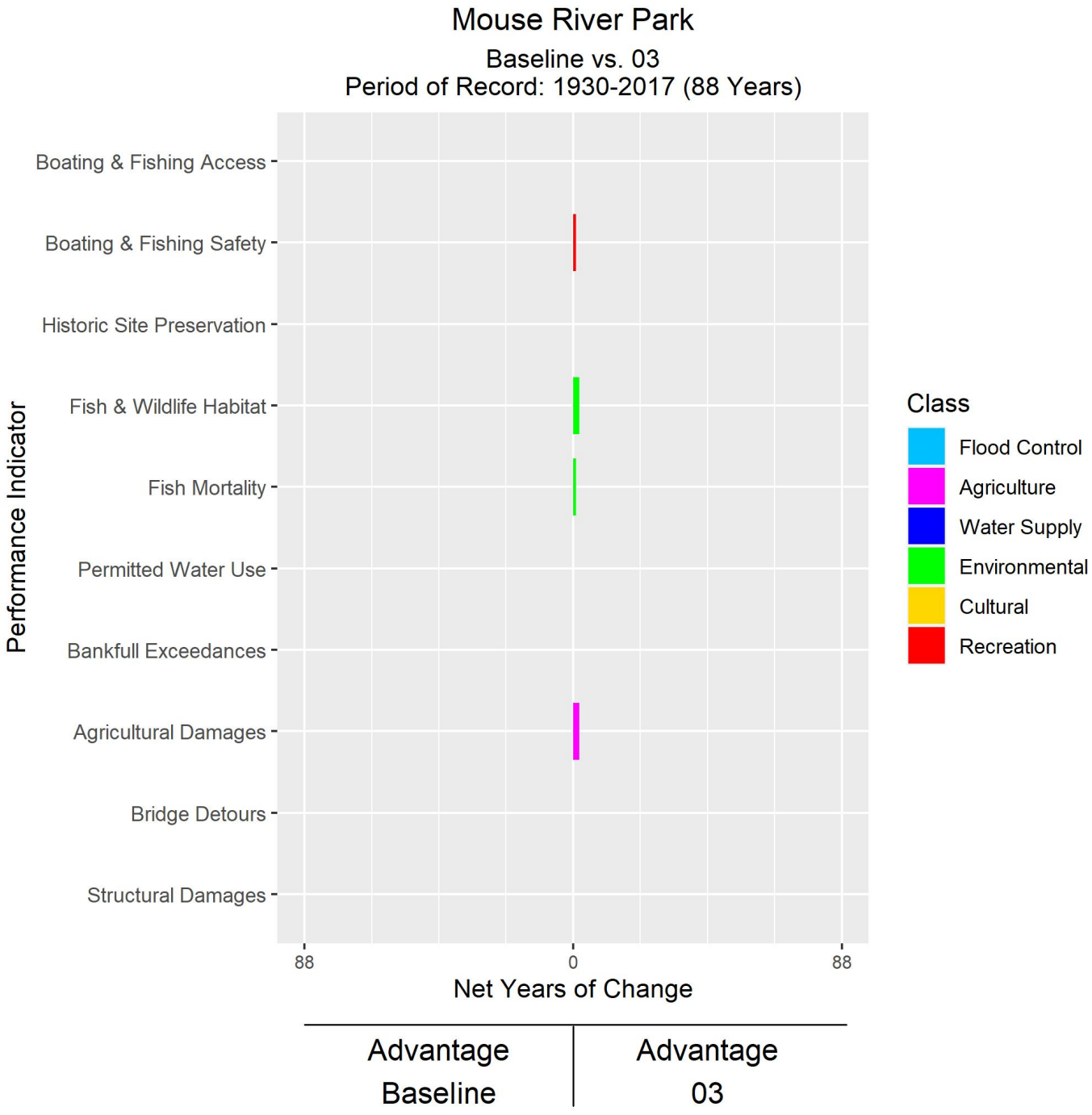

City of Estevan
Baseline vs. 03
Period of Record: 1930-2017 (88 Years)
Performance Indicator
Campground Availability
Duck Derby Conditions
Historic Site Preservation
Fish Habitat
Bankfull Exceedances
Agricultural Damages
Coal Stockpile
2nd Coal Crossing
1st Coal Crossing
Bridge Inundation
Structural Damages
88
0
88
Net Years of Change
Advantage Baseline
Advantage 03
Class
Flood Control
Agriculture
Environmental
Cultural
Recreation

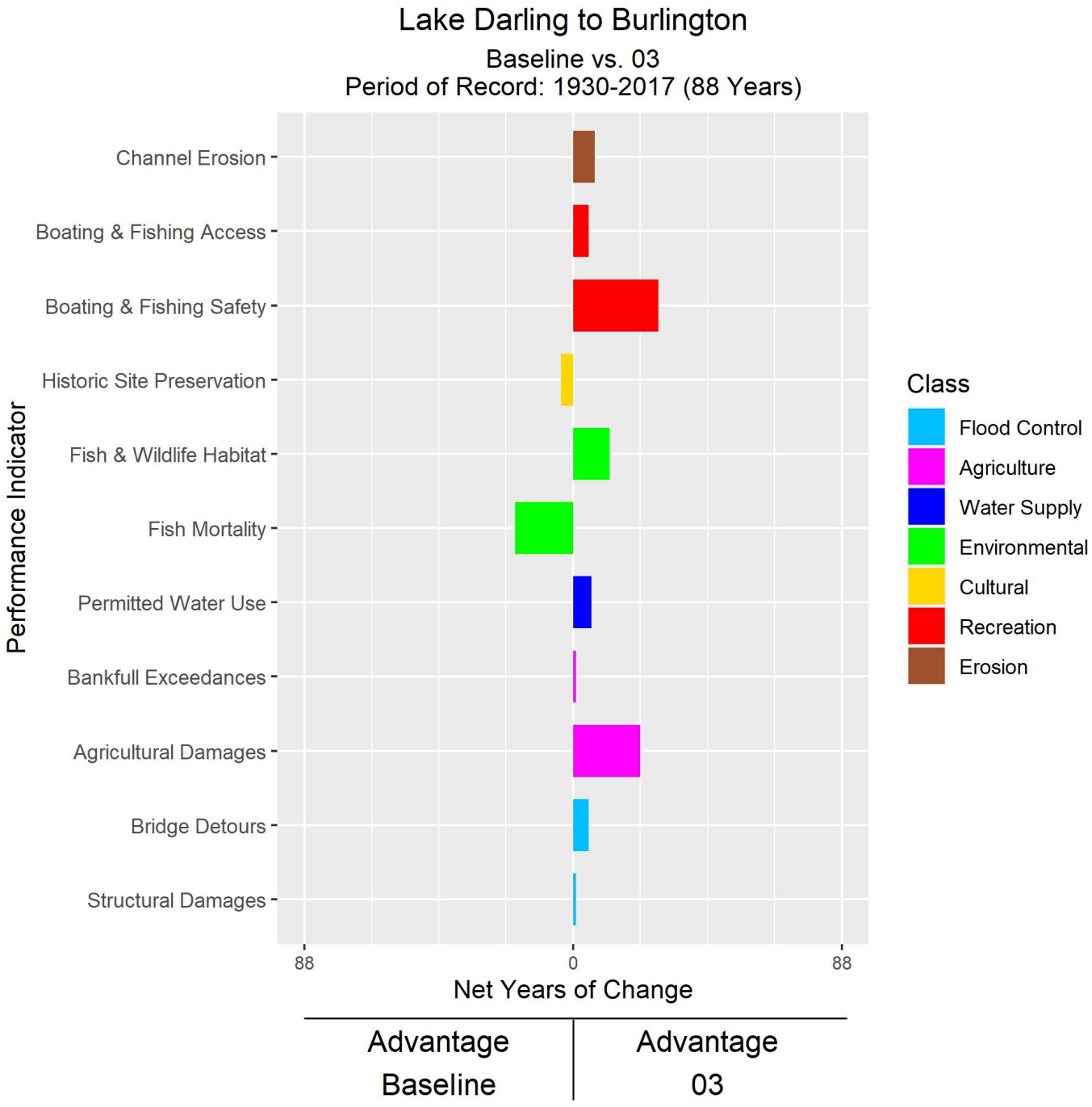

City of Roche Percee
Baseline vs. 03
Period of Record: 1930-2017 (88 Years)
Performance Indicator
Bankfull Exceedances
Agricultural Damages
Oil Well Inundation
Bridge Inundation
Structural Damages
88
0
88
Net Years of Change
Advantage Baseline
Advantage 03
Class
Flood Control
Agriculture

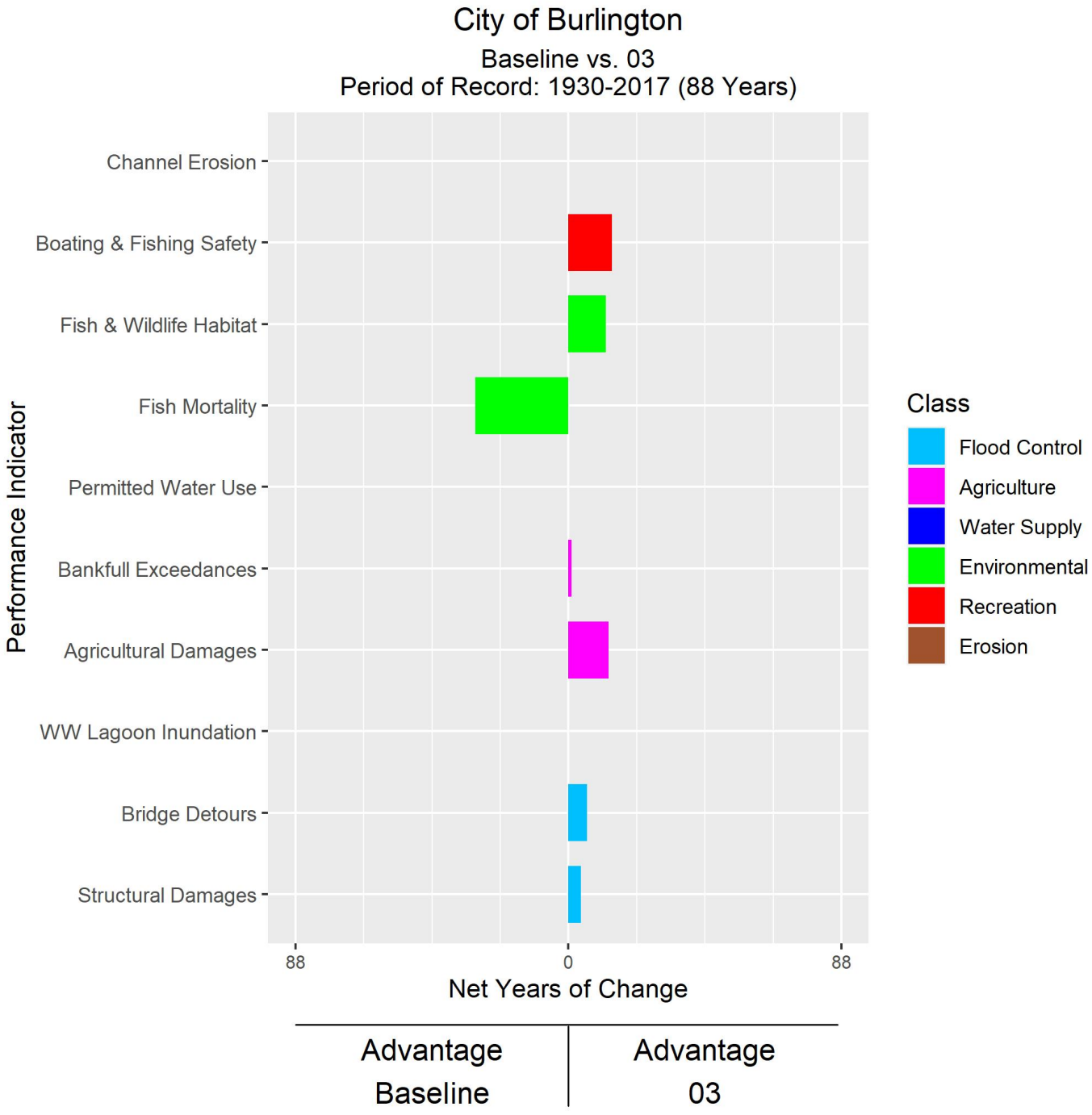

Roche Percee to Moose Mountain Creek
Baseline vs. 03
Period of Record: 1930-2017 (88 Years)
Performance Indicator
Historic Site Preservation
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
Oil Well Inundation
Bridge Inundation
Structural Damages
88
0
88
Net Years of Change
Advantage Baseline
Advantage 03
Class
Flood Control
Agriculture
Water Supply
Cultural

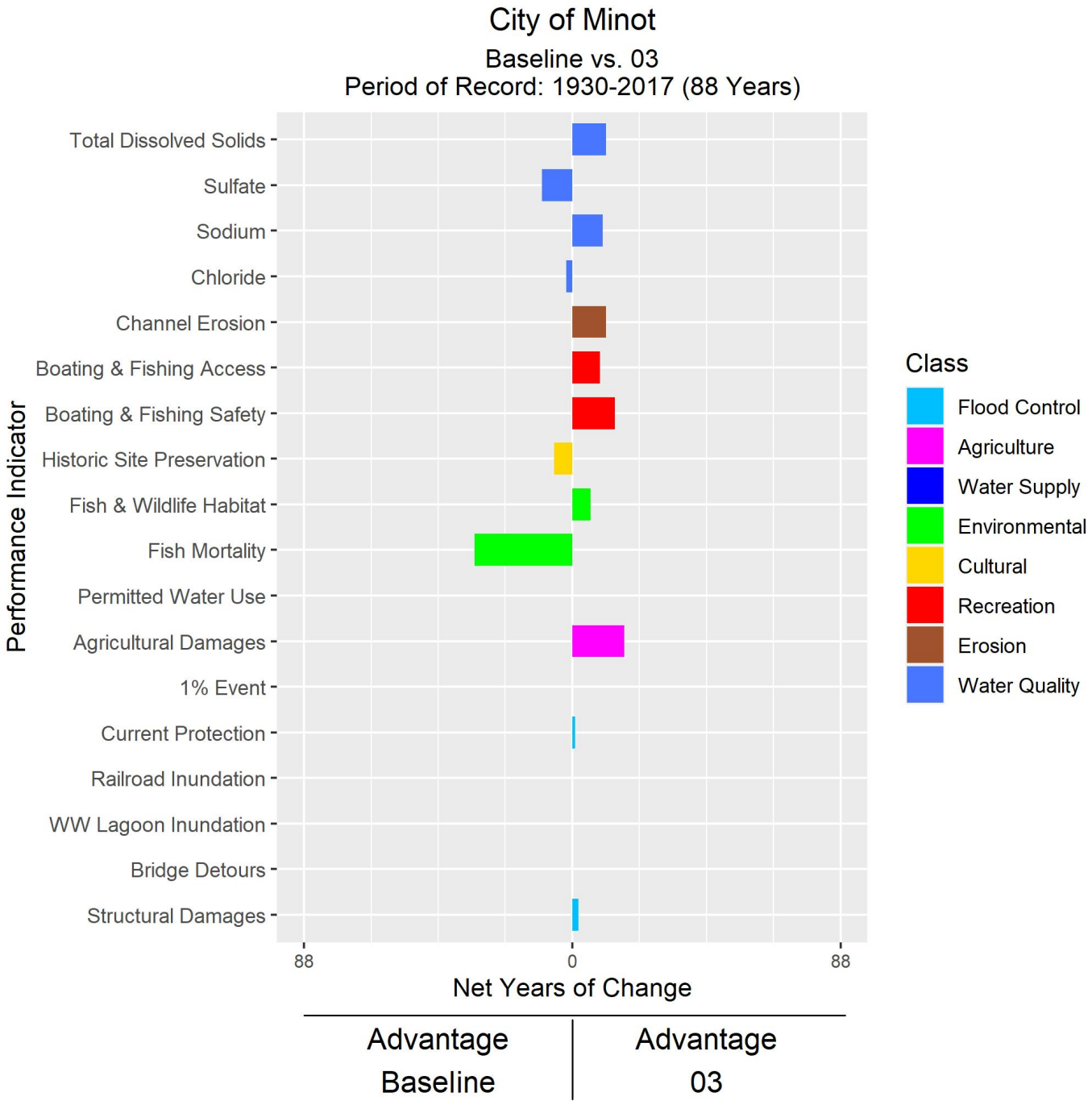

Moose Mountain Creek to Sherwood
Baseline vs. 03
Period of Record: 1930-2017 (88 Years)
Performance Indicator
Historic Site Preservation
Fish Habitat
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
Oil Well Inundation
Bridge Inundation
Structural Damages
88
0
88
Net Years of Change
Advantage
Baseline
Advantage
03
Class
Flood Control
Agriculture
Water Supply
Environmental
Cultural

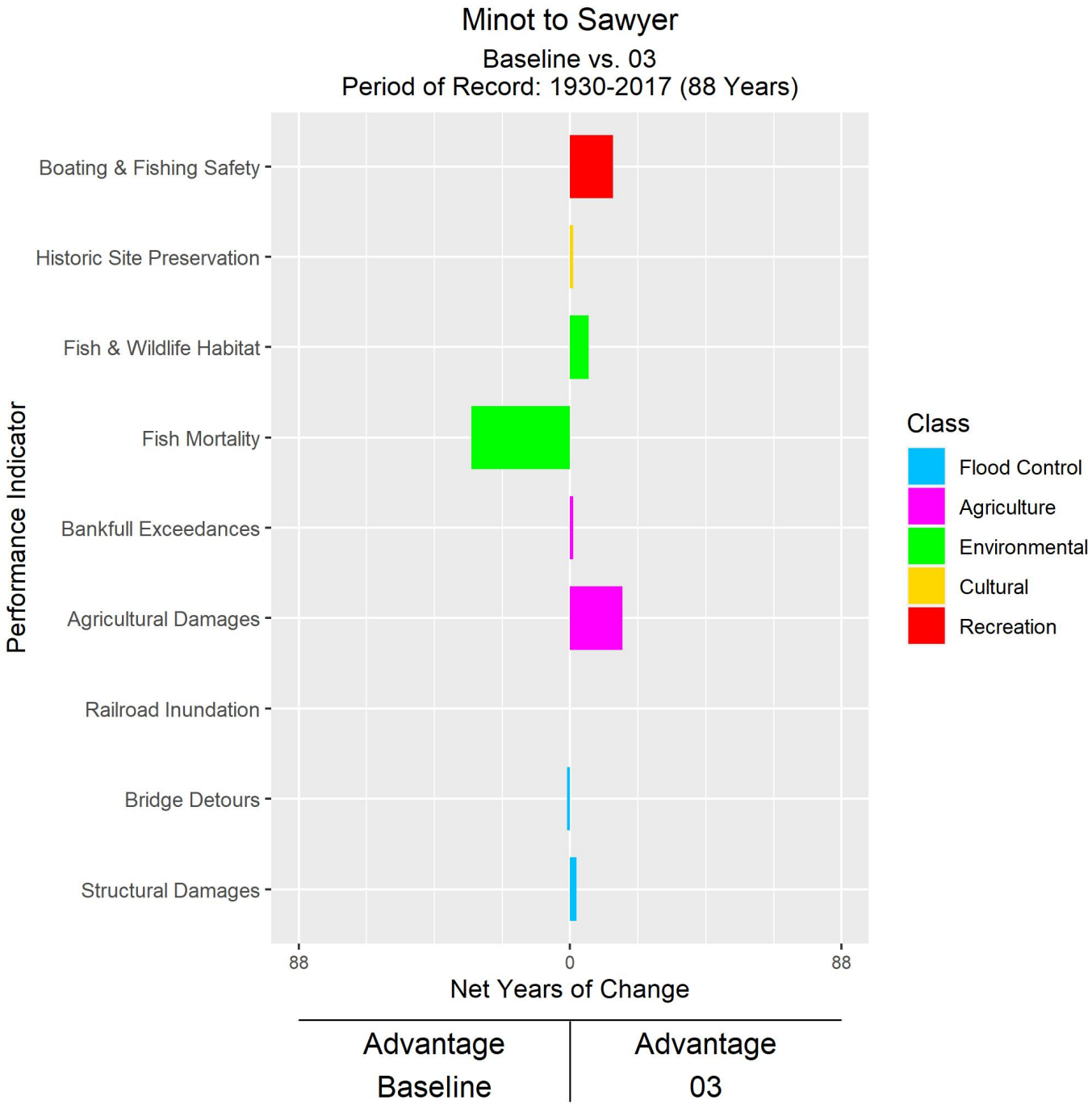

Sherwood to Mouse River Park
Baseline vs. 03
Period of Record: 1930-2017 (88 Years)
Performance Indicator
Total Dissolved Solids
Sulfate
Sodium
Chloride
Channel Erosion
Boating & Fishing Safety
Historic Site Preservation
Fish & Wildlife Habitat
Fish Mortality
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
Bridge Detours
Structural Damages
88
0
88
Net Years of Change
Advantage
Baseline
Advantage
03
Class
Flood Control
Agriculture
Water Supply
Environmental
Cultural
Recreation
Erosion
Water Quality

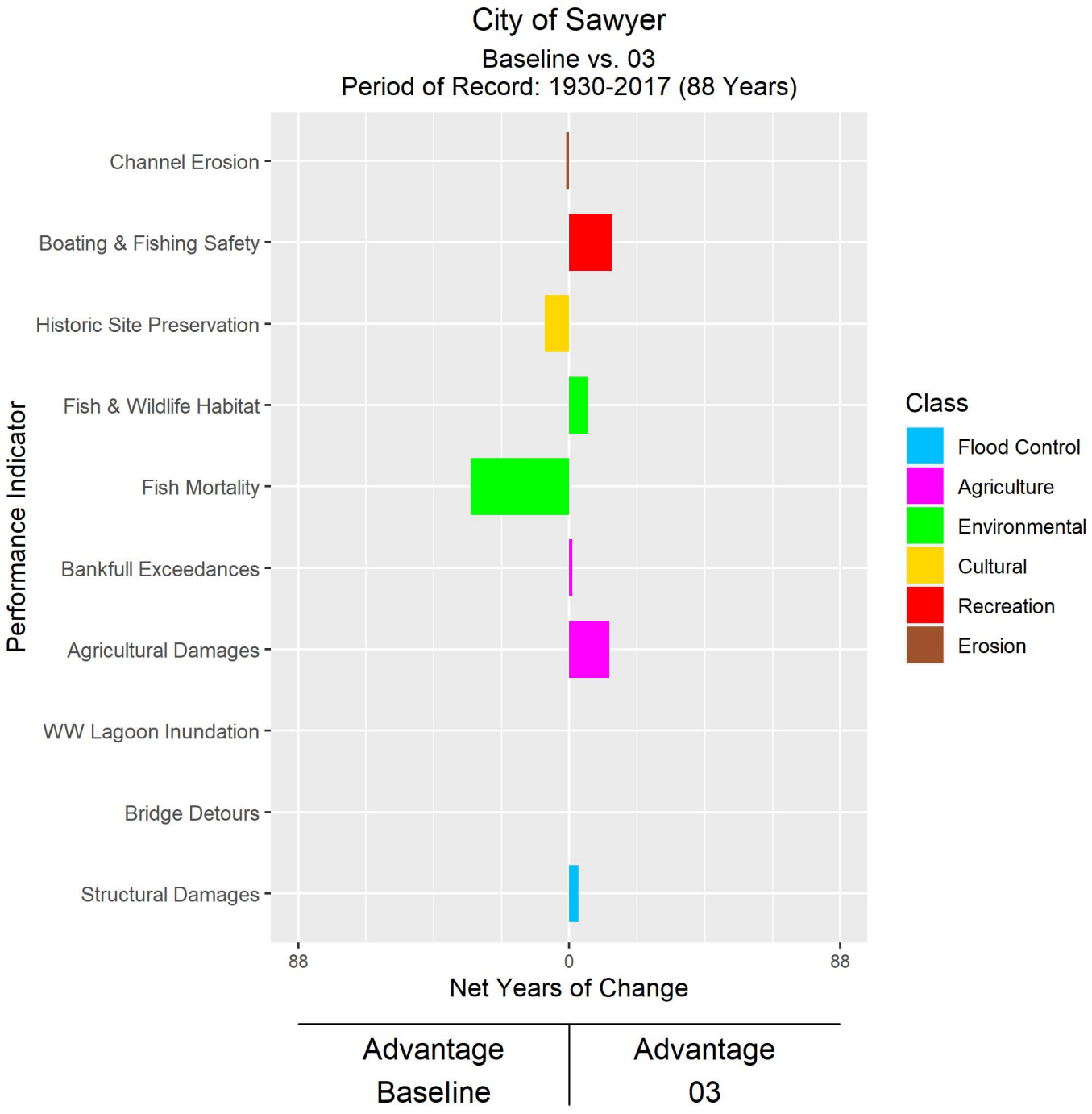

Mouse River Park
Baseline vs. 03
Period of Record: 1930-2017 (88 Years)
Performance Indicator
Boating & Fishing Access
Boating & Fishing Safety
Historic Site Preservation
Fish & Wildlife Habitat
Fish Mortality
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
Bridge Detours
Structural Damages
88
0
88
Net Years of Change
Advantage Baseline
Advantage 03
Class
Flood Control
Agriculture
Water Supply
Environmental
Cultural
Recreation

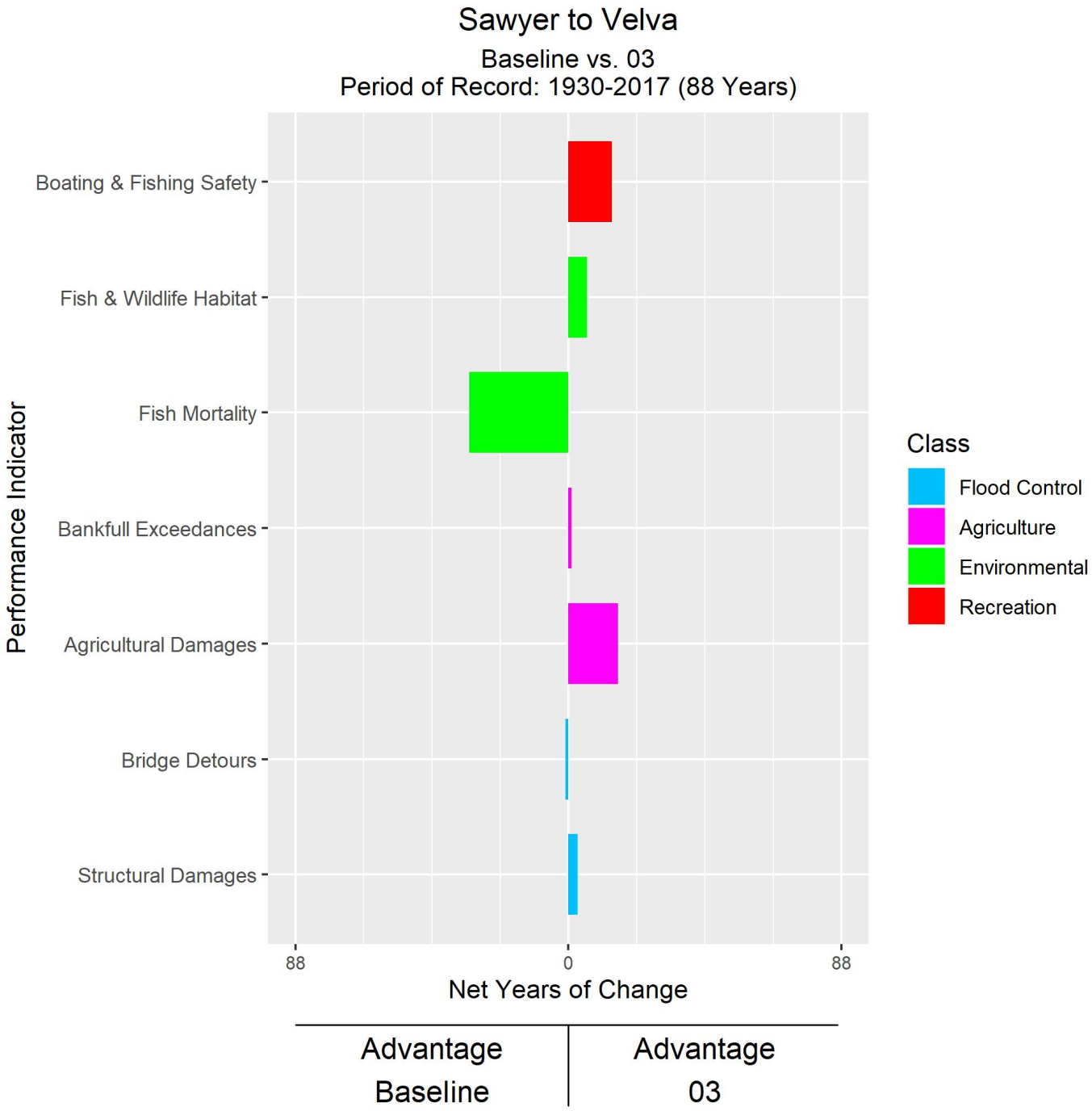

Lake Darling to Burlington
Baseline vs. 03
Period of Record: 1930-2017 (88 Years)
Performance Indicator
Channel Erosion
Boating & Fishing Access
Boating & Fishing Safety
Historic Site Preservation
Fish & Wildlife Habitat
Fish Mortality
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
Bridge Detours
Structural Damages
88
0
88
Net Years of Change
Advantage
Baseline
Advantage
03
Class
Flood Control
Agriculture
Water Supply
Environmental
Cultural
Recreation
Erosion

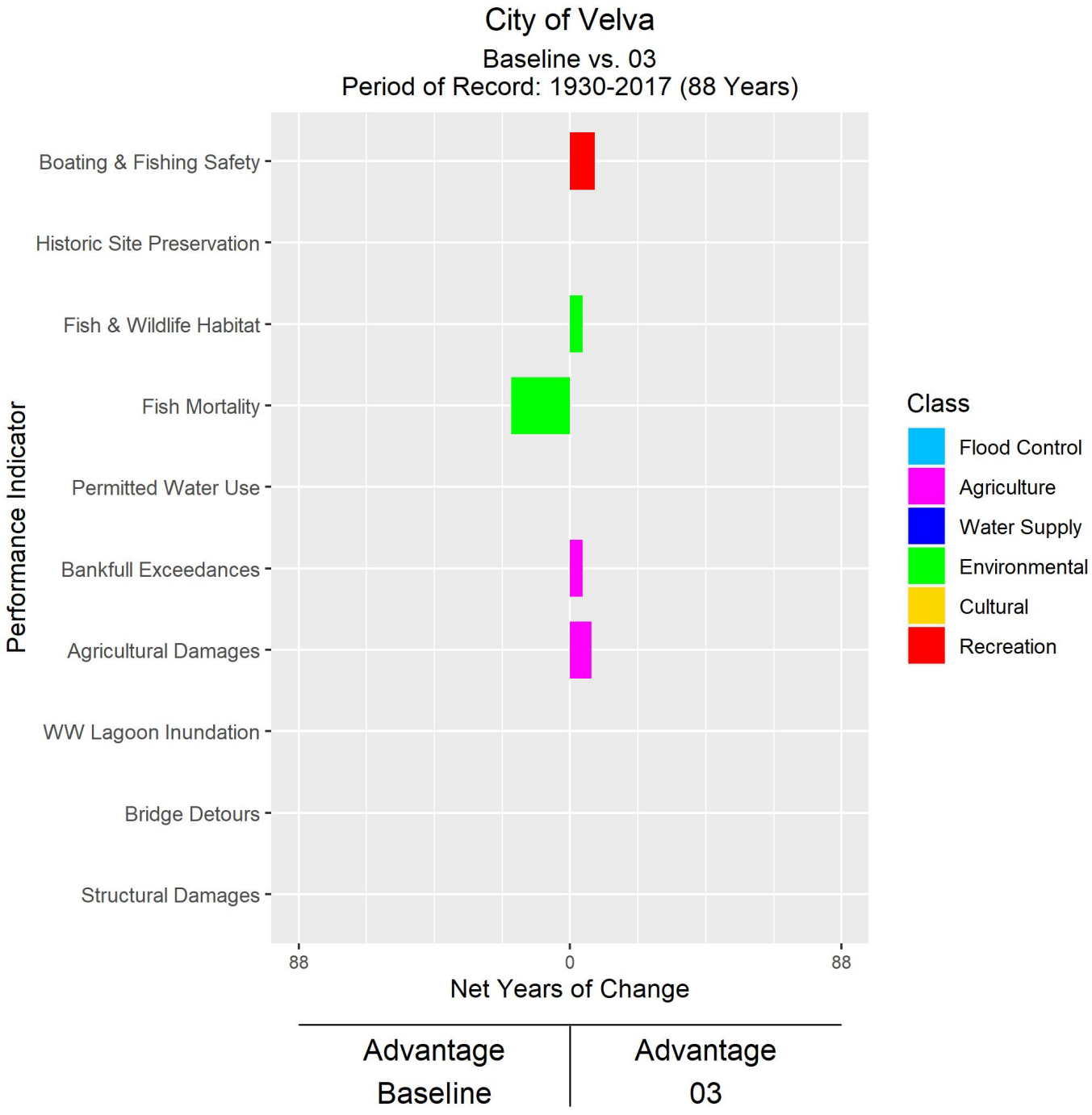

City of Burlington
Baseline vs. 03
Period of Record: 1930-2017 (88 Years)
Performance Indicator
Channel Erosion
Boating & Fishing Safety
Fish & Wildlife Habitat
Fish Mortality
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
WW Lagoon Inundation
Bridge Detours
Structural Damages
88
0
88
Net Years of Change
Advantage Baseline
Advantage 03
Class
Flood Control
Agriculture
Water Supply
Environmental
Recreation
Erosion

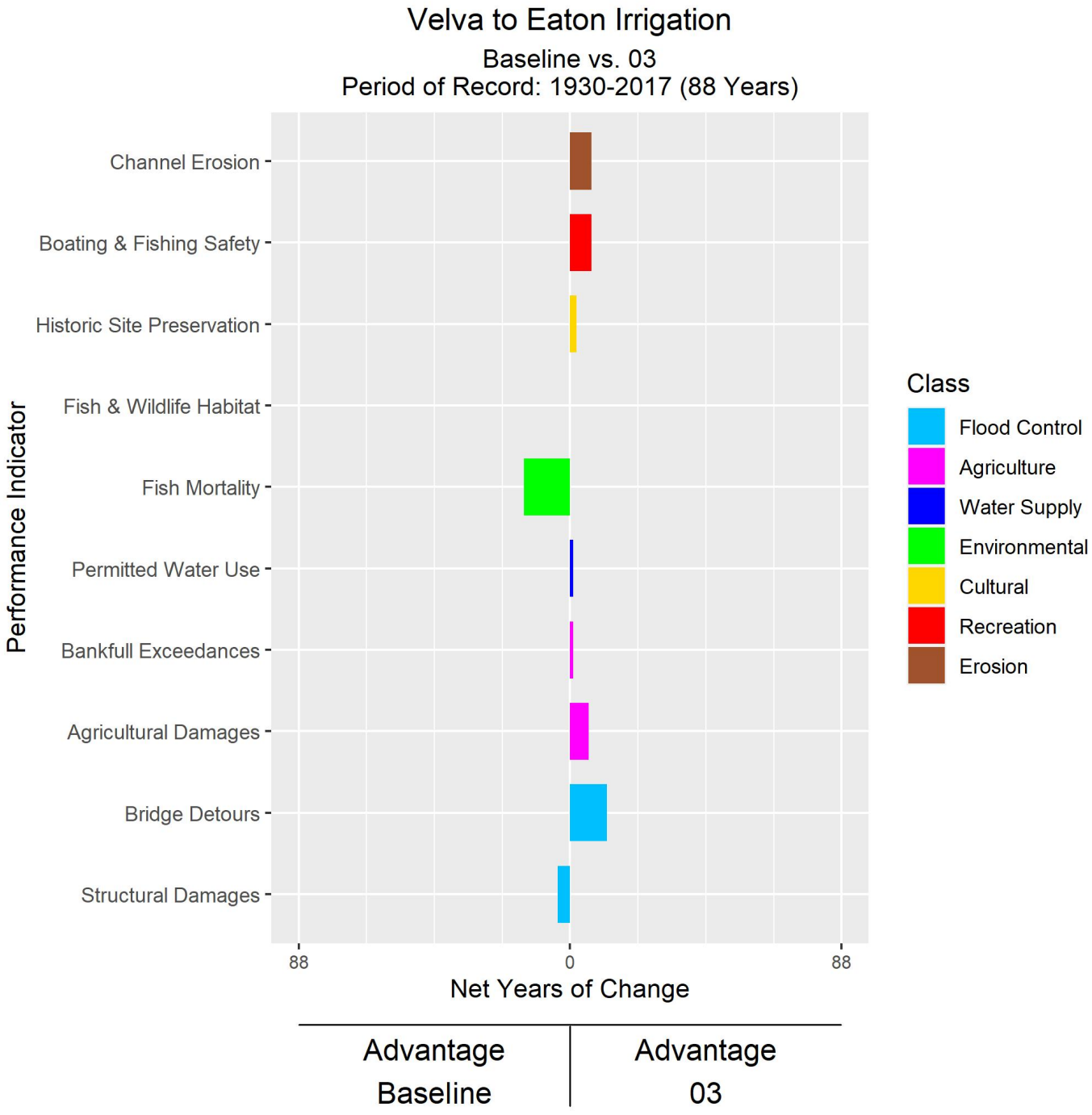

City of Minot
Baseline vs. 03
Period of Record: 1930-2017 (88 Years)
Performance Indicator
Total Dissolved Solids
Sulfate
Sodium
Chloride
Channel Erosion
Boating & Fishing Access
Boating & Fishing Safety
Historic Site Preservation
Fish & Wildlife Habitat
Fish Mortality
Permitted Water Use
Agricultural Damages
1% Event
Current Protection
Railroad Inundation
WW Lagoon Inundation
Bridge Detours
Structural Damages
88
0
88
Net Years of Change
Advantage Baseline
Advantage 03
Class
Flood Control
Agriculture
Water Supply
Environmental
Cultural
Recreation
Erosion
Water Quality

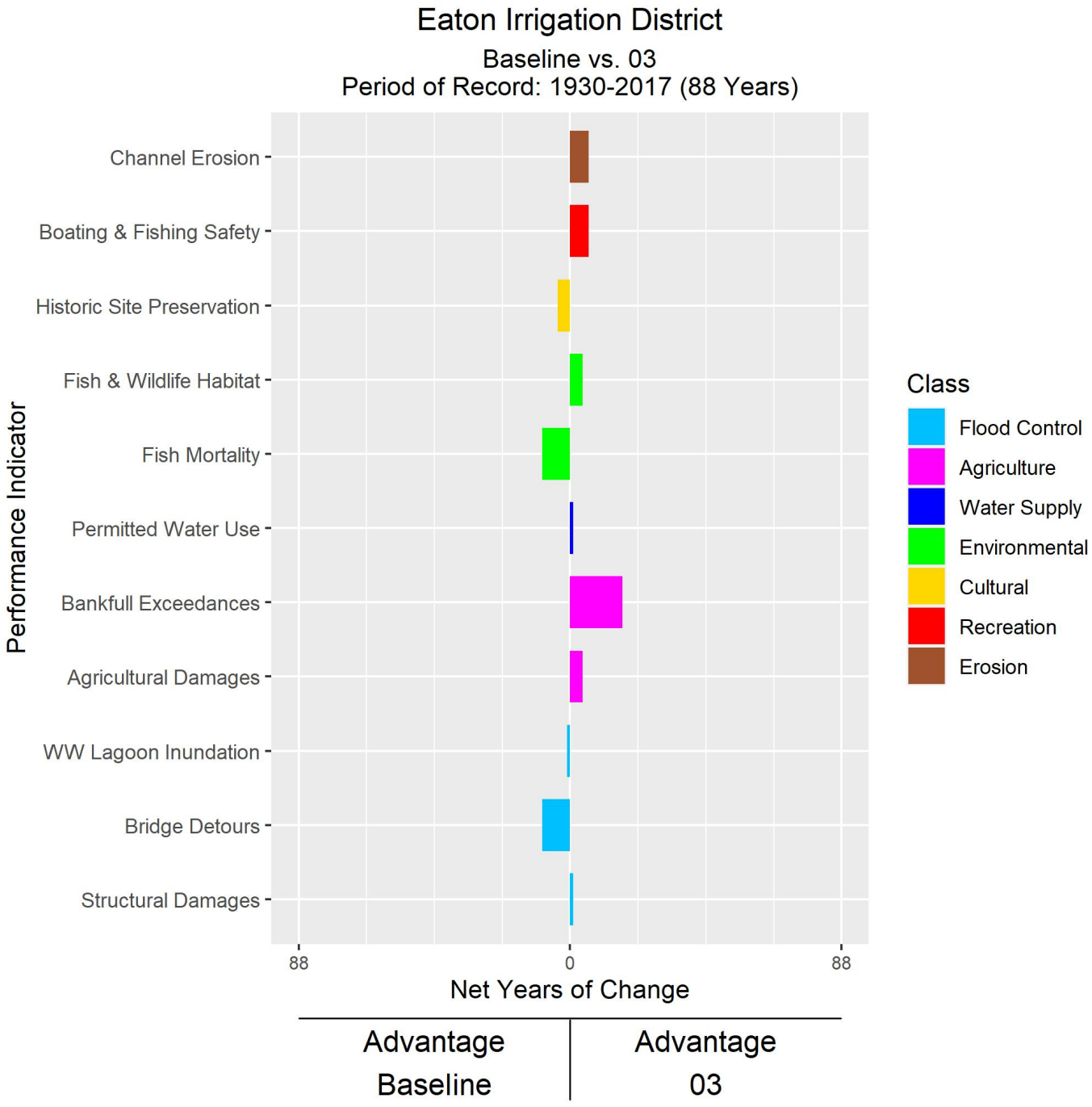

Minot to Sawyer
Baseline vs. 03
Period of Record: 1930-2017 (88 Years)
Performance Indicator
Boating & Fishing Safety
Historic Site Preservation
Fish & Wildlife Habitat
Fish Mortality
Bankfull Exceedances
Agricultural Damages
Railroad Inundation
Bridge Detours
Structural Damages
88
0
88
Net Years of Change
Advantage
Baseline
Advantage
03
Class
Flood Control
Agriculture
Environmental
Cultural
Recreation

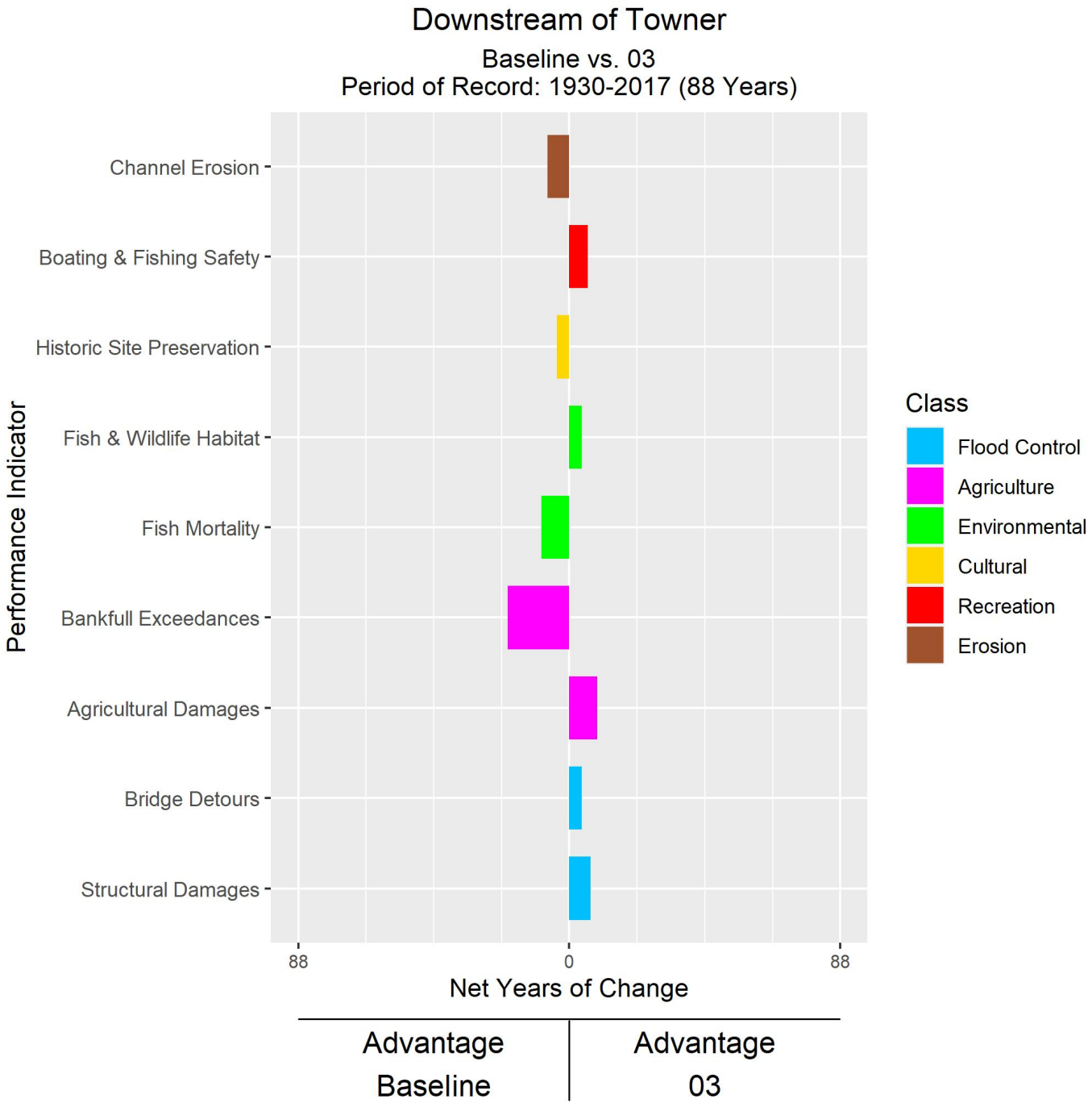

City of Sawyer
Baseline vs. 03
Period of Record: 1930-2017 (88 Years)
Performance Indicator
Channel Erosion
Boating & Fishing Safety
Historic Site Preservation
Fish & Wildlife Habitat
Fish Mortality
Bankfull Exceedances
Agricultural Damages
WW Lagoon Inundation
Bridge Detours
Structural Damages
88
0
88
Net Years of Change
Advantage
Baseline
Advantage
03
Class
Flood Control
Agriculture
Environmental
Cultural
Recreation
Erosion

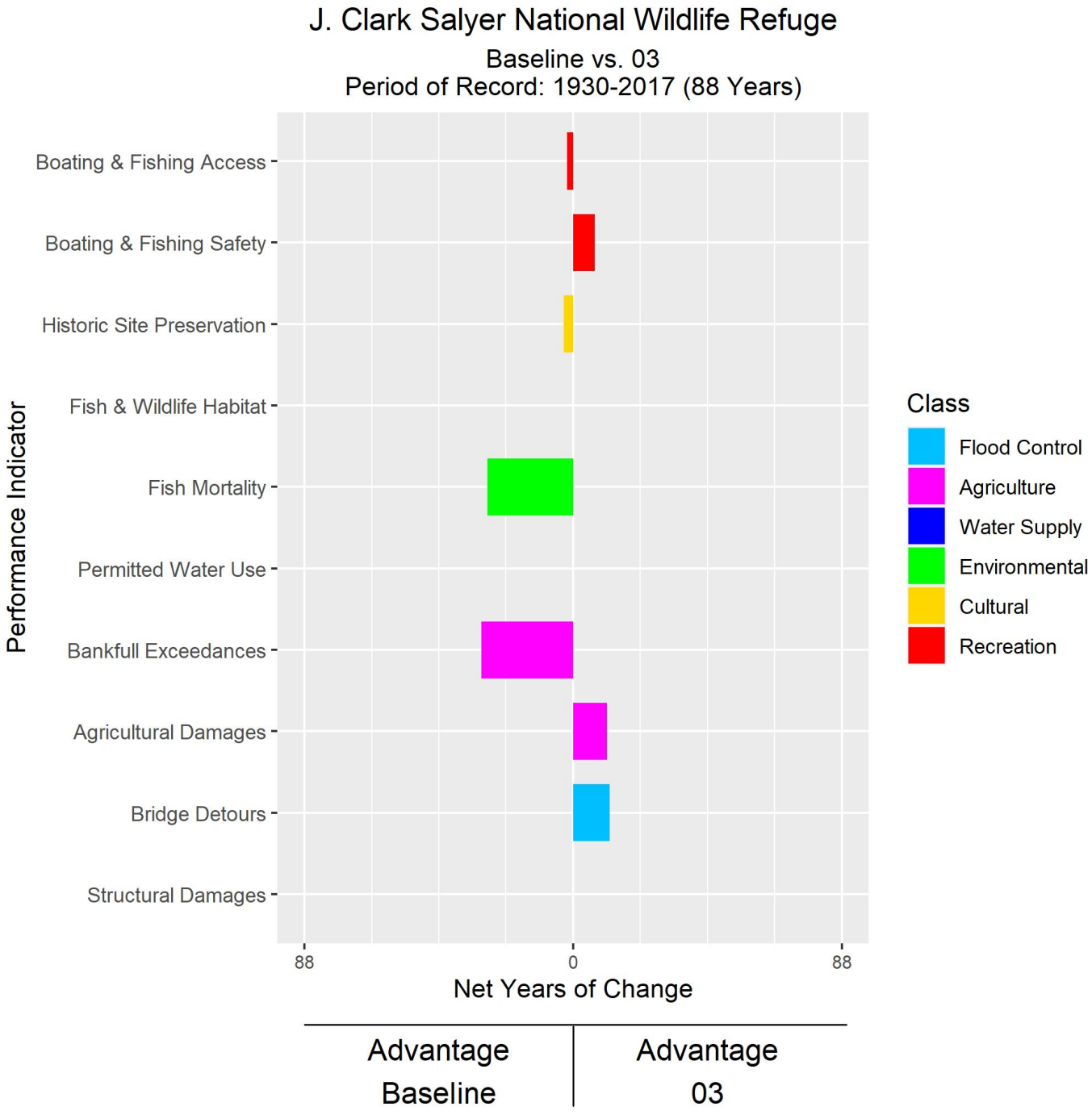

Sawyer to Velva
Baseline vs. 03
Period of Record: 1930-2017 (88 Years)
Performance Indicator
Boating & Fishing Safety
Fish & Wildlife Habitat
Fish Mortality
Bankfull Exceedances
Agricultural Damages
Bridge Detours
Structural Damages
88
0
88
Net Years of Change
Advantage Baseline
Advantage 03
Class
Flood Control
Agriculture
Environmental
Recreation


City of Velva
Baseline vs. 03
Period of Record: 1930-2017 (88 Years)
Performance Indicator
Boating & Fishing Safety
Historic Site Preservation
Fish & Wildlife Habitat
Fish Mortality
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
WW Lagoon Inundation
Bridge Detours
Structural Damages
88
0
88
Net Years of Change
Advantage Baseline
Advantage 03
Class
Flood Control
Agriculture
Water Supply
Environmental
Cultural
Recreation


Velva to Eaton Irrigation
Baseline vs. 03
Period of Record: 1930-2017 (88 Years)
Performance Indicator
Channel Erosion
Boating & Fishing Safety
Historic Site Preservation
Fish & Wildlife Habitat
Fish Mortality
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
Bridge Detours
Structural Damages
88
0
88
Net Years of Change
Advantage Baseline
Advantage 03
Class
Flood Control
Agriculture
Water Supply
Environmental
Cultural
Recreation
Erosion


Eaton Irrigation District
Baseline vs. 03
Period of Record: 1930-2017 (88 Years)
Performance Indicator
Channel Erosion
Boating & Fishing Safety
Historic Site Preservation
Fish & Wildlife Habitat
Fish Mortality
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
WW Lagoon Inundation
Bridge Detours
Structural Damages
88
0
88
Net Years of Change
Advantage Baseline
Advantage 03
Class
Flood Control
Agriculture
Water Supply
Environmental
Cultural
Recreation
Erosion


Downstream of Towner
Baseline vs. 03
Period of Record: 1930-2017 (88 Years)
Performance Indicator
Channel Erosion
Boating & Fishing Safety
Historic Site Preservation
Fish & Wildlife Habitat
Fish Mortality
Bankfull Exceedances
Agricultural Damages
Bridge Detours
Structural Damages
88
0
88
Net Years of Change
Advantage Baseline
Advantage 03
Class
Flood Control
Agriculture
Environmental
Cultural
Recreation
Erosion


J. Clark Salyer National Wildlife Refuge
Baseline vs. 03
Period of Record: 1930-2017 (88 Years)
Performance Indicator
Boating & Fishing Access
Boating & Fishing Safety
Historic Site Preservation
Fish & Wildlife Habitat
Fish Mortality
Permitted Water Use
Bankfull Exceedances
Agricultural Damages
Bridge Detours
Structural Damages
88
0
88
Net Years of Change
Advantage Baseline
Advantage 03
Class
Flood Control
Agriculture
Water Supply
Environmental
Cultural
Recreation