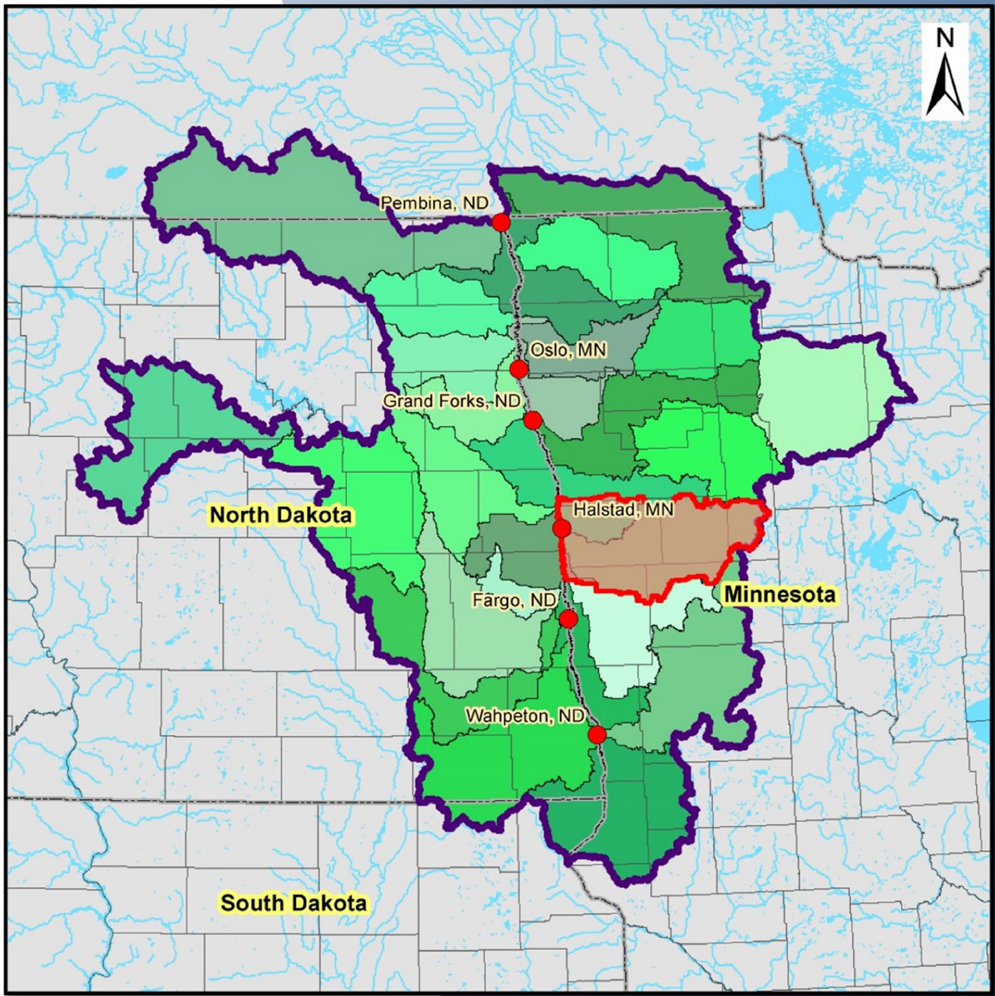
Wild Rice Watershed District
Expanded Distributed Detention Strategy



Prepared for the Wild Rice Watershed District & Red River Watershed Management Board by:

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WILD RICE WATERSHED DISTRICT
EXPANDED DISTRIBUTED DETENTION STRATEGY

Prepared on behalf of:

Wild Rice Watershed District
Red River Watershed Management Board

September 23, 2013

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I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the State of Minnesota.

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EXECUTIVE SUMMARY

Efforts to develop comprehensive flood water detention plans for are being developed throughout the United States portion of the Red River Basin. These planning efforts establish benefit to local damage centers as well as reduction in contribution to the Red River main stem. Planning efforts are largely funded through the Red River Watershed Management Board for Watershed Districts contributing to the MN portion of the Red River Basin and by the North Dakota Joint Red River Water Resource District and the North Dakota State Water Commission for subwatersheds within the ND portion of the Red River Basin. This report summarizes methodology and outcomes of the Wild Rice Watershed District (WRWD) Expanded Distributed Detention Strategy, funded by the Red River Watershed Management Board (RRWMB). The WRWD Expanded Distributed Detention Strategy identifies flood water detention locations aimed at meeting peak flow and volume reduction goals specified in the Red River Basin Commission's (RRBC) Long Term Flood Solutions (LTFS) Basinwide Flow Reduction Strategy Report. This report sets forth a strategy that would alleviate the flood risk throughout the basin by reducing the flood volume enough to provide a 20% peak flow reduction on the Red River main stem.

The WRWD has successfully implemented various flood water impoundment locations within the Watershed District. These impoundments currently provide a total of 2,200 acre-feet of gated storage and 11,900 acre-feet of ungated storage. Since peak flow and volume reduction goals specified in the LTFS Basinwide Flow Reduction Strategy are based on the 1997 spring flood event, storage implemented after the 1997 event are included towards meeting these goals. Of the total storage provided by existing impoundments in WRWD, only the Lockhart Project was implemented after the 1997 spring flood event, and provides approximately 280 acre-feet ungated storage.

The WRWD Expanded Distributed Detention Strategy identifies locations where runoff could be detained on the landscape in an effort to meet peak flow and volume reduction goals specified in the RRBC LTFS Basinwide Flow Reduction Strategy. Selected locations generally correlate to topography that allows three to four inches of gated runoff storage across a contributing area of twenty square miles or more. In total, 25 locations were evaluated during this analysis. These locations provide a total gated storage capacity of approximately 155,600 acre-feet, or 2.3 inches, across 1,249 square miles.

Detention locations identified as part of this study were incorporated into the HEC-HMS hydrologic model and compared to conditions that existed during the 1997 event. Both the 1997 conditions and the proposed conditions were analyzed using the Red River Basin Standardized Melt Progression Event, and indicated that the proposed detention strategy generally met or exceeded volume tributary reductions specified in the RRBC LTFS Basinwide Flow Reduction Strategy. However, peak flow recommendations along the Wild Rice River at Hendrum, MN were not met due to the high amount of floodplain storage that attenuates peak flows along lower portions of the Wild Rice River. As a result, the WRWD was further analyzed with the addition of a Wild Rice River on-channel location. The addition of this on-channel location resulted in peak flow reductions along the Wild Rice River meeting peak flow reduction goals specified in the LTFS Basinwide Flow Reduction Strategy.

1 INTRODUCTION

1.1 RED RIVER BASIN BACKGROUND

The Red River Basin encompasses 49,000 square miles across portions of three states (Minnesota, North Dakota and South Dakota) and one Canadian province (Manitoba). These jurisdictions are further divided into individual Watershed Districts (MN), individual Water Resource Districts (ND) and various governing bodies within Manitoba. Historically, each jurisdiction has generally focused on solving their own flooding problems with limited knowledge of the cumulative impact of their individual projects or programs. Over the years, organizations have been formed to address this issue such as the Red River Watershed Management Board in Minnesota, the Red River Joint Water Resource District in North Dakota, and the Red River Basin Commission. While there have been many success stories that have had a beneficial impact to the entire basin, flooding is still a major problem. In response to a demand to reduce flood damages experienced in the Red River Basin from both MN and ND, the RRBC began the Long Term Flood Solutions report to outline recommendations to reduce the flood risk within the Red River Basin. As part of this process, peak flow and runoff volume reduction goals were established to reduce Red River main stem flooding by twenty percent. The study utilized a Mike 11 flood routing model of the 1997 flood that had been developed previously. These goals were determined by manually modifying 1997 spring flood inflow hydrographs for the Red River Main Stem Mike 11 model. Tributary goals were then summarized in the Red River Basin Commission's Long Term Flood Solutions Basinwide Flow Reduction Strategy Report. Wild Rice River Watershed goals were established to be a 35% peak flow reduction and 20% overall volume reduction. The Marsh River Watershed is also within the WRWD, with LTFS goals of 51% peak flow reduction and 18% overall volume reduction. The WRWD also contains portions of the Halstad Ungaged area and Red Lake River Ungaged area, as defined in the RRBC LTFS. The assigned reductions for these areas were 13% and 12% peak flow reductions and 13% and 10% volume reductions, respectively.

Since completion of the RRBC Long Term Flood Solutions report, new modeling capabilities have become available to analyze potential benefit of flood damage reduction projects within the Red River Basin. Hydrologic models have been developed across the Red River Basin utilizing HEC-HMS software. Standardized procedures for model development and calibration were developed and utilized in creating tributary hydrologic models. Consistency was also attained by utilizing the Red River Basin-wide LiDAR topography data acquired through the International Water Institute's Red River Basin Mapping Initiative. Initial hydrologic model development was funded by the USACE and the communities of Fargo, ND and Moorhead, MN.

In addition, other ongoing efforts have also led to the development of a detailed hydraulic model for the main stem of the Red River. Currently, the model extends from near the White Rock Dam on the upstream end (south), to Emerson, Manitoba on the downstream end (north). This hydraulic model, developed using HEC-RAS software, utilizes unsteady flow hydraulic routing methods to account for the large amount of floodplain storage that occurs on the landscape adjacent to the Red River main stem during large flood events. A combination of field survey and bathymetry elevation information was used to derive channel geometry for the Red River, and was combined with LiDAR topography information to determine floodplain geometry and storage characteristics.

The HEC-HMS models are currently being used throughout the Red River Basin to identify and evaluate potential flood water detention locations. The Red River Watershed Management Board (RRWMB) is funding development of expanded detention strategies for the Minnesota portion of the Red River Basin. Additionally, the North Dakota

Red River Joint Water Resource District (NDRRJWRD), along with cooperation from the North Dakota State Water Commission (NDSWC) and South East Cass Water Resource District, is funding an effort to develop Comprehensive Detention Plans for the ND portion of the Red River Basin.

1.2 WILD RICE RIVER WATERSHED DISTRICT BACKGROUND

The WRWD is located in the southern portion of the Red River Basin and is within the State of Minnesota, as illustrated in **Figure 1**. The WRWD consists of approximately 1,569 square miles of the Wild Rice River Basin, 368 square miles of the Marsh River Basin, and 77 square miles that drains directly to the Red River. Additionally, the WRWD contains an adjacent 69 square miles considered to be non-contributing (closed) basins. A map of the WRWD is presented in **Figure 2**. Topography within the WRWD is characterized as extremely flat in the west to rolling hills with lakes and wetland areas in the east. Land use varies from predominantly agricultural activities in western portions of the district to predominantly forested lands in eastern portions of the district.

1.3 SCOPE AND PURPOSE

Development of the WRWD Expanded Distributed Detention Strategy first involved identifying areas of the watershed that are conducive to storing runoff on the landscape. This involved review of LiDAR data, the International Water Institute's Project Planning tools, and consultation with WRWD staff. Additionally, flood water detention locations previously identified and/or under investigation by the WRWD were included in the analysis. Ideal locations were generally considered to have topographic characteristics exhibiting capacity for three to four inches of gated storage of runoff from twenty or more square miles contributing to the impoundment. Runoff volumes greater than the gated storage capacity were assumed to by-pass the flood water detention location.

Identified flood water detention locations were incorporated in the HEC-HMS hydrologic model of the WRWD. The hydrologic model was then used to determine if selected locations met volume and peak flow reduction percentages outlined in the RRBC LTFS Basinwide Flow Reduction Strategy. These volume and peak flow recommendations were developed in comparison to the 1997 spring flood event based on conditions existing at that time. Runoff storage provided by the Lockhart Project was implemented after the 1997 spring flood event, and was counted towards meeting RRBC LTFS peak flow and volume reduction goals. Synthetic hydrology developed as part of the Red River Basin Commission Standardized Melt Progression Analysis was used to calculate peak flow reductions and volume reduction benefits. This event utilizes 100-year runoff depths described in NRCS's Technical Release No. 60 publication. Additional details of this hydrology are included in Section 3.3.

Potential flood water detention locations identified as part of this planning effort are not intended to dictate specific impoundment sites for development of future projects. Rather, the analysis was intended to indicate the net effect of detaining flood waters at various locations within the WRWD. It is anticipated that the WRWD, working through the Project Team Mediation Agreement, will further pursue and optimize flood water detention in general locations outlined in this report to develop and optimize the actual impoundment site locations.

2 FLOOD WATER DETENTION LOCATION SELECTION

2.1 EXISTING FLOOD WATER DETENTION LOCATIONS

Several flood water impoundment locations have been implemented within the WRWD. **Table 1** summarizes the available storage and drainage area characteristics of the existing impoundments. In total, existing locations provide approximately 2,200 acre-feet of gated storage capacity and 11,900 acre-feet of ungated storage capacity. **Figure 2** illustrates the locations and the associated drainage areas of the existing flood water impoundment locations. The Lockhart Project was implemented after the 1997 spring flood event, and thus are included towards meeting LTFS Basinwide Flow Reduction Strategy goals. The focus of this planning effort is to reduce severe flooding within the Red River Basin typically associated with spring snow melt events, thus spring operation procedures were assumed for all existing impoundments.

2.2 INTERNATIONAL WATER INSTITUTE – PROJECT PLANNING TOOL

To assist in identifying areas to store runoff, the International Water Institute's Project Planning Tool was used. The Project Planning Tool provided a hypothetical analysis to illustrate the runoff storage potential if all roads within the watershed were raised. Utilizing LiDAR data, the analysis indicates the resultant flood pool, the available storage, and the contributing watershed. These locations were reviewed to assist in selecting areas of the watershed conducive to detaining flood water.

The International Water Institute's Project Planning Tool was also utilized to evaluate environmental obstacles associated with flood water detention locations through the Permit Complexity layer. This GIS layer provides information on the general level of difficulty associated with regulatory permitting and review.

2.3 SELECTION CRITERIA

Prior to this planning effort, selection criteria was developed for locating areas to detain runoff. The primary criteria was that locations should have the ability to detain three to four inches of runoff from a minimum of twenty square miles, wherever possible. This criterion was utilized to limit the number of detention locations needing analysis, while still identifying realistic locations where the topography suggests impoundments could be constructed with sufficient gated storage capacity.

The International Water Institute's Project Planning Tool aided in identifying initial locations on the landscape for flood water detention. Once general areas were identified, embankment alignments were developed to minimize or eliminate potential structural impacts to rural residences and farming operations based on review of aerial photography and LiDAR data. Locations of cut-off ditches for off-channel flood water detention locations were also evaluated with the aid of LiDAR data to ensure flood waters could be diverted into potential impoundments at a reasonable gradient and depth of required cut to construct.

The WRWD had previously identified several potential flood water detention locations within the Watershed District. These locations were further reviewed, optimized with the aid of LiDAR information, included in the WRWD Expanded Distributed Detention Strategy wherever practical.

2.4 SUMMARY OF SELECTED LOCATIONS

In total, 25 locations meeting the general criteria previously described were selected during this planning effort. In total, these locations would provide a gated storage capacity of approximately 155,600 acre-feet, or 2.3 inches, across 1,249 square miles. In addition, a Wild Rice main stem location was also included as part of this planning effort. While this location was not assumed to provide any additional gate storage capacity, it was assumed to provide approximately 20,400 acre-feet of ungated storage. The additional site was required to achieve the desired peak flow reductions. The contributing areas to the evaluated detention locations as well as existing impoundment locations are illustrated on **Figure 3**. Runoff storage potential is provided in on **Table 2**.

3 HYDROLOGIC ANALYSIS

The identified potential flood water detention locations were incorporated into the WRWD HEC-HMS hydrologic model. This encompasses approximately 2083 square miles contributing to the Red River Basin, and was previously developed by the US Army Corps of Engineers.

3.1 MODIFICATIONS TO EXISTING CONDITIONS

The existing conditions HEC-HMS model was modified as necessary to provide a more accurate comparison between existing and proposed conditions. Subbasins were divided at critical locations such as at outlet structures and/or diversion inlet locations for off channel sites. At locations where subbasins were required to be split, HEC-HMS reach routing variables were also adjusted. The existing conditions HEC-HMS model utilized the Modified Puls and Muskingum Cunge routing methods for all reach routing elements. Storage/Outflow relationships used for Modified Puls routing in the baseline HEC-HMS model were assigned proportional to reach length for the split reaches. Split reaches using Muskingum Cunge methods required slope and typical cross sections to be derived from LiDAR data. Muskingum Cunge routing methods were utilized in instances where new reaches were required. This new modified existing conditions model was validated with the baseline calibrated model by comparing the results of the TR-60 Melt Progression scenario.

3.2 DEVELOPMENT OF PROPOSED CONDITIONS

Storage information for the identified flood water detention locations was derived from LiDAR data and incorporated into the HEC-HMS model to develop a proposed conditions modeling scenario. GIS Terrain Analysis techniques were used to determine alterations to subbasin boundaries and reach alignments as a result of constructing embankments and excavating diversion ditches for each of the sites. HEC-HMS model parameters for proposed conditions were derived in a consistent manner as was used for existing conditions model development.

For simplicity, all flood water detention locations were assumed to operate with a full drawdown, or dry, initial condition. Locations where runoff is proposed to be diverted from natural water courses were assumed to allow a base flow within those systems before excess runoff was diverted out of the channel and into the impoundment locations. Runoff diverted from legal ditches and intermittent watercourses was assumed to collect all runoff reaching the cut-off channel diverted into the impoundment location. When the diverted runoff volume exceeded the available gated storage within the impoundment, additional runoff was allowed to outflow from the site and continue downstream. This same “fill and spill” methodology was assumed for the analysis of all selected detention locations.

3.3 RED RIVER BASIN STANDARDIZED MELT PROGRESSION EVENT

To more accurately simulate a synthetic spring melt condition within the US portion of the Red River Basin, the Red River Basin Commission completed an analysis in early 2013. This analysis utilized temperature data at observation locations throughout the Red River Basin to estimate when snowmelt conditions generally occur during a typical spring. The results of this virtual thaw progression are illustrated in **Figure 4**. This timing analysis was applied to a 10-day runoff scenario depth illustrated in **Figure 5**. Based on the 10-day runoff scenario shown in

Figure 5, equivalent rainfall depths for the 10-day runoff were developed using the composite 24-hour NRCS curve number for the portion of the Red River Basin upstream of Halstad, MN. This composite 24-hour curve number was found to be approximately 73. The resultant equivalent rainfall depths are illustrated in **Figure 6**. This equivalent rainfall depth was then applied using the Minnesota Principal Spillway Temporal Rainfall Distribution, as defined in the Minnesota Hydrology Guide. This temporal distribution is illustrated in **Figure 7**. Start time for the rainfall was set by the Virtual Thaw Progression (**Figure 4**) at each respective location. This information was developed in a manner to allow application via the gridded precipitation meteorological option within HEC-HMS. Gridded precipitation allows for each subbasin to depict a unique temporal distribution and total depth depending on its geographic orientation in relation to the Standardized Melt Progression. The resultant Red River Basin Standardized Melt Progression Event was utilized to determine volume and peak flow reduction criteria based on the Long Term Flood Solutions recommendations. For further information regarding the Red River Basin Standardized Melt Progression Event, refer to the *Red River Basin Standardized Melt Progression Event Analysis* Report completed by the Red River Basin Commission, April 2013 (Reference No. 1).

4 RESULTS

4.1 WILD RICE WATERSHED DISTRICT SUMMARY

The WRWD lies within all, or portions of, four areas where runoff volume and peak flow percent reductions are specified within the Red River Basin Commission's Long Term Flood Solutions Basinwide Flow Reduction Strategy Report. The majority of the WRWD is comprised of the gaged tributaries described as *Wild Rice MN @ Hendrum*. Peak flow and volume reduction goals for this region are 35% and 20%, respectively, with an emphasis indicated on peak flow reduction. The second gaged area referenced in the RRBC LTFS within the WRWD is described as *Marsh River near Shelly.* Peak flow and volume reduction goals for this region are 51% and 18%, respectively. Peak flow and runoff volumes experienced along the Marsh River have historically been influenced by breakout flows from the Wild Rice River watershed that occur near the community of Ada, MN. Thus, peak flow and volume reductions along the Marsh River require reductions along the Wild Rice River, as well as conditions influencing the magnitude of breakout flows near Ada, MN. The two remaining areas are specified as *Halstad ungaged* and *Red Lake River ungaged.* These ungaged areas have recommended runoff volume reduction goals of 13% and 10%, respectively, and peak flow reduction goals of 13% and 12%, respectively.

The identified detention locations and existing post-1997 impoundment resulted in a peak flow reduction of 28% and runoff volume reduction of 27% at the USGS Gage on the Wild Rice River at Hendrum, MN (USGS Gage 05064000) when compared with existing conditions. The existing condition flood hydrograph and the hydrograph resulting from implementation of the Expanded Distributed Detention Strategy is provided in **Figure 8**. When comparing results of the USGS Gage on the Marsh River near Shelly, MN (USGS Gage 05067500), the identified locations and existing post-1997 impoundment provided a peak flow reduction of 9% and runoff volume reduction of 44%. Comparison hydrographs at this location provided in **Figure 9**. As discussed previously, peak flow and volume reductions experienced along the Marsh River are largely influenced by the magnitude of breakout flows near the community of Ada, MN. When conditions exist that result in additional breakout flows near Ada, MN (similar to 1997), percent reductions for peak flow and volume along the Marsh River are expected to increase. Additionally, several other hydrograph locations were included to better quantify the benefits of implementing the WRWD Expanded Distributed Detention Strategy. Comparison hydrographs at these locations are provided in **Figures 11-17**. Specific performance statistics for each location during the Red River Basin Standardized Melt Progression Event is illustrated in **Table 3**. Additionally, runoff volume and peak flow reductions at various locations within the WRWD are presented in **Table 4**.

A Wild Rice main-stem storage site was also included in combination with the 25 other identified locations to assist in obtaining the desired peak flow reductions. Since this site was added primarily to reduce peak flows, the storage location was assumed to allow 6,000 CFS to flow through the site before significant attenuation of runoff would occur. This flow rate correlates to approximately a 10-year to 20-year peak discharge. When the main-stem storage was analyzed along with the 25 identified locations, HEC-HMS model results indicated a peak flow reduction of 36% and a total volume reduction of 27% at the USGS Gage on the Wild Rice River at Hendrum, MN. Hydrographs presenting the benefit provided by the Wild Rice main-stem storage option are provided in **Figures 8-11**. Runoff volume and peak flow reductions at various locations within the WRWD are presented in **Table 5**.

4.2 RECOMMENDATIONS

Potential detention locations identified as part of this effort present one possible scenario to reach runoff volume and peak flow reduction goals specified in the Red River Basin Commission's Long Term Flood Solutions Basinwide Flow Reduction Strategy. It is anticipated that this report serve as a framework for the WRWD to assist in providing Red River main stem benefits while pursuing projects that maximize local benefit within the WRWD.

REFERENCES

1. Red River Basin Commission, *Red River Basin Standardized Melt Progression Event Analysis,* April 10, 2013.

2. Red River Basin Commission and Wild Rice Watershed District, *Effect on the 1997 Flood as a Result of Storage Reservoirs in the Wild Rice Watershed District,* November 8, 2010.

3. Red River Basin Commission, *LTFS Basinwide Flow Reduction Strategy,* January 20, 2010.

4. Red River Basin Commission, Long Term Flood Solutions for the Red River Basin, September 2011.

5. U.S. Department of Agriculture, Natural Resources Conservation Service, *Earth Dams and Reservoirs*, Technical Release No. 60, July 2005.

6. U.S. Department of Agriculture, Natural Resources Conservation Service, *Hydrology Guide for Minnesota.*

7. Fargo-Moorhead Metro Basin-Wide Modeling Approach – Hydrologic Modeling, *HEC-HMS Model Development for Various Tributaries above the Red River of the North at Halstad, MN*, December 23, 2011.

Tables

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Table 1
Existing Conditions Flood Water Detention Location Statistics

Site Name	Year Implemented	Drainage Area	Gated Volume	Ungated Volume	Total Volume
Impoundment Locations Constructed Before the 1997 Spring Flood Event					
Marsh Creek Site No. 3	1983	8.1 Mi²	0 Ac-ft *(0")*	285 Ac-ft *(0.7")*	285 Ac-ft *(0.7")*
Moccasin Creek Dam	1982	56.8 Mi²	1,060 Ac-ft *(0.3")*	709 Ac-ft *(0.2")*	1,769 Ac-ft *(0.6")*
Mashaug Dam 34	1984	14.3 Mi²	0 Ac-ft *(0")*	489 Ac-ft *(0.6")*	489 Ac-ft *(0.6")*
Mashaug Dam 151	1980	10.6 Mi²	0 Ac-ft *(0")*	403 Ac-ft *(0.7")*	403 Ac-ft *(0.7")*
Upper Becker	1978	37.8 Mi²	0 Ac-ft *(0")*	2,185 Ac-ft *(1.1")*	2,185 Ac-ft *(1.1")*
Lower Becker*	1978	40.8 Mi²	0 Ac-ft *(0")*	2,615 Ac-ft *(1.2")*	2,615 Ac-ft *(1.2")*
Rockwell	1989	2.0 Mi²	0 Ac-ft *(0")*	211 Ac-ft *(2.0")*	211 Ac-ft *(2.0")*
Northern Improvement	1979	5.3 Mi²	0 Ac-ft *(0")*	113 Ac-ft *(0.4")*	113 Ac-ft *(0.4")*
Lake Ida	1979	7.4 Mi²	0 Ac-ft *(0")*	85 Ac-ft *(0.2")*	85 Ac-ft *(0.2")*
Green Meadow	1973	29.6 Mi²	0 Ac-ft *(0")*	2,216 Ac-ft *(1.4")*	2,216 Ac-ft *(1.4")*
AGSCO	1990	5.1 Mi²	0 Ac-ft *(0")*	290 Ac-ft *(1.1")*	290 Ac-ft *(1.1")*
Olson-Agassiz**	1981	28.9 Mi²	0 Ac-ft *(0")*	3,136 Ac-ft *(2.0")*	3,136 Ac-ft *(2.0")*
Subtotal *(Before 1997)*		246.8 Mi²	1,060 Ac-ft *(0.1")*	12,737 Ac-ft *(1.0")*	13,797 Ac-ft *(1.0")*

** Downstream of Upper Becker Dam*

***Downstream of AGSCO*

Table 1 continued on next page.

Table 1 *(continued)*
Existing Conditions Flood Water Detention Location Statistics

Site Name	Year Implemented	Drainage Area	Gated Volume	Ungated Volume	Total Volume
Impoundment Locations Constructed After the 1997 Spring Flood Event					
Olson-Agassiz***	1981	28.9 Mi^2	*1,120 Ac-ft (0.7")*	*2,016 Ac-ft (1.3")*	3,136 Ac-ft *(2.0")*
Lockhart	2001	2.4 Mi^2	*0 Ac-ft (0")*	*280 Ac-ft (2.2")*	280 Ac-ft *(2.2")*
Subtotal *(After 1997)*		31.3 Mi^2	1,120 Ac-ft *(0.7")*	2,296 Ac-ft *(2.2")*	3,416 Ac-ft *(2.2")*
Total *(Current Conditions)*		**249.2 Mi^2**	**2,180 Ac-ft *(0.2")***	**11,897 Ac-ft *(0.9")***	**14,077 Ac-ft *(1.1")***

****Post - 1997 operational changes to accommodate the presented gated volume*

Table 2 Proposed Conditions Flood Water Detention Location Statistics					
Site Name	**Year Implemented**	**Drainage Area**	**Gated Volume**	**Ungated Volume**	**Total Volume**
Identified Future Detention Locations					
A-1 (Upper Wild Rice)	Proposed	24.0 Mi²	5,563 Ac-ft *(4.3")*	6,852 Ac-ft *(5.4")*	12,415 Ac-ft *(9.7")*
A-2 (Upper Wild Rice)	Proposed	215.8 Mi²	11,339 Ac-ft *(1.5")*	9,644 Ac-ft *(1.4")*	20,983 Ac-ft *(2.9")*
A-3 (Upper Wild Rice)	Proposed	53.7 Mi²	6,771 Ac-ft *(2.4")*	2,970 Ac-ft *(1.0")*	9,741 Ac-ft *(3.4")*
B-1 (White Earth)	Proposed	25.3 Mi²	5,959 Ac-ft *(4.4")*	3,169 Ac-ft *(2.3")*	9,128 Ac-ft *(6.8")*
C-1 (Spring Creek)	Proposed	8.4 Mi²	2,161 Ac-ft *(4.8")*	1,727 Ac-ft *(3.8")*	3,888 Ac-ft *(8.6")*
C-2 (Spring Creek)	Proposed	65.6 Mi²	1,518 Ac-ft *(1.1")*	800 Ac-ft *(0.7")*	2,317 Ac-ft *(1.8")*
D-1 (Marsh Creek)	Proposed	50.1 Mi²	10,367 Ac-ft *(3.9")*	8,684 Ac-ft *(3.3")*	19,051 Ac-ft *(7.1")*
D-2 (Marsh Creek)	Proposed	26.1 Mi²	2,749 Ac-ft *(2.0")*	4,430 Ac-ft *(3.2")*	7,179 Ac-ft *(5.2")*
D-3 (Marsh Creek)	Proposed	124.8 Mi²	6,028 Ac-ft *(2.9")*	3,907 Ac-ft *(2.6")*	9,935 Ac-ft *(5.4")*
E-1 (Mossasin Creek)	Proposed	31.6 Mi²	7,085 Ac-ft *(4.2")*	11,007 Ac-ft *(6.5")*	18,092 Ac-ft *(10.7")*
F-1 (Middle Wild Rice)	Proposed	23.3 Mi²	3,504 Ac-ft *(2.8")*	4,102 Ac-ft *(3.3")*	7,606 Ac-ft *(6.1")*
G-1 (Mashaug Creek)	Proposed	22.6 Mi²	4,824 Ac-ft *(4.0")*	3,757 Ac-ft *(3.1")*	8,581 Ac-ft *(7.1")*
G-2 (Mashaug Creek)	Proposed	38.1 Mi²	8,338 Ac-ft *(4.1")*	6,948 Ac-ft *(3.4")*	15,286 Ac-ft *(7.5")*
H-1 (Coon Creek)	Proposed	20.7 Mi²	4,398 Ac-ft *(4.0")*	4,396 Ac-ft *(4.0")*	8,794 Ac-ft *(8.0")*

Table 2 continued on next page

Table 2 *(continued)* **Proposed Conditions Flood Water Detention Location Statistics**					
Site Name	**Year Implemented**	**Drainage Area**	**Gated Volume**	**Ungated Volume**	**Total Volume**
Identified Future Detention Locations					
I-1 (South Branch)*	Proposed	37.9 Mi²	8,549 Ac-ft *(4.2")*	5,678 Ac-ft *(2.8")*	14,227 Ac-ft *(7.0")*
I-2 (South Branch)	Proposed	11.8 Mi²	2,518 Ac-ft *(4.0")*	2,918 Ac-ft *(4.6")*	5,436 Ac-ft *(8.6")*
I-3 (South Branch)	Proposed	19.8 Mi²	4,284 Ac-ft *(4.1")*	4,482 Ac-ft *(4.2")*	8,766 Ac-ft *(8.3")*
I-4 (South Branch)	Proposed	9.9 Mi²	1,087 Ac-ft *(2.1")*	2,333 Ac-ft *(4.4")*	3,367 Ac-ft *(6.4")*
I-5 (South Branch)	Proposed	25.1 Mi²	5,342 Ac-ft *(4.0")*	4,519 Ac-ft *(3.4")*	9,861 Ac-ft *(7.4")*
I-6 (South Branch)	Proposed	208.1 Mi²	14,810 Ac-ft *(1.3")*	11,513 Ac-ft *(1.0")*	26,323 Ac-ft *(2.4")*
J-1 (Felton)	Proposed	61.7 Mi²	13,412 Ac-ft *(4.1")*	17,599 Ac-ft *(5.3")*	31,011 Ac-ft *(9.4")*
N-1 (Marsh River)	Proposed	30.8 Mi²	5,484 Ac-ft *(3.3")*	3,970 Ac-ft *(2.4")*	9,454 Ac-ft *(5.7")*
N-2 (Marsh River)	Proposed	49.8 Mi²	11,435 Ac-ft *(4.3")*	8,045 Ac-ft *(3.0")*	19,480 Ac-ft *(7.3")*
N-3 (Green Meadow)**	Proposed	29.6 Mi²	1,820 Ac-ft *(1.2")*	396 Ac-ft *(0.3")*	2,216 Ac-ft *(1.4")*
0-1 (Ungaged Marsh River)	Proposed	34.4 Mi²	8,047 Ac-ft *(4.4")*	9,522 Ac-ft *(5.2")*	17,569 Ac-ft *(9.6")*
Subtotal *(All Identified)*		1249.0 Mi²	155,573 Ac-ft *(2.3")*	142,971 Ac-ft *(2.1")*	298,490 Ac-ft *(4.5")*
Subtotal *(Identified and Existing Post-1997)*		1280.3 Mi²	156,693 Ac-ft *(2.3")*	143,251 Ac-ft *(2.1")*	299,890 Ac-ft *(4.4")*
Total ***(All Existing & Identified)***		**1527.0 Mi²**	**157,753 Ac-ft** ***(1.9")***	**155,987 Ac-ft** ***(1.9")***	**313,687 Ac-ft** ***(3.9")***

**Proposed enhancements to Upper Becker Dam (From Table 1)*

***Proposed change in operation of Green Meadow*

Table 2 continued on next page

Table 2 *(continued)* **Proposed Conditions Flood Water Detention Location Statistics**					
Site Name	**Year Implemented**	**Drainage Area**	**Gated Volume**	**Ungated Volume**	**Total Volume**
Identified Main Stem Detention Location					
F-2 (Middle Wild Rice)***	Proposed	857.3 Mi²	0 Ac-ft *(0")*	20,400 Ac-ft *(0.4")*	20,400 Ac-ft *(0.4")*
Subtotal *(Identified, Identified Main Stem and Existing Post-1997)*		1451.4 Mi²	156,693 Ac-ft *(2.0")*	163,651 Ac-ft *(2.1")*	320,344 Ac-ft *(4.1")*
Total ***(All Existing, Identified, and Identified Main Stem)***		**1527.0 Mi²**	**157,753 Ac-ft** ***(1.9")***	**163,651 Ac-ft** ***(1.9")***	**313,687 Ac-ft** ***(3.9")***

****Assumed to pass between 10 and 20 year flow before peaks substantially attenuated*

Table 3
Flood Water Detention Location Performance Statistics (Proposed Conditions)

Red River Basin Standardized Melt Progression Event

Site Name	Year Implemented	Drainage Area	Peak Inflow	Peak Outflow	Peak Flow Reduction	Inflow Volume	Outflow Volume	Volume Reduction
Impoundment Locations Constructed Before the 1997 Spring Flood Event								
Marsh Creek Site No. 3	1983	8.1 Mi²	749 cfs	682 cfs	-8.9%	2,484 Ac-ft (5.8")	2,484 Ac-ft (5.8")	0%
Moccasin Creek Dam	1982	56.8 Mi²	1,897 cfs	1,819 cfs	-4.1%	10,432 Ac-ft (3.4")	9,371 Ac-ft *(3.1")*	-10%
Mashaug Dam 34	1984	14.3 Mi²	96 cfs	80 cfs	-16.7%	220 Ac-ft (0.3")	220 Ac-ft *(0.3")*	0%
Mashaug Dam 151	1980	10.6 Mi²	478 cfs	244 cfs	-49.0%	1,152 Ac-ft (2.0")	1,152 Ac-ft *(2.0")*	0%
Lower Becker*	1978	40.8 Mi²	298 cfs	190 cfs	-36.2%	4,097 Ac-ft (1.9")	4,097 Ac-ft *(1.9")*	0%
Rockwell	1989	2.0 Mi²	120 cfs	67 cfs	-44.2%	510 Ac-ft (4.8")	510 Ac-ft *(4.8")*	0%
Northern Improvement	1979	5.3 Mi²	253 cfs	233 cfs	-7.9%	1,392 Ac-ft (4.9")	1,392 Ac-ft *(4.9")*	0%
Lake Ida	1979	7.4 Mi²	347 cfs	331 cfs	-4.6%	1,943 Ac-ft (4.9")	1,943 Ac-ft *(4.9")*	0%
AGSCO	1990	5.1 Mi²	138 cfs	108 cfs	-21.7%	888 Ac-ft (3.3")	884 Ac-ft *(3.2")*	-1%
Impoundment Locations Constructed After the 1997 Spring Flood Event								
Olson-Aggassiz**	1981	28.9 Mi²	1,065 cfs	709 cfs	-33.4%	8,808 Ac-ft (5.7")	7,686 Ac-ft *(5.0")*	-13%
Lockhart	2001	2.4 Mi²	200 cfs	31 cfs	-84.3%	577 Ac-ft (4.5")	577 Ac-ft *(4.5")*	0%

** Downstream of I-1 (Former location of Upper Becker)*

***Post - 1997 operational changes to accomidate the presented gated volume*

Table 3 continued on next page.

Table 3 *(continued)*

Flood Water Detention Location Performance Statistics (Proposed Conditions)

Red River Basin Standardized Melt Progression Event

Site Name	Year Implemented	Drainage Area	Peak Inflow	Peak Outflow	Peak Flow Reduction	Inflow Volume	Outflow Volume	Volume Reduction
Identified Future Detention Locations								
A-1 (Upper Wild Rice)	Proposed	24.0 Mi²	402 cfs	113 cfs	-71.9%	7,509 Ac-ft *(5.9")*	1,885 Ac-ft *(1.5")*	-75%
A-2 (Upper Wild Rice)	Proposed	215.8 Mi²	2,121 cfs	1,922 cfs	-9.4%	56,416 Ac-ft (4.9")	44,369 Ac-ft *(3.9")*	-21%
A-3 (Upper Wild Rice)	Proposed	53.7 Mi²	499 cfs	152 cfs	-69.5%	13,575 Ac-ft (4.7")	6,867 Ac-ft *(2.4")*	-49%
B-1 (White Earth)	Proposed	25.3 Mi²	578 cfs	227 cfs	-60.7%	8,229 Ac-ft (6.1")	2,265 Ac-ft *(1.7")*	-72%
C-1 (Spring Creek)	Proposed	8.4 Mi²	520 cfs	104 cfs	-80.0%	2,639 Ac-ft (5.9")	477 Ac-ft *(1.1")*	-82%
C-2 (Spring Creek)	Proposed	65.6 Mi²	2,117 cfs	2,112 cfs	-0.2%	18,279 Ac-ft (5.2")	16,758 Ac-ft *(4.8")*	-8%
D-1 (Marsh Creek)	Proposed	50.1 Mi²	1,692 cfs	718 cfs	-57.6%	15,969 Ac-ft (6.0")	5,972 Ac-ft *(2.2")*	-63%
D-2 (Marsh Creek)	Proposed	26.1 Mi²	1,605 cfs	836 cfs	-47.9%	8,549 Ac-ft (6.1")	5,787 Ac-ft *(4.2")*	-32%
D-3 (Marsh Creek)	Proposed	124.8 Mi²	2,110 cfs	1,923 cfs	-8.9%	27,402 Ac-ft (4.1")	21,339 Ac-ft *(3.2")*	-22%
E-1 (Mossasin Creek)	Proposed	31.6 Mi²	2,221 cfs	331 cfs	-85.1%	9,918 Ac-ft (5.9")	2,800 Ac-ft *(1.7")*	-72%
F-1 (Middle Wild Rice)	Proposed	23.3 Mi²	1,054 cfs	315 cfs	-70.1%	6,066 Ac-ft (4.9")	2,561 Ac-ft *(2.1")*	-58%
G-1 (Mashaug Creek)	Proposed	22.6 Mi²	1,424 cfs	265 cfs	-81.4%	6,280 Ac-ft (5.2")	1,454 Ac-ft *(1.2")*	-77%
G-2 (Mashaug Creek)	Proposed	38.1 Mi²	2,703 cfs	447 cfs	-83.5%	11,375 Ac-ft (5.6")	3,027 Ac-ft *(1.5")*	-73%

Table 3 continued on next page.

Table 3 *(continued)*

Flood Water Detention Location Performance Statistics (Proposed Conditions)

Red River Basin Standardized Melt Progression Event

Site Name	Year Implemented	Drainage Area	Peak Inflow	Peak Outflow	Peak Flow Reduction	Inflow Volume	Outflow Volume	Total Volume
Identified Future Detention Locations								
H-1 (Coon Creek)	Proposed	20.7 Mi²	818 cfs	172 cfs	-79.0%	5,357 Ac-ft (4.8")	956 Ac-ft *(0.9")*	-82%
I-1 (South Branch)	Proposed	37.9 Mi²	1,068 cfs	380 cfs	-64.4%	11,760 Ac-ft (5.8")	3,206 Ac-ft *(1.6")*	-73%
I-2 (South Branch)	Proposed	11.8 Mi²	829 cfs	150 cfs	-81.9%	3,500 Ac-ft (5.6")	982 Ac-ft *(1.6")*	-72%
I-3 (South Branch)	Proposed	19.8 Mi²	1,478 cfs	241 cfs	-83.7%	5,889 Ac-ft (5.6")	1,603 Ac-ft *(1.5")*	-73%
I-4 (South Branch)	Proposed	9.9 Mi²	388 cfs	267 cfs	-31.2%	3,019 Ac-ft (5.7")	1,932 Ac-ft *(3.7")*	-36%
I-5 (South Branch)	Proposed	25.1 Mi²	1,844 cfs	306 cfs	-83.4%	7,144 Ac-ft (5.3")	1,801 Ac-ft *(1.3")*	-75%
I-6 (South Branch)	Proposed	208.1 Mi²	4,148 cfs	1,997 cfs	-51.9%	40,782 Ac-ft (3.7")	25,860 Ac-ft *(2.3")*	-37%
J-1 (Felton)	Proposed	61.7 Mi²	1,315 cfs	63 cfs	-95.2%	14,811 Ac-ft (4.5")	1,296 Ac-ft *(0.4")*	-91%
N-1 (Marsh River)	Proposed	30.8 Mi²	942 cfs	69 cfs	-92.7%	5,922 Ac-ft (3.6")	435 Ac-ft *(0.3")*	-93%
N-2 (Marsh River)	Proposed	49.8 Mi²	835 cfs	12 cfs	-98.6%	11,696 Ac-ft (4.4")	235 Ac-ft *(0.1")*	-98%
N-3 (Green Meadow)***	Proposed	29.6 Mi²	1,140 cfs	1,024 cfs	-10.2%	7,350 Ac-ft (4.7")	5,527 Ac-ft (3.5")	-25%
0-1 (Ungaged Marsh River)	Proposed	34.4 Mi²	1,777 cfs	95 cfs	-94.7%	9,037 Ac-ft (4.9")	969 Ac-ft *(0.5")*	-89%

****Proposed change in operation of Green Meadow*

Table 3 continued on next page.

Table 3 *(continued)*
Flood Water Detention Location Performance Statistics (Proposed Conditions)
Red River Basin Standardized Melt Progression Event

Site Name	Year Implemented	Drainage Area	Peak Inflow	Peak Outflow	Peak Flow Reduction	Inflow Volume	Outflow Volume	Total Volume
Identified Main Stem Detention								
F-2 (Middle Wild Rice)****	Proposed	857.3 Mi^2	8,316 cfs	6,000 cfs	-27.9%	200,532 Ac-ft (4.4")	200,518 Ac-ft *(4.4")*	0%

*****Assumed to pass between 10 and 20 year flow before runoff volume substantially attenuated.*

Table 4

Performance Statistics at Monitoring Locations without Additional Mainstem Detention Location

Red River Basin Standardized Melt Progression Event

Location	Contributing Drainage Area	Existing Conditions		Proposed Conditions		Percent Reductions	
		Peak Flow	Volume	Peak Flow	Volume	Peak Flow	Volume
USGS Gage 05064000 Wild Rice River at Hendrum, MN	1536.8 Mi^2	10,597 cfs	411,204 Ac-ft *(5.0")*	7,576 cfs	299,325 Ac-ft *(3.7")*	-29 %	-27 %
USGS Gage 05062500 Wild Rice River at Twin Valley, MN	867.1 Mi^2	11,181 cfs	267,145 Ac-ft *(5.8")*	8,343 cfs	203,220 Ac-ft *(4.4")*	-25 %	-24 %
USGS Gage 05067500 Marsh River near Shelly, MN	231.4 Mi^2	5,424 cfs	95,219 Ac-ft *(7.7")*	4,946 cfs	52,915 Ac-ft *(4.3")*	-9 %	-44 %
Wild Rice River near confluence with Twin Creek	320.2 Mi^2	3,861 cfs	96,782 Ac-ft *(5.7")*	2,503 cfs	71,949 Ac-ft *(4.2")*	-35 %	-26 %
Wild Rice River near Mahnomen, MN	518.2 Mi^2	6,406 cfs	159,550 Ac-ft *(5.8")*	4,151 cfs	128,511 Ac-ft *(4.7")*	-35 %	-19 %
Wild Rice River near MN Hwy 9 - Ada, MN	1041.7 Mi^2	10,387 cfs	290,633 Ac-ft *(5.2")*	7,612 cfs	220,822 Ac-ft *(4.0")*	-27 %	-24 %
Felton Ditch near confluence with Wild Rice River	146.9 Mi^2	3,601 cfs	40,706 Ac-ft *(5.2")*	3,437 cfs	27,031 Ac-ft *(3.5")*	-5 %	-34 %
Norman Polk No. 5 near confluence with Red River	75.1 Mi^2	2,866 cfs	21,400 Ac-ft *(5.3")*	2,495 cfs	14,258 Ac-ft *(3.6")*	-13 %	-33 %
South Branch Wild Rice River near Ulen, MN	141.8 Mi^2	5,109 cfs	42,447 Ac-ft *(5.6")*	2,448 cfs	23,961 Ac-ft *(3.2")*	-52 %	-44 %
South Branch Wild Rice River near MN Hwy 9 - Borup, MN	212.5 Mi^2	7,099 cfs	60,316 Ac-ft *(5.3")*	1,997 cfs	26,212 Ac-ft *(2.3")*	-72 %	-57 %

Table 5
Performance Statistics at Monitoring Locations with Additional Mainstem Detention Location

Red River Basin Standardized Melt Progression Event

Location	Contributing Drainage Area	Existing Conditions		Proposed Conditions		Percent Reductions	
		Peak Flow	Volume	Peak Flow	Volume	Peak Flow	Volume
USGS Gage 05064000 Wild Rice River at Hendrum, MN	1536.8 Mi²	10,597 cfs	411,204 Ac-ft *(5.0")*	6,807 cfs	299,977 Ac-ft *(3.7")*	-36 %	-27 %
USGS Gage 05062500 Wild Rice River at Twin Valley, MN	867.1 Mi²	11,181 cfs	267,145 Ac-ft *(5.8")*	6,121 cfs	203,207 Ac-ft *(4.4")*	-45 %	-24 %
USGS Gage 05067500 Marsh River near Shelly, MN	231.4 Mi²	5,424 cfs	95,219 Ac-ft *(7.7")*	4,946 cfs	52,118 Ac-ft *(4.2")*	-9 %	-45 %
Wild Rice River near confluence with Twin Creek	320.2 Mi²	3,861 cfs	96,782 Ac-ft *(5.7")*	2,503 cfs	71,949 Ac-ft *(4.2")*	-35 %	-26 %
Wild Rice River near Mahnomen, MN	518.2 Mi²	6,406 cfs	159,550 Ac-ft *(5.8")*	4,151 cfs	128,511 Ac-ft *(4.7")*	-35 %	-19 %
Wild Rice River near MN Hwy 9 - Ada, MN	1041.7 Mi²	10,387 cfs	290,633 Ac-ft *(5.2")*	6,282 cfs	221,491 Ac-ft *(4.0")*	-40 %	-24 %
Felton Ditch near confluence with Wild Rice River	146.9 Mi²	3,601 cfs	40,706 Ac-ft *(5.2")*	3,437 cfs	27,031 Ac-ft *(3.5")*	-5 %	-34 %
Norman Polk No. 5 near confluence with Red River	75.1 Mi²	2,866 cfs	21,400 Ac-ft *(5.3")*	2,495 cfs	14,258 Ac-ft *(3.6")*	-13 %	-33 %
South Branch Wild Rice River near Ulen, MN	141.8 Mi²	5,109 cfs	42,447 Ac-ft *(5.6")*	2,448 cfs	23,962 Ac-ft *(3.2")*	-52 %	-44 %
South Branch Wild Rice River near MN Hwy 9 - Borup, MN	212.5 Mi²	7,099 cfs	60,316 Ac-ft *(5.3")*	1,997 cfs	26,212 Ac-ft *(2.3")*	-72 %	-57 %

Figures

HoustonEngineering Inc.

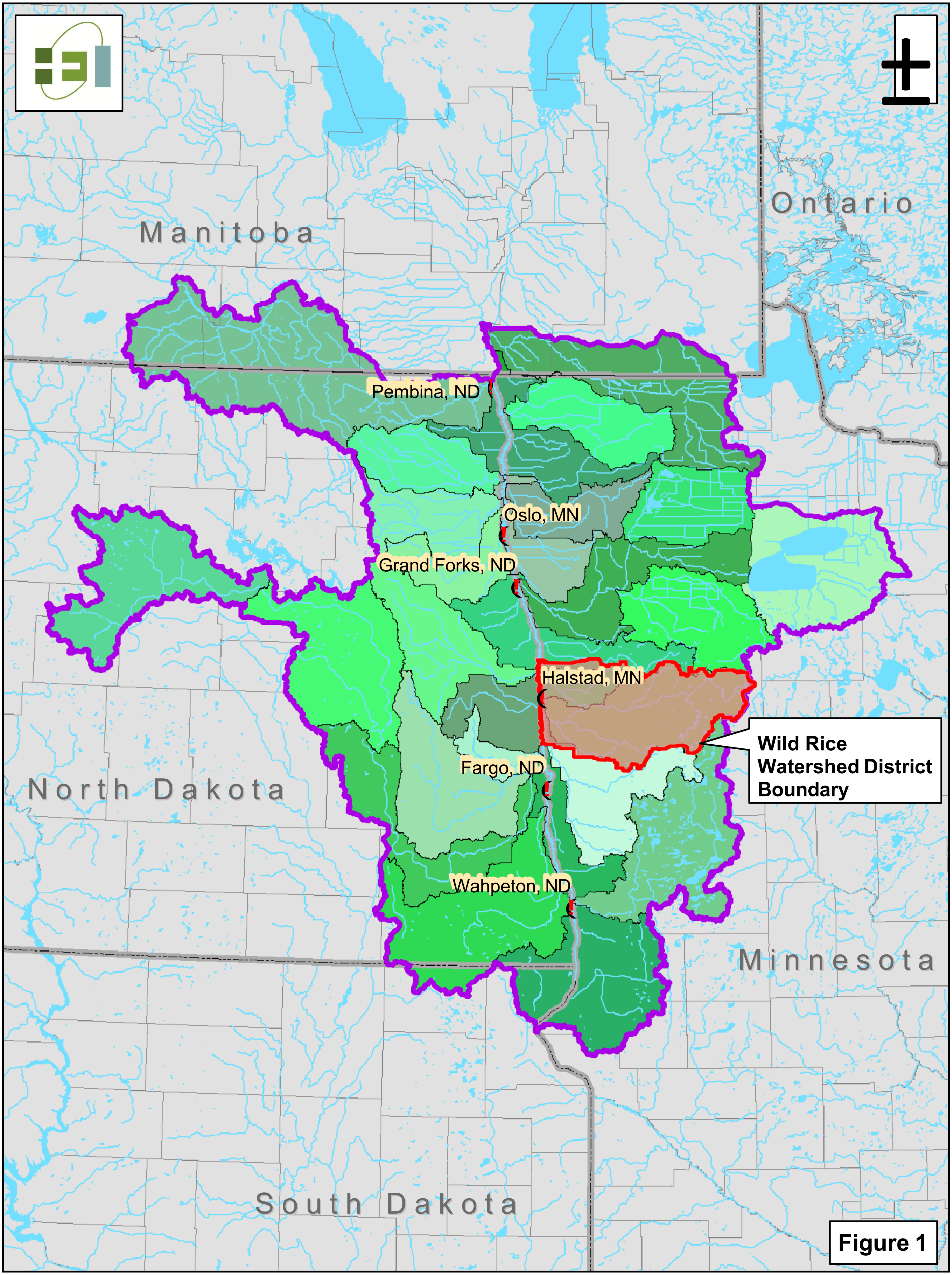
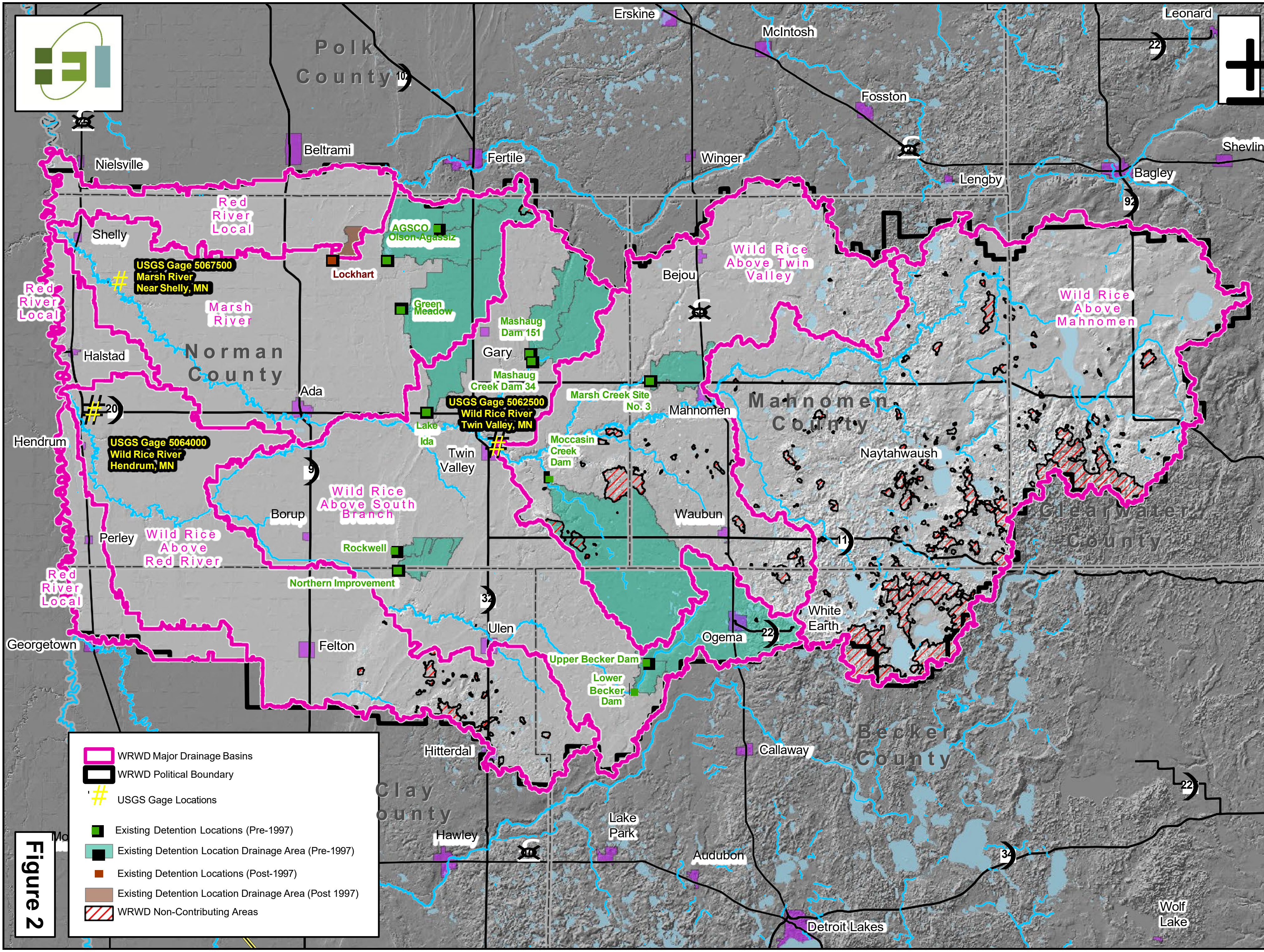
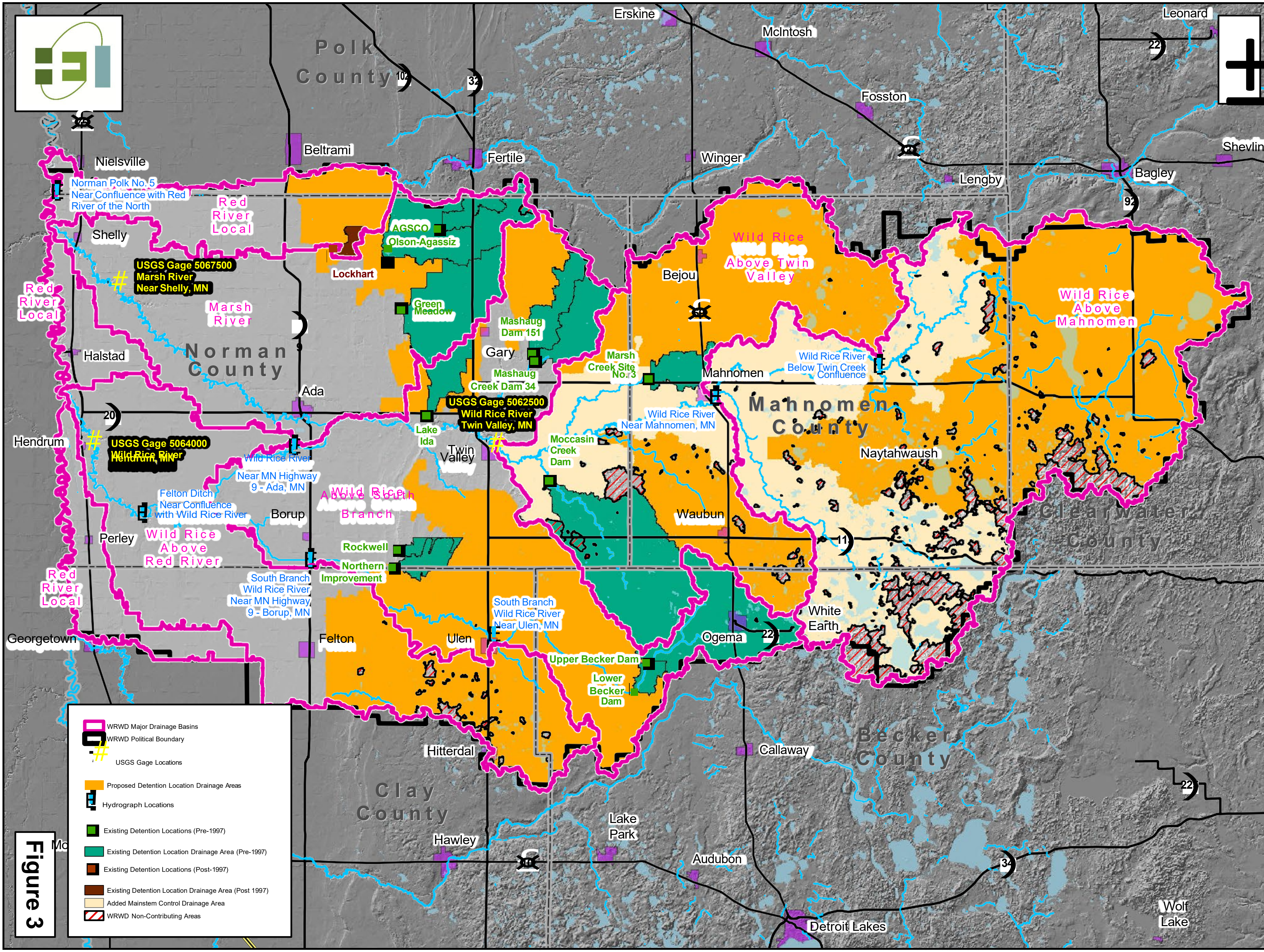

Manitoba
Ontario
Pembina, ND
Oslo, MN
Grand Forks, ND
Halstad, MN
Wild Rice
Watershed District
Boundary
Fargo, ND
North Dakota
Wahpeton, ND
Minnesota
South Dakota

Figure 1



Polk County
Norman County
Mahnomen County
Clearwater County
Becker County
Clay County
Erskine
McIntosh
Fosston
Leonard
Shevlin
Bagley
Lengby
Winger
Fertile
Beltrami
Nielsville
Shelly
Halstad
Hendrum
Perley
Georgetown
Ada
Borup
Felton
Twin Valley
Gary
Bejou
Mahnomen
Naytahwaush
Waubun
White Earth
Ogema
Ulen
Hitterdal
Callaway
Hawley
Lake Park
Audubon
Detroit Lakes
Wolf Lake
Lockhart
Red River Local
Marsh River
Wild Rice Above Twin Valley
Wild Rice Above Mahnomen
Wild Rice Above South Branch
Wild Rice Above Red River
USGS Gage 5067500 Marsh River Near Shelly, MN
USGS Gage 5064000 Wild Rice River Hendrum, MN
USGS Gage 5062500 Wild Rice River Twin Valley, MN
AGSCO Olson-Agassiz
Green Meadow
Mashaug Dam 151
Mashaug Creek Dam 34
Marsh Creek Site No. 3
Lake Ida
Moccasin Creek Dam
Rockwell
Northern Improvement
Upper Becker Dam
Lower Becker Dam
WRWD Major Drainage Basins
WRWD Political Boundary
USGS Gage Locations
Existing Detention Locations (Pre-1997)
Existing Detention Location Drainage Area (Pre-1997)
Existing Detention Locations (Post-1997)
Existing Detention Location Drainage Area (Post 1997)
WRWD Non-Contributing Areas

Figure 2



Polk County
Norman County
Mahnomen County
Clearwater County
Becker County
Clay County
Erskine
McIntosh
Leonard
Fosston
Shevlin
Bagley
Lengby
Winger
Fertile
Beltrami
Nielsville
Shelly
Halstad
Hendrum
Perley
Georgetown
Ada
Borup
Felton
Ulen
Hitterdal
Hawley
Twin Valley
Gary
Bejou
Mahnomen
Naytahwaush
Waubun
Ogema
White Earth
Callaway
Lake Park
Audubon
Detroit Lakes
Wolf Lake
Lockhart
Norman Polk No. 5
Near Confluence with Red
River of the North
Red River Local
Marsh River
USGS Gage 5067500
Marsh River
Near Shelly, MN
USGS Gage 5064000
Wild Rice River
Hendrum, MN
USGS Gage 5062500
Wild Rice River
Twin Valley, MN
Wild Rice River
Near MN Highway
9 - Ada, MN
Felton Ditch
Near Confluence
with Wild Rice River
Wild Rice Above Red River
Wild Rice Above South Branch
South Branch
Wild Rice River
Near MN Highway
9 - Borup, MN
South Branch
Wild Rice River
Near Ulen, MN
Wild Rice Above Twin Valley
Wild Rice Above Mahnomen
Wild Rice River
Below Twin Creek
Confluence
Wild Rice River
Near Mahnomen, MN
AGSCO
Olson-Agassiz
Green Meadow
Mashaug Dam 151
Mashaug Creek Dam 34
Marsh Creek Site No. 3
Lake Ida
Moccasin Creek Dam
Rockwell
Northern Improvement
Upper Becker Dam
Lower Becker Dam
WRWD Major Drainage Basins
WRWD Political Boundary
USGS Gage Locations
Proposed Detention Location Drainage Areas
Hydrograph Locations
Existing Detention Locations (Pre-1997)
Existing Detention Location Drainage Area (Pre-1997)
Existing Detention Locations (Post-1997)
Existing Detention Location Drainage Area (Post 1997)
Added Mainstem Control Drainage Area
WRWD Non-Contributing Areas

Figure 3

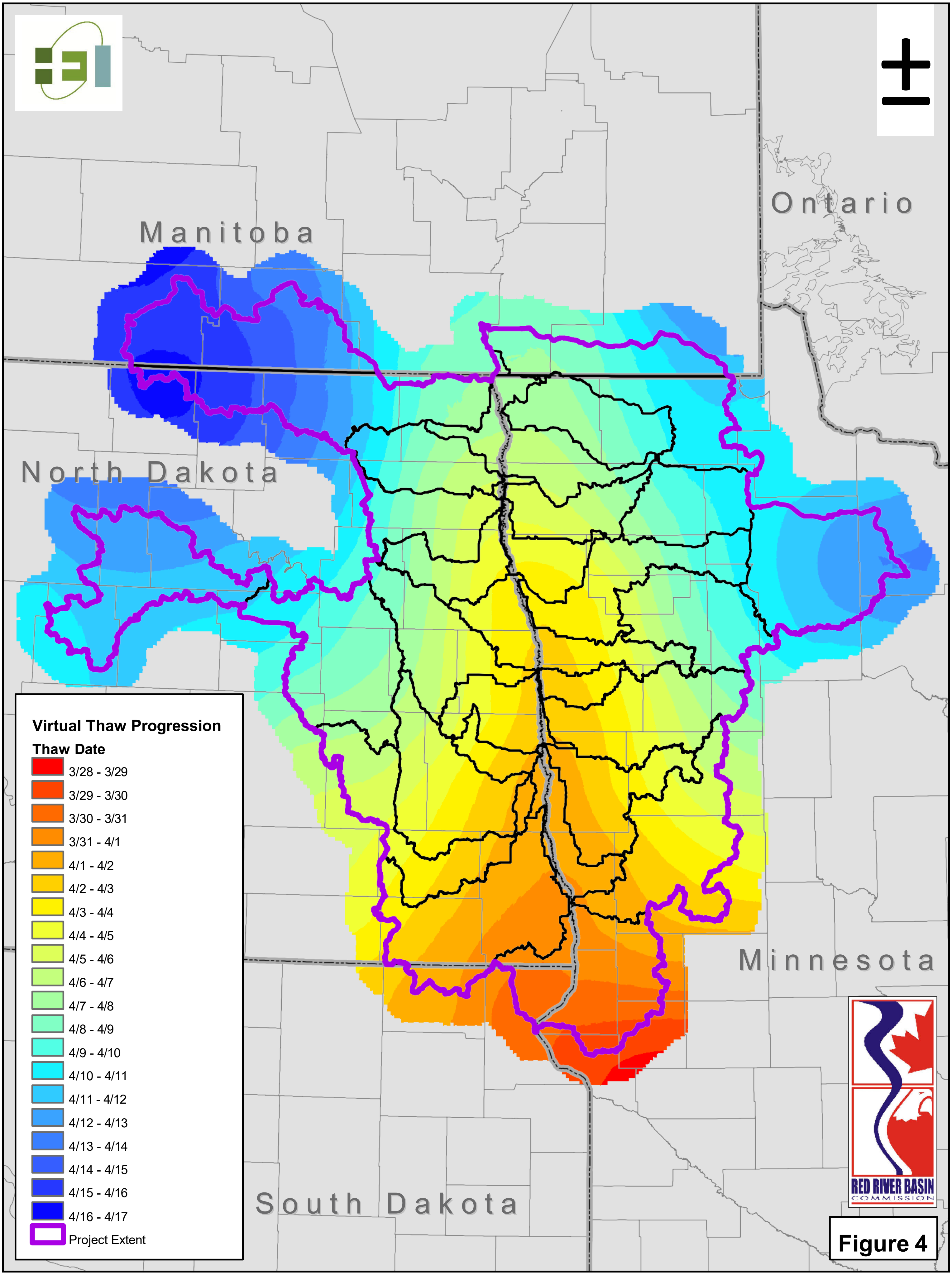
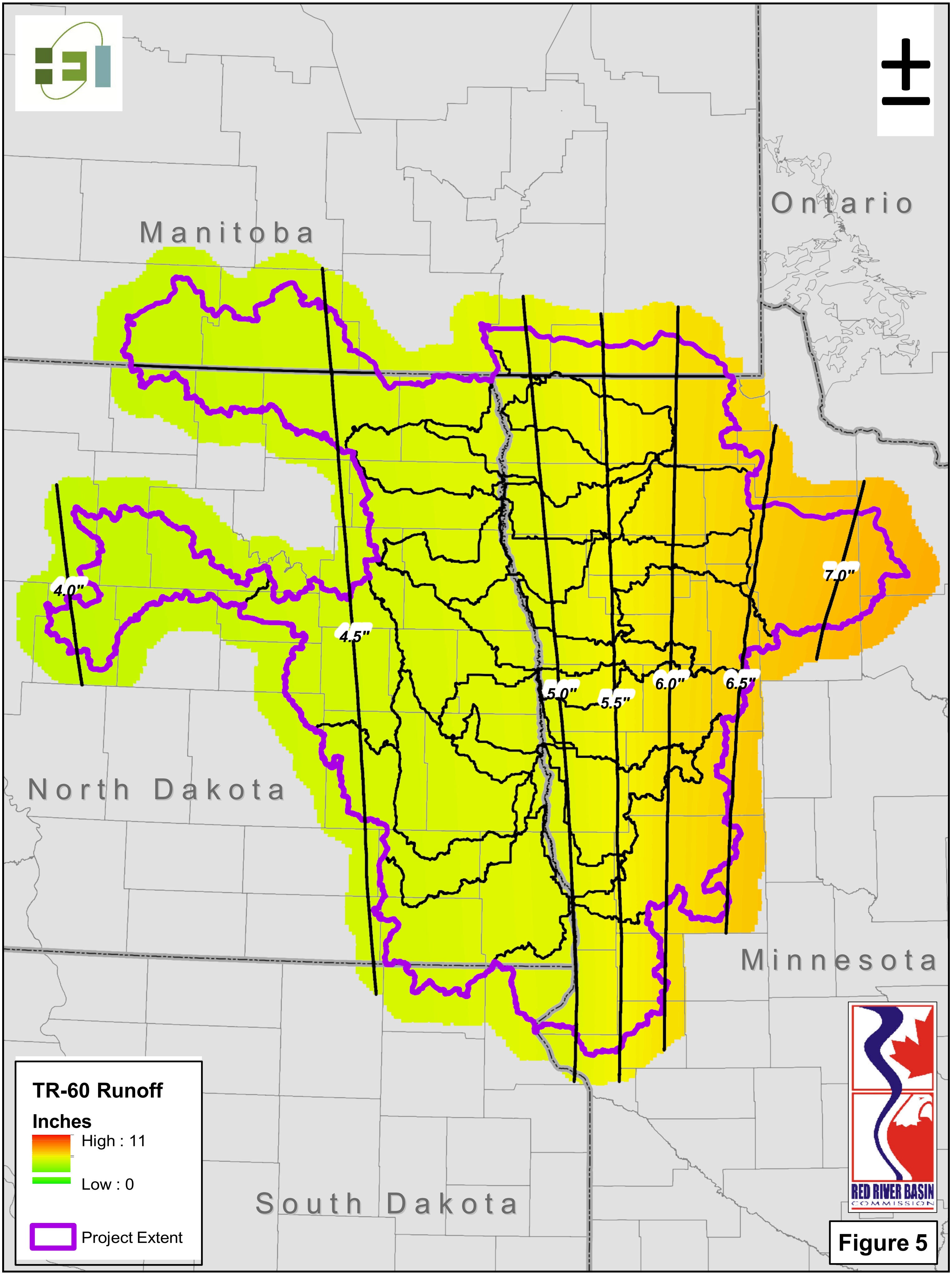

Ontario
Manitoba
North Dakota
Minnesota
South Dakota
Virtual Thaw Progression
Thaw Date
3/28 - 3/29
3/29 - 3/30
3/30 - 3/31
3/31 - 4/1
4/1 - 4/2
4/2 - 4/3
4/3 - 4/4
4/4 - 4/5
4/5 - 4/6
4/6 - 4/7
4/7 - 4/8
4/8 - 4/9
4/9 - 4/10
4/10 - 4/11
4/11 - 4/12
4/12 - 4/13
4/13 - 4/14
4/14 - 4/15
4/15 - 4/16
4/16 - 4/17
Project Extent
RED RIVER BASIN
COMMISSION

Figure 4



Manitoba
Ontario
North Dakota
Minnesota
South Dakota
4.0"
4.5"
5.0"
5.5"
6.0"
6.5"
7.0"
TR-60 Runoff
Inches
High : 11
Low : 0
Project Extent
RED RIVER BASIN
COMMISSION

Figure 5

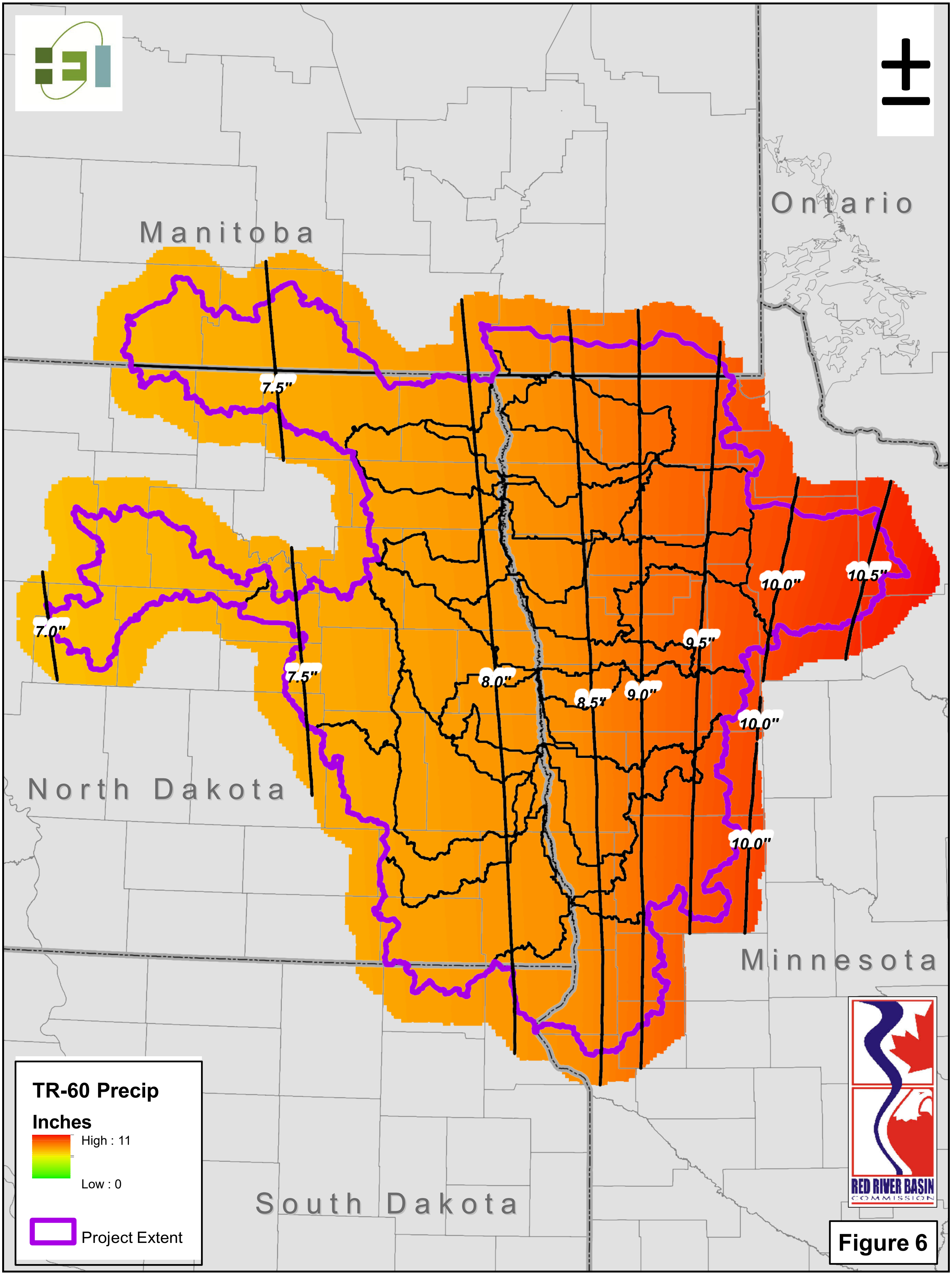
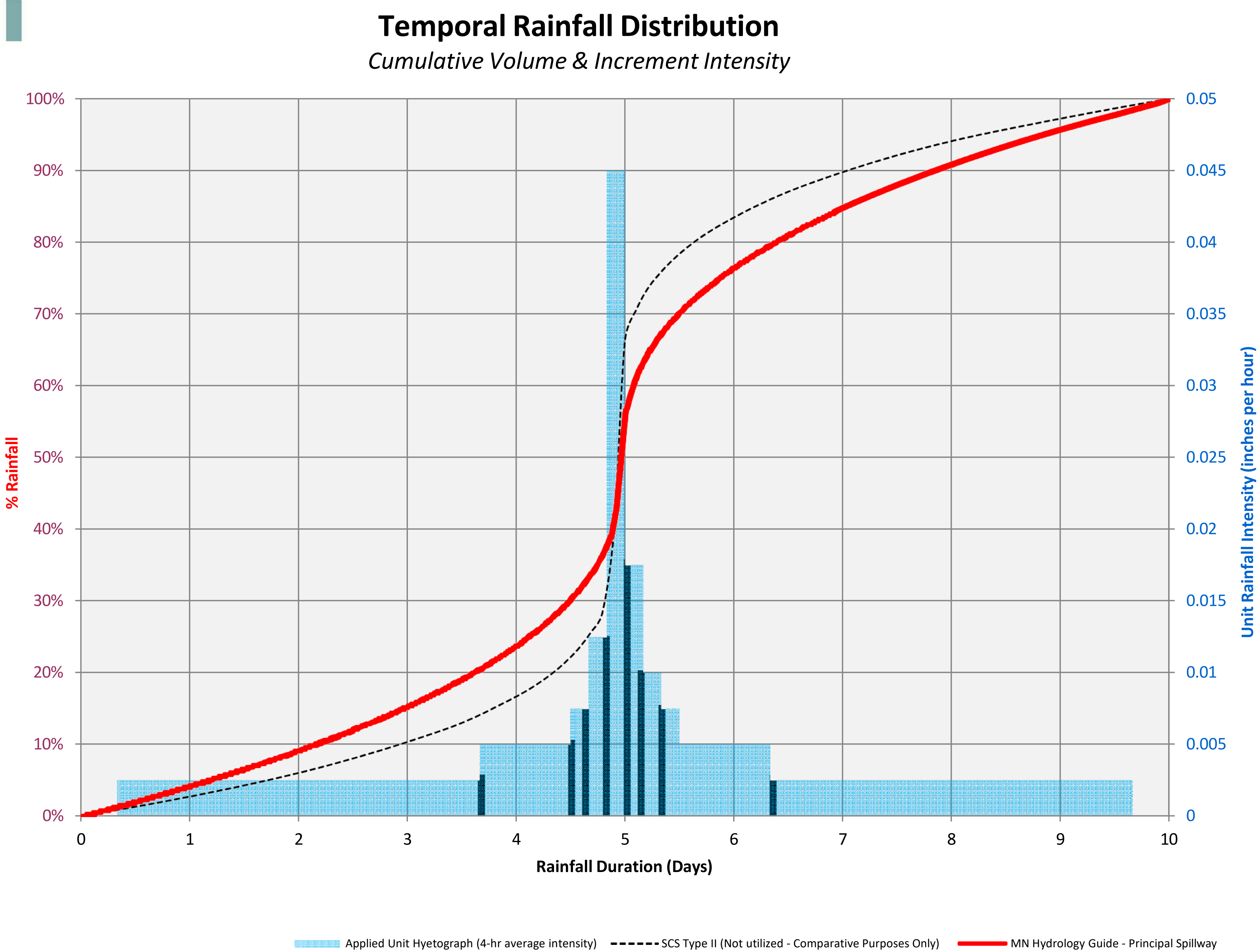

Manitoba
Ontario
North Dakota
Minnesota
South Dakota
7.0"
7.5"
7.5"
8.0"
8.5"
9.0"
9.5"
10.0"
10.0"
10.0"
10.5"
TR-60 Precip
Inches
High : 11
Low : 0
Project Extent
RED RIVER BASIN COMMISSION

Figure 6

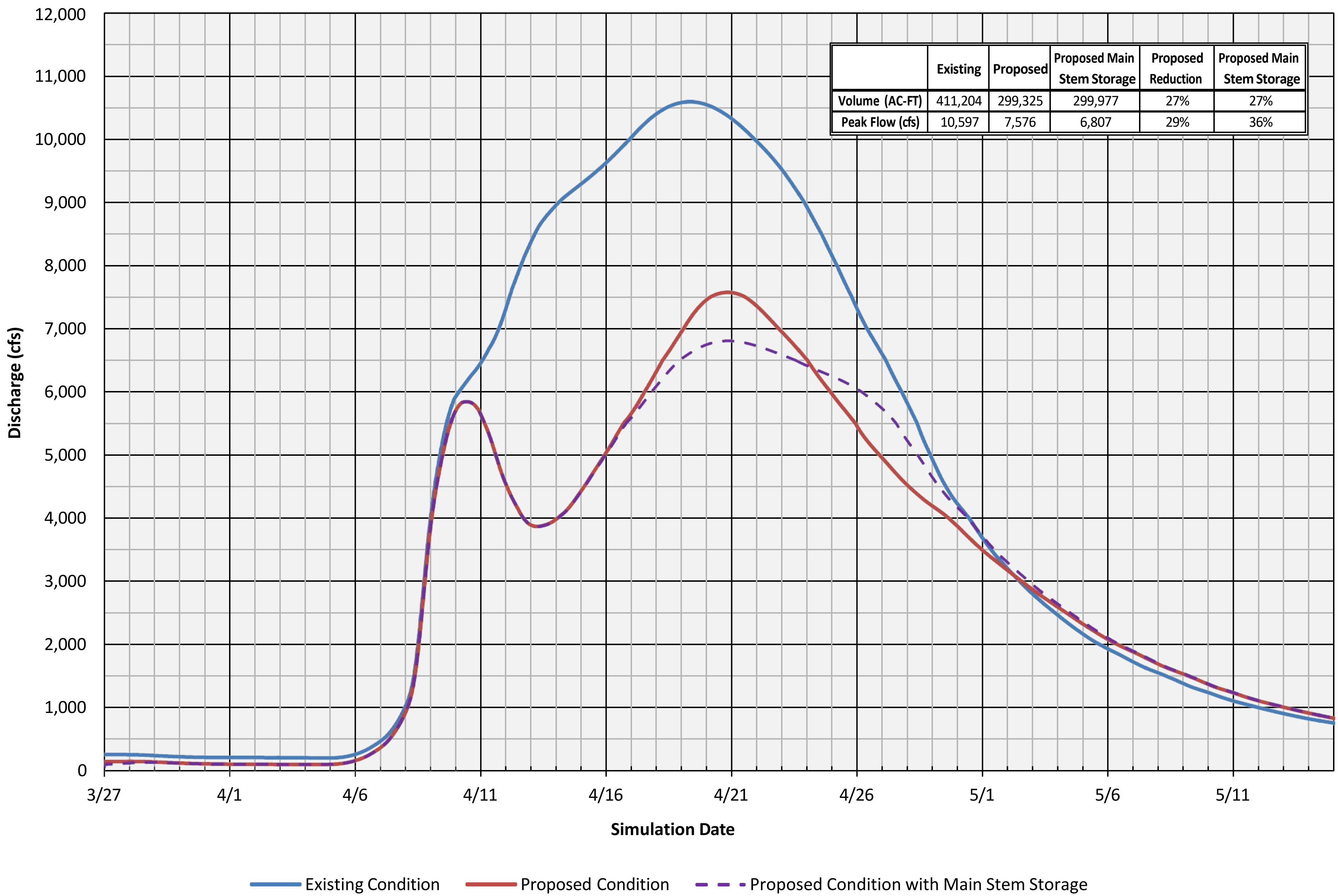


Temporal Rainfall Distribution
Cumulative Volume & Increment Intensity
% Rainfall
Unit Rainfall Intensity (inches per hour)
Rainfall Duration (Days)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0 1 2 3 4 5 6 7 8 9 10
Applied Unit Hyetograph (4-hr average intensity)
SCS Type II (Not utilized - Comparative Purposes Only)
MN Hydrology Guide - Principal Spillway

Figure 7

USGS Gage 05064000 Wild Rice River at Hendrum, MN

Red River Basin Standardized Melt Progression
TR60 100-yr, 10-day Runoff Depths

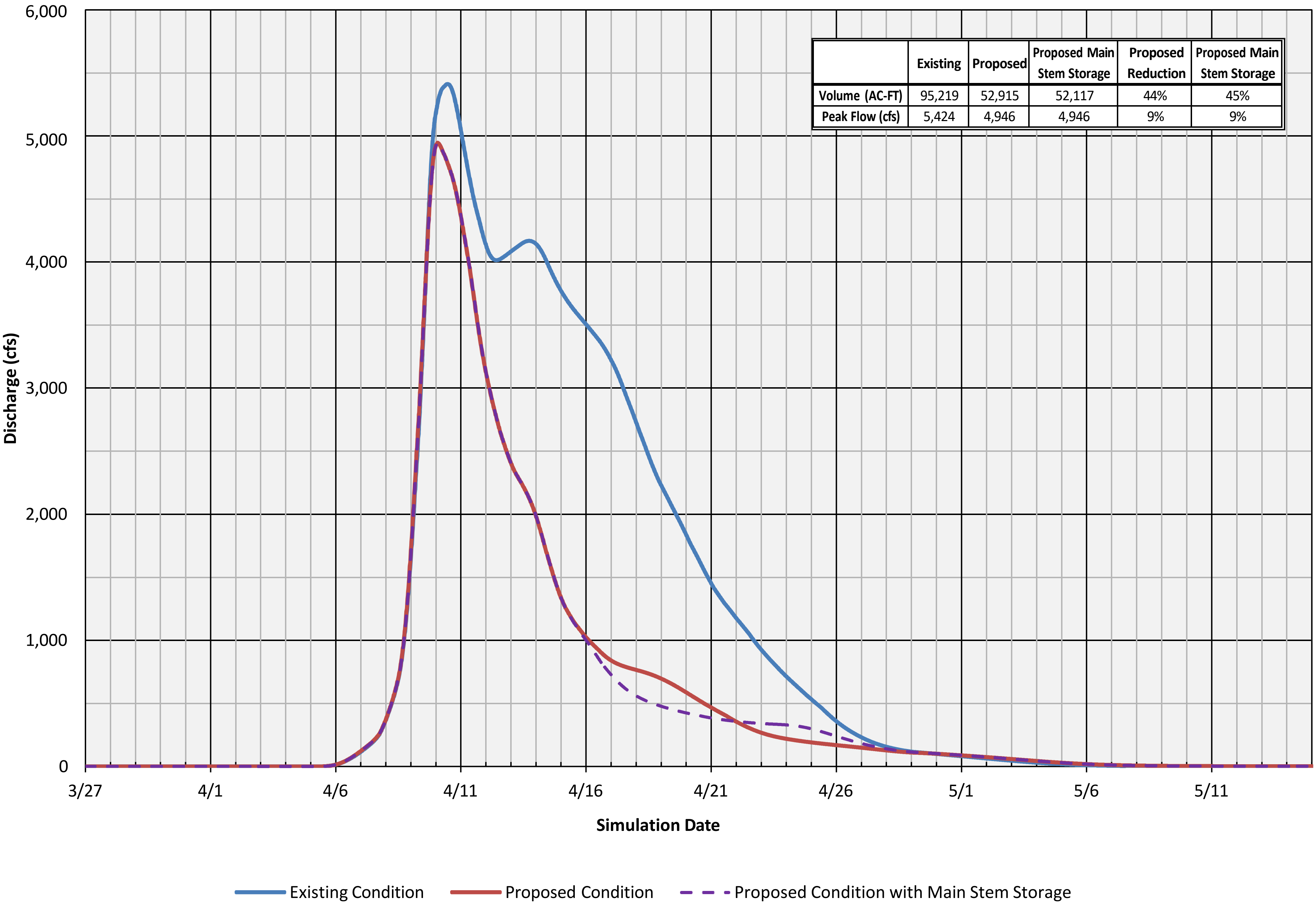


	Existing	Proposed	Proposed Main Stem Storage	Proposed Reduction	Proposed Main Stem Storage
Volume (AC-FT)	411,204	299,325	299,977	27%	27%
Peak Flow (cfs)	10,597	7,576	6,807	29%	36%

USGS Gage 05064000 Wild Rice River at Hendrum, MN - **Figure 8**

USGS Gage 05067500 Marsh River near Shelly, MN

Red River Basin Standardized Melt Progression
TR60 100-yr, 10-day Runoff Depths



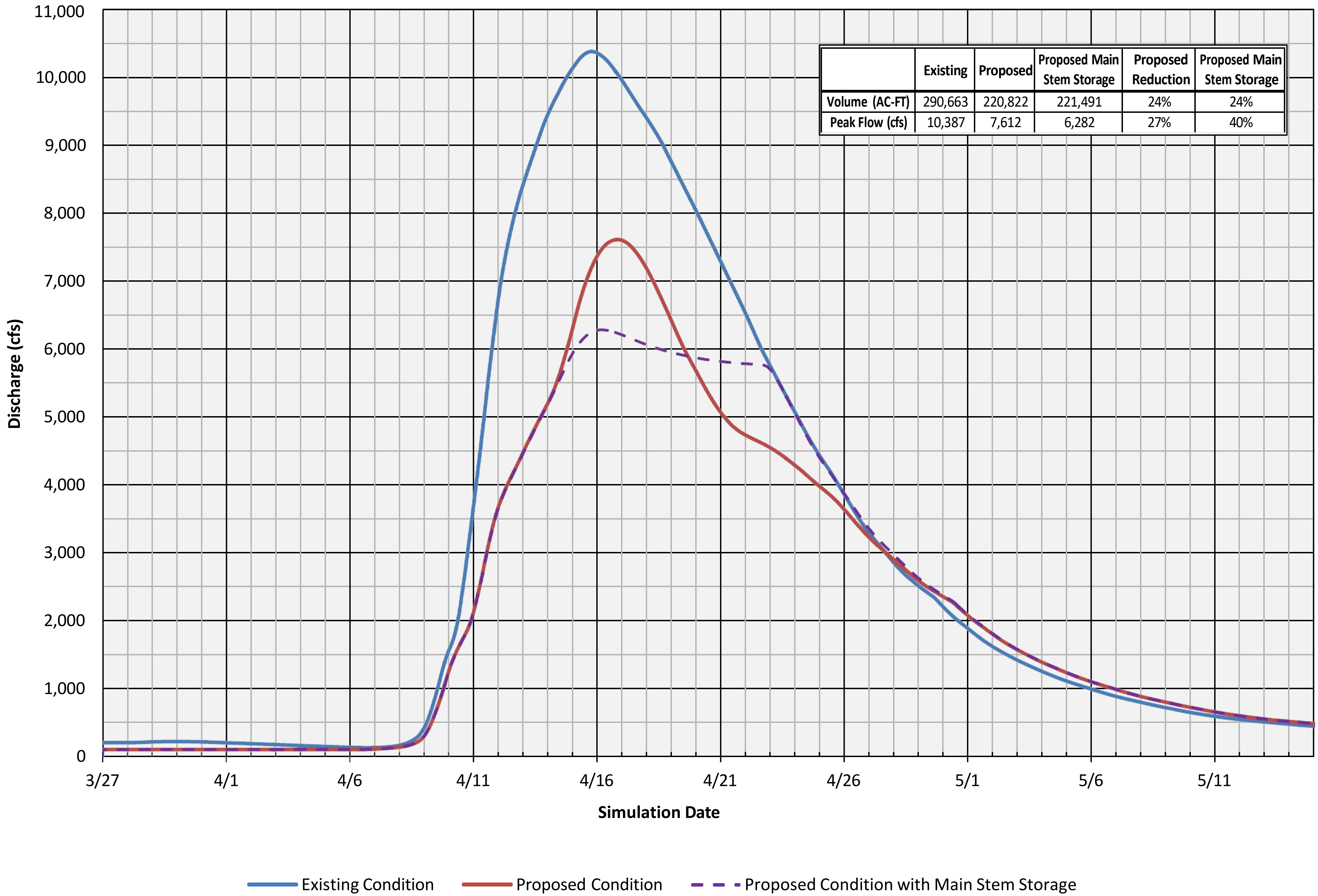
	Existing	Proposed	Proposed Main Stem Storage	Proposed Reduction	Proposed Main Stem Storage
Volume (AC-FT)	95,219	52,915	52,117	44%	45%
Peak Flow (cfs)	5,424	4,946	4,946	9%	9%

USGS Gage 05067500 Marsh River near Shelly, MN - **Figure 9**

Wild Rice River downstream of MN Hwy 9 - Ada, MN

Red River Basin Standardized Melt Progression

TR60 100-yr, 10-day Runoff Depths

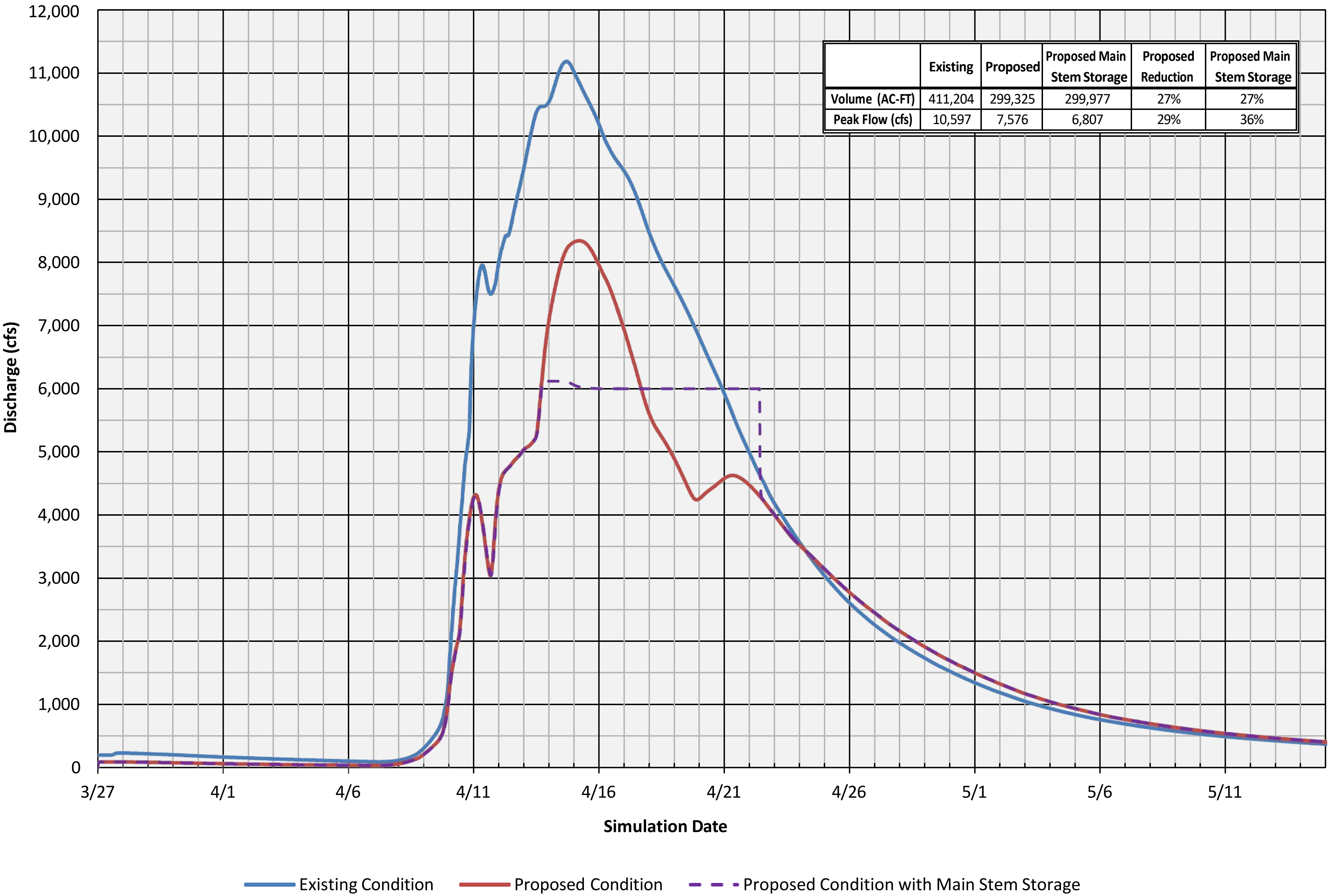


	Existing	Proposed	Proposed Main Stem Storage	Proposed Reduction	Proposed Main Stem Storage
Volume (AC-FT)	290,663	220,822	221,491	24%	24%
Peak Flow (cfs)	10,387	7,612	6,282	27%	40%

Wild Rice River downstream of MN Highway 9 - Ada, MN- **Figure 10**

USGS Gage 05062500 Wild Rice River at Twin Valley, MN

Red River Basin Standardized Melt Progression
TR60 100-yr, 10-day Runoff Depths

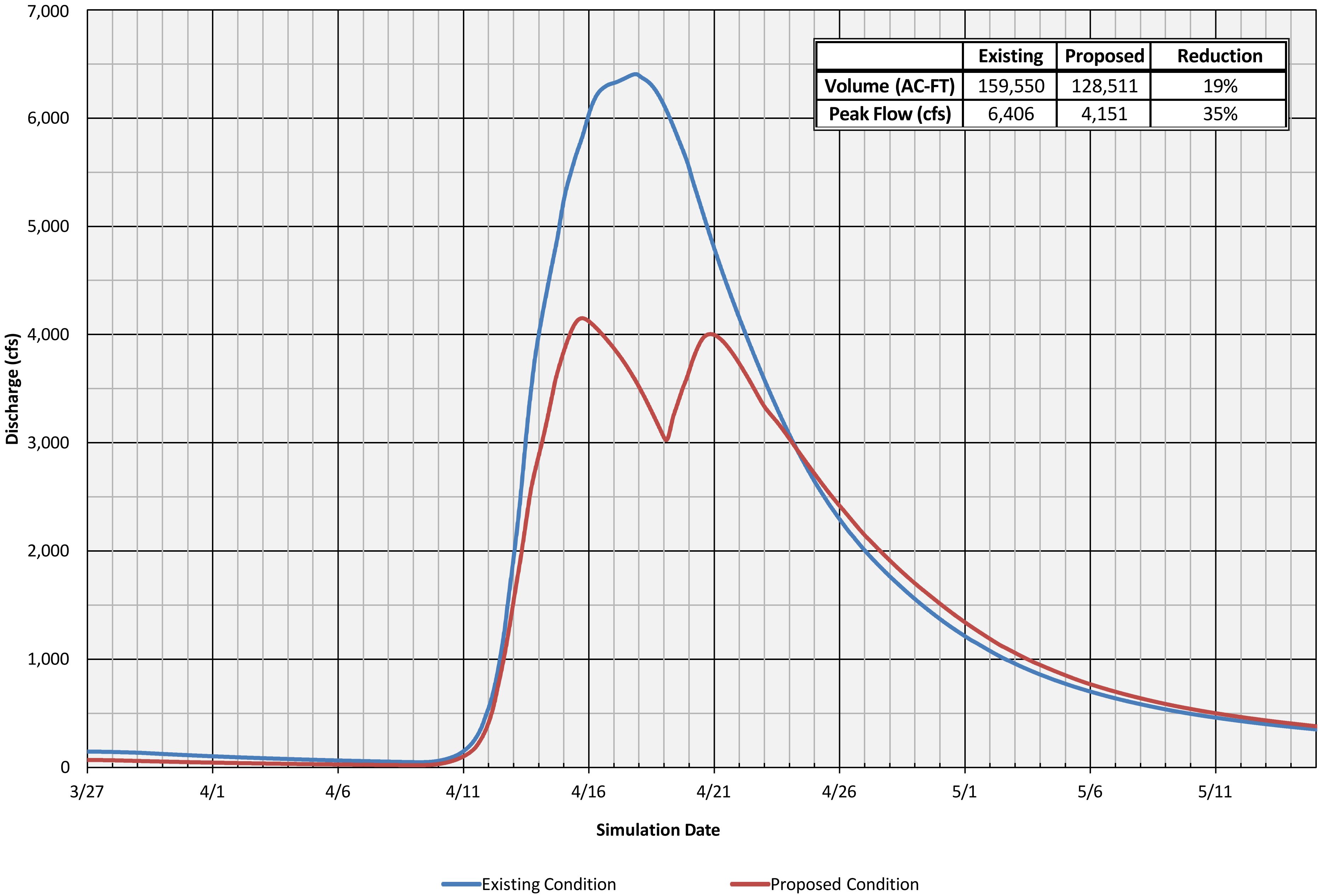


	Existing	Proposed	Proposed Main Stem Storage	Proposed Reduction	Proposed Main Stem Storage
Volume (AC-FT)	411,204	299,325	299,977	27%	27%
Peak Flow (cfs)	10,597	7,576	6,807	29%	36%

USGS Gage 05062500 Wild Rice River at Twin Valley, MN - **Figure 11**

Wild Rice River upstream of Mahnomen, MN

Red River Basin Standardized Melt Progression
TR60 100-yr, 10-day Runoff Depths



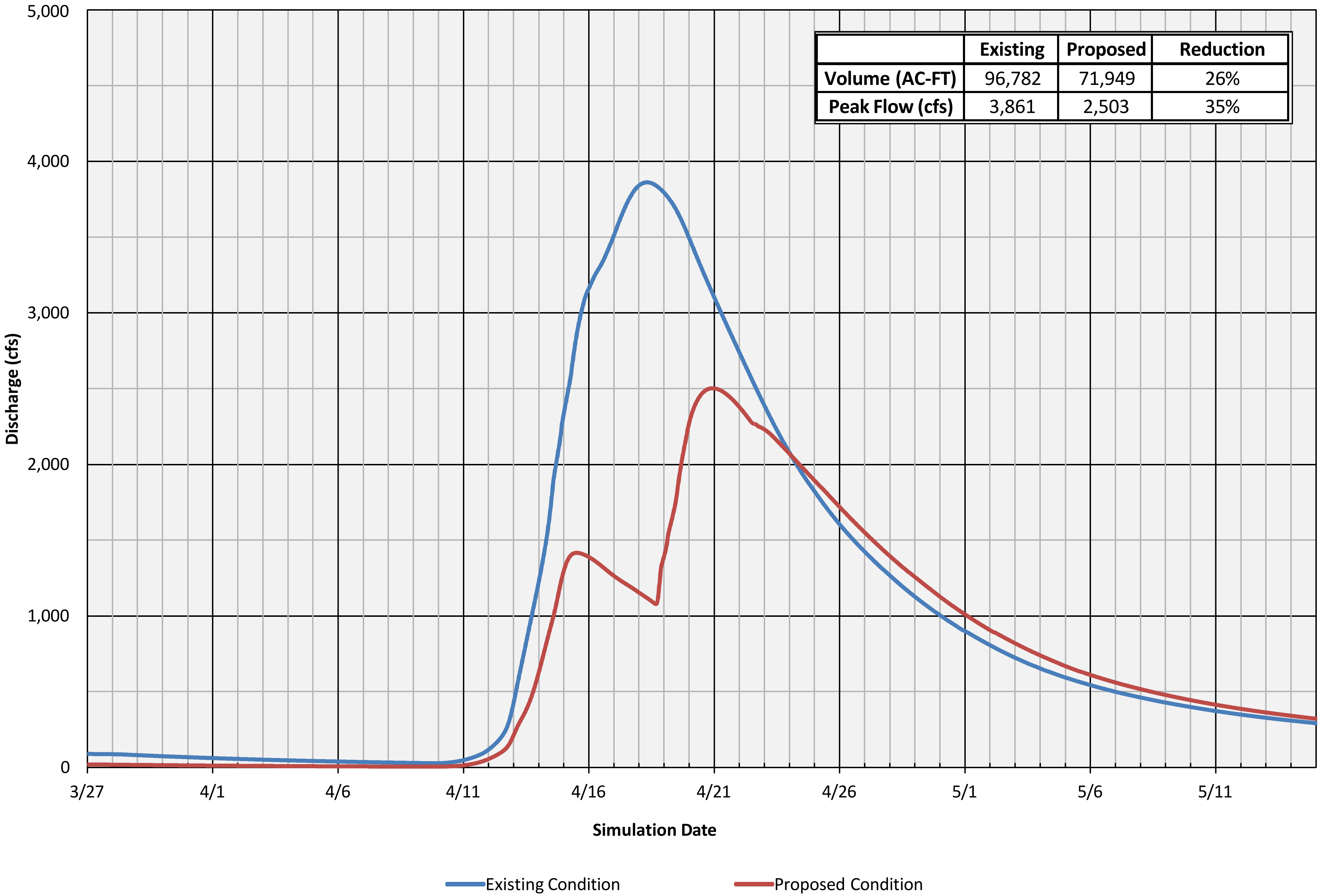
	Existing	Proposed	Reduction
Volume (AC-FT)	159,550	128,511	19%
Peak Flow (cfs)	6,406	4,151	35%

Wild Rice River upstream of Mahnomen, MN - **Figure 12**

Wild Rice River upstream of confluence with Twin Creek

Red River Basin Standardized Melt Progression

TR60 100-yr, 10-day Runoff Depths

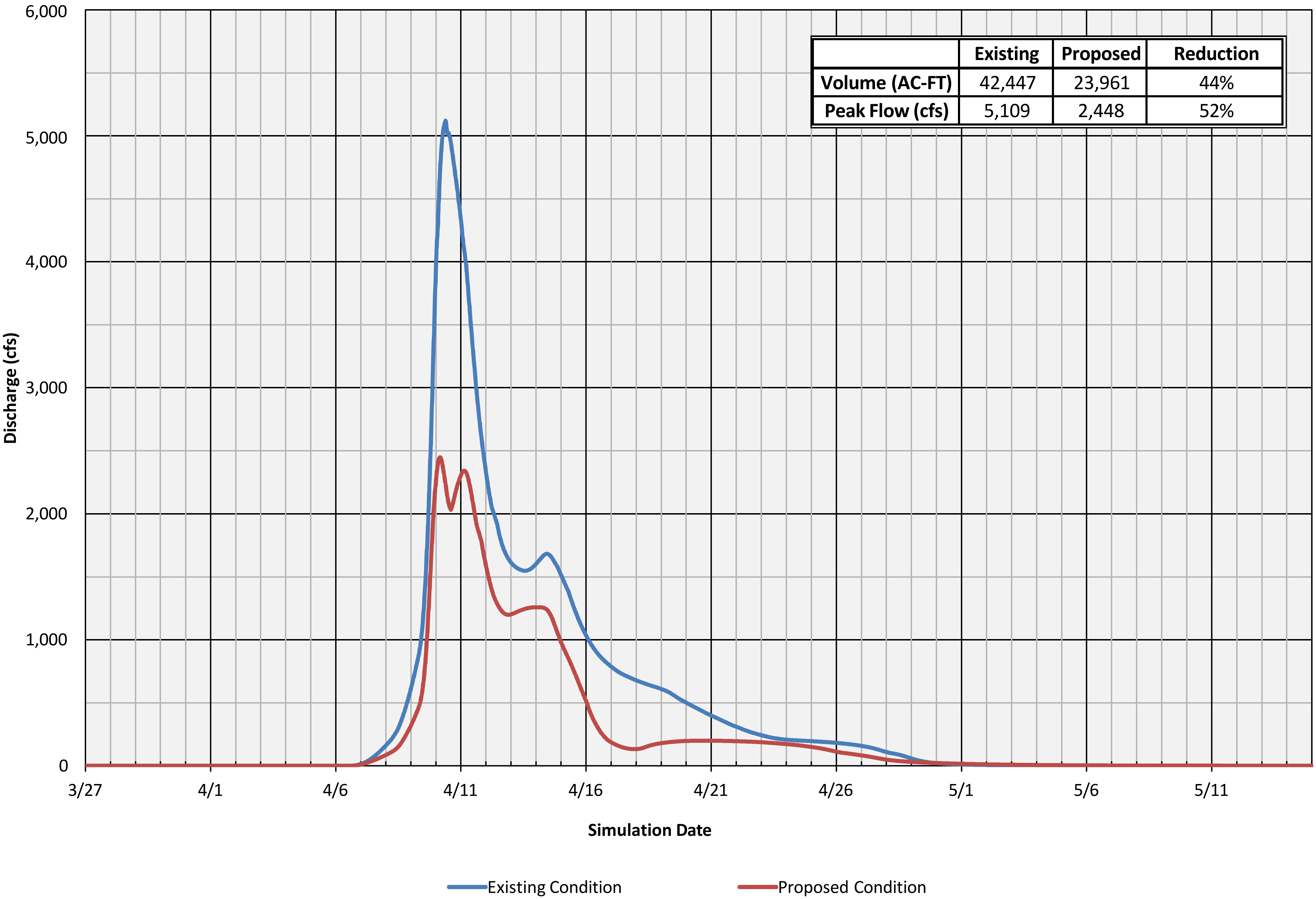


	Existing	Proposed	Reduction
Volume (AC-FT)	96,782	71,949	26%
Peak Flow (cfs)	3,861	2,503	35%

Wild Rice River upstream of confluence with Twin Creek **- Figure 13**

South Branch Wild Rice River upstream of Ulen, MN

Red River Basin Standardized Melt Progression
TR60 100-yr, 10-day Runoff Depths



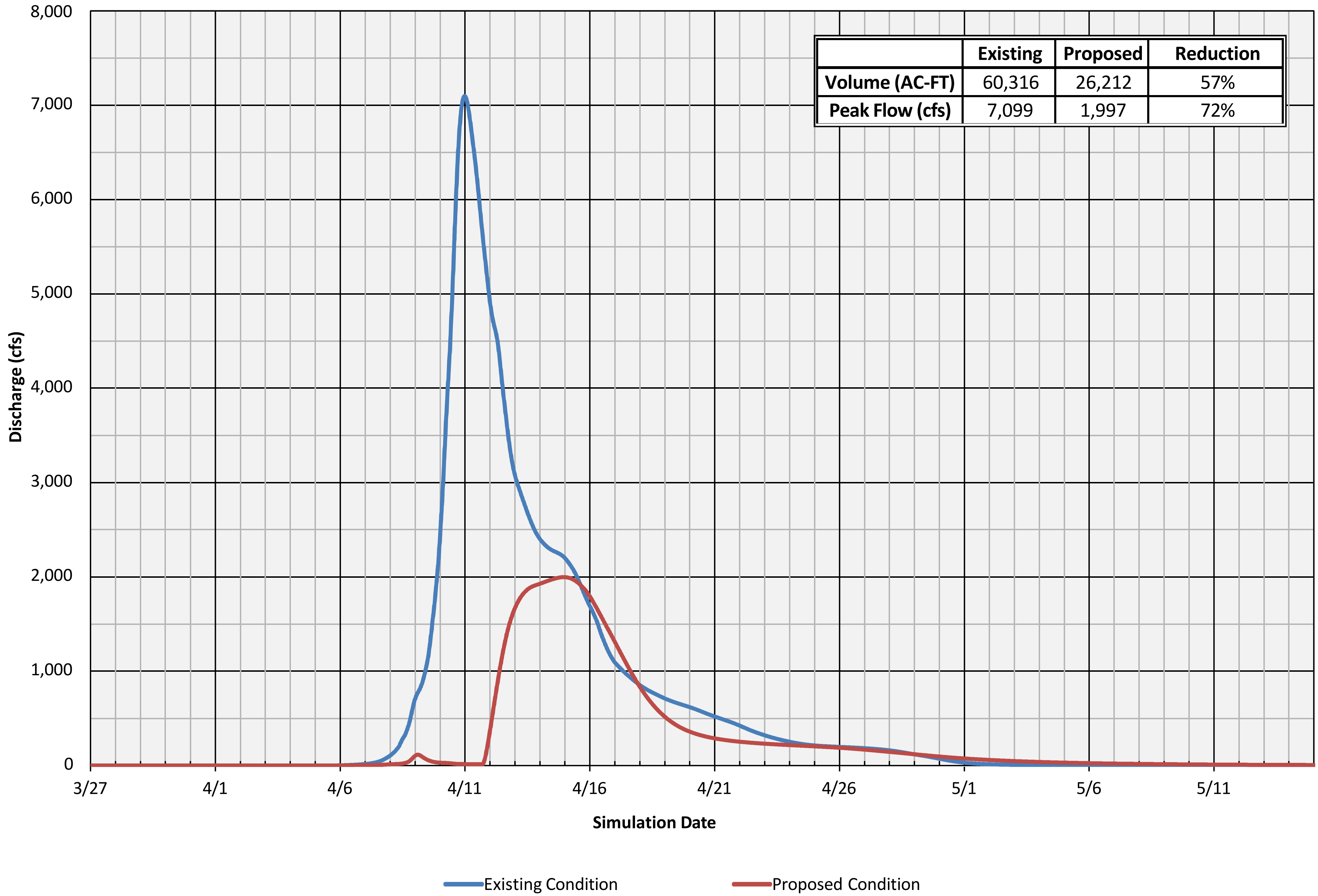
	Existing	Proposed	Reduction
Volume (AC-FT)	42,447	23,961	44%
Peak Flow (cfs)	5,109	2,448	52%

South Branch Wild Rice River upstream of Ulen, MN - **Figure 14**

South Branch Wild Rice River upstream of MN Hwy 9 - Borup, MN

Red River Basin Standardized Melt Progression
TR60 100-yr, 10-day Runoff Depths

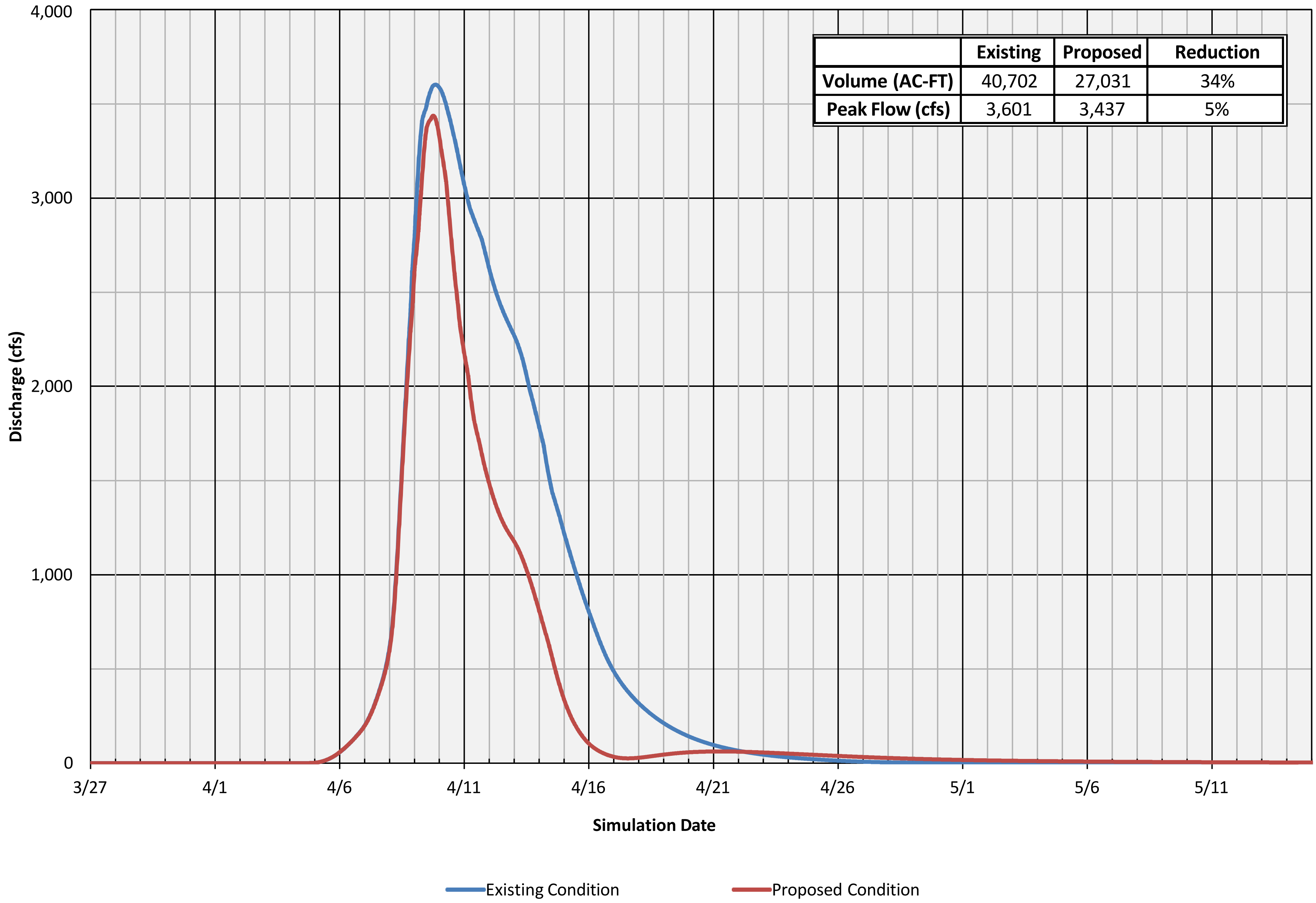
	Existing	Proposed	Reduction
Volume (AC-FT)	60,316	26,212	57%
Peak Flow (cfs)	7,099	1,997	72%



South Branch Wild Rice River upstream of MN Highway 9 - Borup, MN **- Figure 15**

Felton Ditch above confluence with Wild Rice River

Red River Basin Standardized Melt Progression
TR60 100-yr, 10-day Runoff Depths



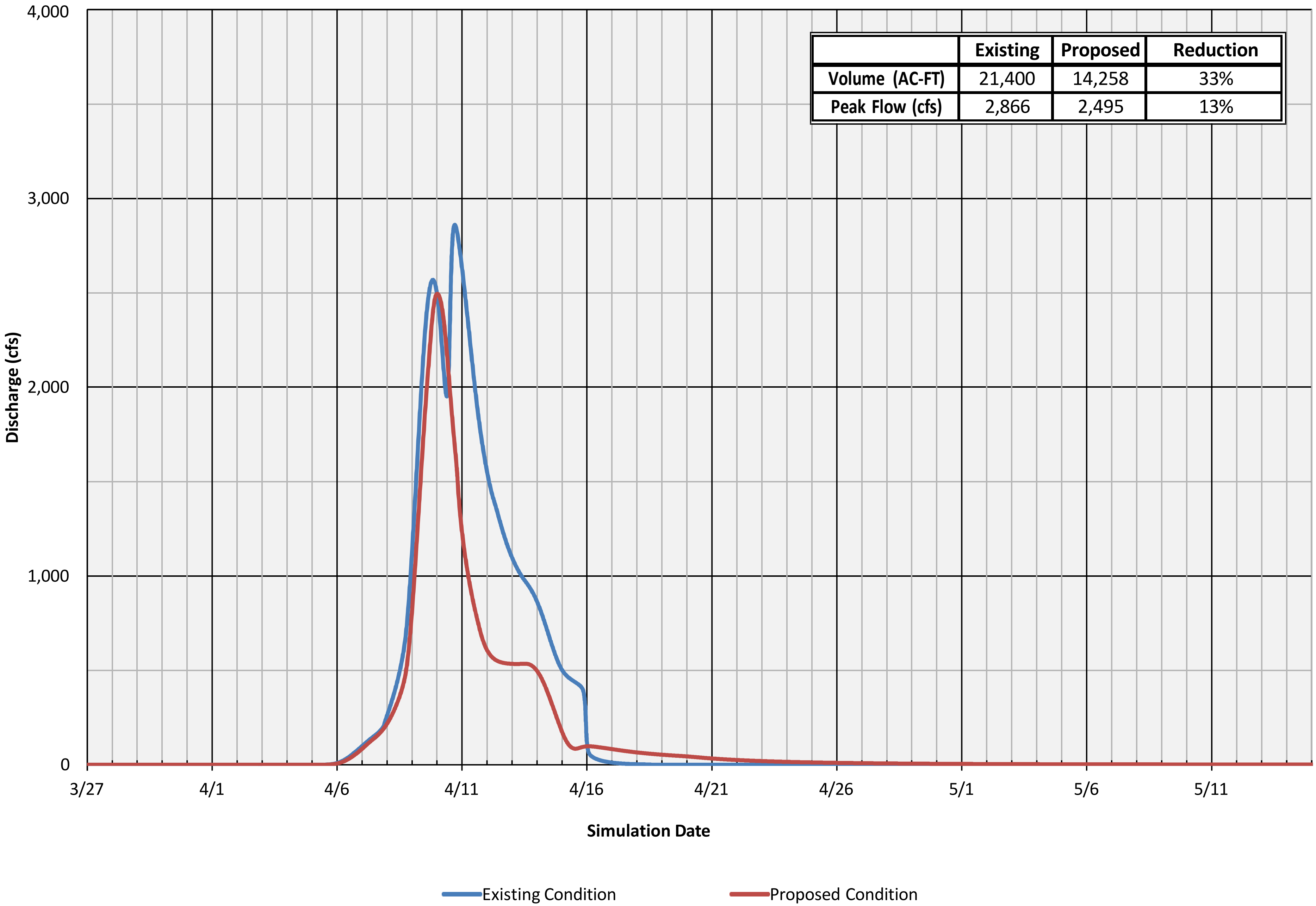
	Existing	Proposed	Reduction
Volume (AC-FT)	40,702	27,031	34%
Peak Flow (cfs)	3,601	3,437	5%

Felton Ditch above confluence with Wild Rice River - **Figure 16**

Norman Polk No. 5 above confluence with Red River

Red River Basin Standardized Melt Progression
TR60 100-yr, 10-day Runoff Depths

	Existing	Proposed	Reduction
Volume (AC-FT)	21,400	14,258	33%
Peak Flow (cfs)	2,866	2,495	13%



Norman Polk No. 5 above confluence with Red River - **Figure 17**