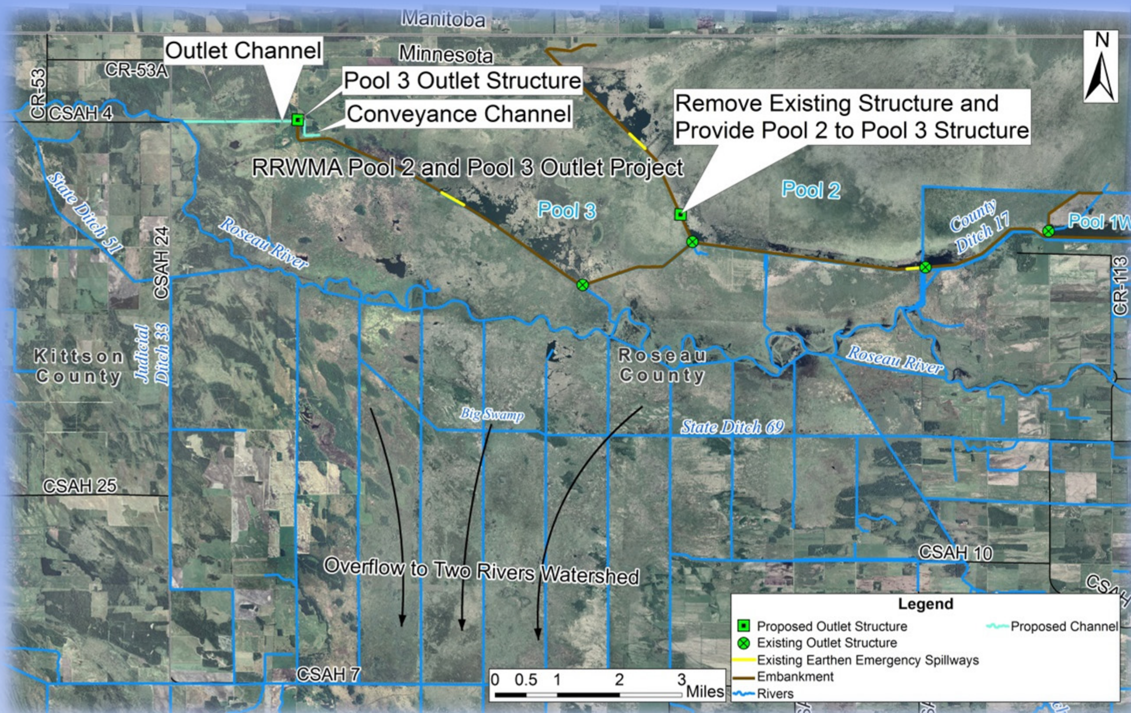
ROSEAU RIVER WATERSHED DISTRICT

ROSEAU RIVER WILDLIFE MANAGEMENT AREA POOL 2 AND POOL 3 OUTLET PROJECT



FINAL ENGINEER'S REPORT

In Cooperation With:

Minnesota DEPARTMENT OF NATURAL RESOURCES

HDR Project 179114
June 2014

HDR

324 2nd Street East
Thief River Falls, Minnesota 56701

Roseau River Watershed District
Roseau River Wildlife Management Area Pool 2 and Pool 3 Outlet

Final Engineer's Report

June 30, 2014

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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ACRONYMS AND SHORT FORMS

BMP	Best Management Practices
BWSR	Board of Water and Soil Resources
CD	County Ditch
CMP	Corrugated Metal Pipe
CN	Curve Number
DEM	Digital Elevation Model
EAW	Environmental Assessment Worksheet
EFM	Ecosystem Functions Model
EPA	Environmental Protection Agency
FDR	Flood Damage Reduction
fps	feet per second
FEMA	Federal Emergency Management Agency
FT	Foot
GIS	Geographic Information System
GPS	Geographic Positioning System
HEC	USACE Hydrologic Engineering Center
HMS	HEC Hydrologic Modeling System
IN	Inch
MnDOT	Minnesota Department of Transportation
MnDNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency
NAVD88	North American Vertical Datum of 1988
NGVD29	National Geodetic Vertical Datum of 1929
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service, formally the SCS
NRE	Natural Resource Enhancement
NWS	National Weather Service
PWT	Project Work Team
R	Clark Storage Coefficient
RAS	HEC River Analysis System
RCP	Reinforced Concrete Pipe
RRFDRWG	Red River Flood Damage Reduction Work Group
RRWD	Roseau River Watershed District
RRWMA	Roseau River Wildlife Management Area
SCS	Soil Conservation Service
SWCD	Soil and Water Conservation District

SWPPP Stormwater Pollution Prevention Plan
SWMM Stormwater Management Model
T_C Time of Concentration
USACE United States Army Corps of Engineers
USDA United States Department of Agriculture
USGS United States Geologic Survey
WSE Water Surface Elevation
WMA Wildlife Management Area

1.0 INTRODUCTION

In cooperation with the Minnesota Department of Natural Resources (DNR), the Roseau River Watershed District (RRWD) has prepared a Final Engineer's Report for the Roseau River Wildlife Management Area (RRWMA) Pool 2 and Pool 3 Outlet (Project) located in the northwest corner of Roseau County, Minnesota. The Project covers an area of over 74,000 acres, including about 10,600 acres of shallow water in four pools. It is managed to provide both wildlife benefits and flood control. The purpose of the Project will be to provide reduced peak flows downstream on the Roseau River by better timing outflows from the RRWMA, and taking better advantage of the existing storage in Pool 2 and Pool 3. For the purposes of this report, all elevations discussed in this report are in North American Vertical Datum of 1988 (NAVD88).

2.0 SUMMARY OF ACTIVITIES

2.1 BACKGROUND

The RRWD was formed on June 17, 1963 under provisions of Minnesota Statute 103D. The District covers portions of Beltrami, Lake of the Woods, Marshall, Kittson, and Roseau Counties. The District is flood prone; it is affected by repetitive flooding on a consistent basis. The primary reason for flooding in this area is due to topography. The west portion of the basin is the flat ancestral bed of Lake Agassiz; averaging 3 to 5 feet of elevation drop in per mile. When heavy rains fall on this flat area, the land is unable to drain quickly and flooding can result. Compounding the flooding is the fact that there are ridges and steeper topography in the southern and eastern portions of the watershed. These areas drain more quickly, and inundate the flatter land to the north and west.

In 1987, the Minnesota legislature established the Flood Damage Reduction (FDR) Grant Program to provide technical and financial assistance to local governments for flood hazard mitigation planning and implementation (Minnesota Department of Natural Resources, 2014). Since then, over 350 projects have been funded in part by this program. This program funds a portion of this Project.

In 2008, the USACE implemented the Red River Basin-wide Feasibility Study in cooperation with the Red River Watershed Management Board and the North Dakota Joint Water Resource District. This integrates several ongoing planning effors, which build upon the International Red River Board and Red River Basin Commission initiatives. Study tasks include collecting basin-wide LiDAR mapping data, refining hydrologic and hydraulic models to be used for project planning and flood forecasting, updating the floodplain information and management tools available on the Red River Basin Decision Information Network, developing a basin-wide flood storage strategy and developing a comprehensive watershed management plan. The study supports local officials' efforts to set reasonable and attainable goals that provide both local and regional benefits. Integration of individual hydrologic models with the main-stem model will be complete this year (U.S. Army Corps of Engineers - St. Paul District, 2014). The soils investigation completed by the USACE, located in Appendix C.2, was completed under this feasibility study.

2.2 PROJECT INCEPTION

The concept of this RRWMA Project has been in the planning stages for many years. In February 2006, the MnDNR Flood Damage Reduction (FDR) program awarded a 75% state funded grant to help fund a study intended to assess a project that would replace structures on the RRWMA. After a brief postponement, the RRWD applied for a MnDNR FDR grant in 2011to re-establish the RRWMA Project in order to proceed into the preliminary engineering stage. The RRWD appointed HDR to perform preliminary engineering services. HDR completed a preliminary engineer's report for review by the RRWD and the Minnesota Board of Water & Soil Resources (BWSR). In April 2013, BWSR completed an advisory report, in accordance with Minnesota Statutes, Section 103D.711, Subdivision 5 and Section 103D.605, Subdivision 2.

2.3 FLOOD DAMAGE REDUCTION APPROACH

The RRWD's flooding problems will not be solved with the construction of one project at one specific location. Only a comprehensive approach with many types of projects and various water management techniques will be successful in solving the flooding problems in the District. The Red River Flood Damage Reduction Work Group (RRFDRWG) Agreement of December 1998 is the framework for flood damage reduction projects in the Red River Basin. The RRWD works within the guidelines of the mediation process established by the RRFDRWG in the development of potential flood control projects. The purpose of the mediation process was to reach an agreement on long-term solutions for reducing flood damage and ensuring the protection and enhancement of natural resources. The primary focus of this agreement is to balance economic, environmental, and social considerations when planning and implementing flood damage reduction and natural resource enhancement projects in the District. The District encourages participation by local, state, and federal governments, natural resource agencies, conservation organizations, and local citizens in this planning process.

A Project Team was reorganized in 2010 and has met to discuss project planning and design elements. Project team membership has included:

- Todd Miller – RRWD Board
- Cody Schmalz – RRWD Board
- LaVerne Voll – RRWD Board
- LeRoy Carriere – RRWD Board
- Floyd Haugen – RRWD Board
- Aaron Magnusson – RRWD Board
- Tony Wensloff – RRWD Board
- Cary Hernandez - MPCA
- Brian Ketring – Roseau County HD
- Dick Novacek- Two Rivers WD
- Warren Stoe - Landowner
- Garry Bennett - DNR Waters
- Paul Telander – DNR Wildlife
- Phil Talmage - DNR Fisheries
- Randy Prachar – RRWMA Manager
- Kelly Urbanek - USACE
- Casey Olson - NRCS
- Brian Dwight - BWSR
- Scott Johnson – Roseau SWCD
- Marlin Elton – Dieter Twp.
- Danni Halvorson – IWI
- RRWD Staff and OTHERS

The Project Team has discussed the components addressed in this report; to the extent, that consensus has been achieved as an indication of willingness and agreement to participate by the District, State, and landowners in attendance at the meetings.

2.4 SUMMARY OF CHANGES SINCE PRELIMINARY ENGINEER'S REPORT

Since the development of the Preliminary Engineer's Report in February 2013, several scope and design changes have been made. These changes have also impacted the results of the project performance. The changes are summarized below.

Changes in Design

- Elevations in the Final Engineer's Report are in NAVD88 instead of NGVD29.
- The Conveyance Channel was reduced to extend the minimum distance needed to convey water to the Pool 3 Outlet Structure (about 2,200 feet upstream of Pool 3 Outlet Structure).
- The Conveyance Channel and Pool 3 Outlet Channel bottom width for the recommended Alternative has changed from 22 feet wide to 10 feet wide in the Final Engineer's Report.
- A second alternative for the Pool 3 Outlet Channel was examined in which the channel is placed on the north side of 400th street.
- The vertical profile of 400th Street is proposed to be raised with spoil material to reduce the amount that needs to be wasted along the Outlet or Conveyance Channel alignment, decreasing wetland impacts.
- The Pool 2 to 3 Structure will be located at the location of the existing inoperable hydraulic structure, which will be removed.
- The proposed Pool 3 Outlet Structure will have two gates and two stoplog bays instead of three gates and one stoplog bay for more flexible control of Pool 3 water surface elevations.

Changes in Hydrology and Hydraulics

- The hydrologic model utilized in the Final Engineer's Report is the USACE Red River Basin-wide HEC-HMS model. The hydrologic model utilized in the Preliminary Engineer's Report was the District HEC-1 model, originally developed by JOR Engineering.
- As a result of using the USACE HEC-HMS model, drainage areas, curve numbers, rainfall distribution, and time of concentrations were updated.
- Design storm events were updated to reflect the recently developed NOAA Atlas 14 data. This resulted in larger runoff volumes and peak flows for the 100-year events.
- A sensitivity analysis was performed to examine a range of trigger points in which to close the gates and stoplogs in order to maximize the reduction in peak flow on the Roseau River. It was also determined that a two-stage closure of the gates is more beneficial than closing the gates entirely at one time.

- Three synthetic events were analyzed to determine how the project would be able to reduce the maximum bounce in the pools. A 4.75-inch 24-hour event, 3.7-inch 24-hour event, and 2.8-inch 24-hour event were analyzed.

Changes in Results

- Due to the updated design storm events, overall existing and proposed flow rates decreased for the 10-year 24-hour event and increased for the 100-year 24-hour and 100-year 10-day events. The percent reduction in peak flow at Caribou for the proposed events slightly decreased for the 100-year 10-day and 10-year 24-hour events, and remained approximately the same for the 100-year 24-hour event, compared with results in the Preliminary Engineer's Report.
- As a result of the updated modeling, compared with the Preliminary Engineer's Report, inflows to the Big Swamp from Pools 2 and 3 decreased, resulting in more storage available in the Big Swamp.
- Overflow volume reductions to the Two Rivers Watershed slightly decreased compared with the Preliminary Engineer's Report. Overflow peak flow reductions decreased slightly for the 100-year 10-day event and remained approximately the same for the 100-year 24-hour event.
- Due to the improvement in the operation plan, bounce reduction in Pools 2 and 3 is dramatically improved compared with the Preliminary Engineer's Report, for all events.
- The duration of time that vegetation inside Pools 2 and 3 is inundated is generally improved, compared with the Preliminary Engineer's Report.
- After the wetland delineation was completed in 2013, estimates for proposed wetland disturbance area decreased by about 90% compared with the Preliminary Engineer's Report.
- Due to the reduced scope of the project, the recommended Alternative has reduced in overall cost from $3.6 million to about $2.5 million.

3.0 PROJECT SETTING

The project is located within four miles of the Canadian border, in northwestern Roseau County, Minnesota. The primary sources of water for the RRWMA are the Pine Creek Diversion and the Sundown Bog, both of which are in Manitoba. The Pine Creek Diversion takes the majority of water from Pine Creek and brings it into Pool 1 West. The location of the Pine Creek is illustrated in Figure 3. The Sundown Bog flows directly into Pool 2. Pool 1 East is fed by its own drainage area and discharges to a County Ditch.

A large portion of the project's drainage area is classified as woody wetland or emergent wetland, with portions of the upstream drainage area consisting of agricultural land and land that has reverted to conservation lands. The RRWMA is bordered to the east and south by agricultural land, pasture, and conservation land, and bordered to the west and north by areas of deciduous forest, pasture, agricultural land, and emergent wetlands.

The project area is located in the Aspen Parklands biome, which was a part of the lake plain of Glacial Lake Agassiz. The Aspen Parklands can be described as a fire-maintained mosaic of wet prairie, sedge meadow, shrub thicket, and aspen groves. The topography of the area is quite flat. A series of low beach ridges and swales can be found west of the project area, in the lacustrine plain portion of the Aspen Parklands. The area of the biome occupied by the project contains water re-worked till plain with herbaceous wetlands, substantial peat deposits, and low relief.

Figure 1 shows the project location with respect to the Roseau River Watershed District, Roseau County, and the State of Minnesota. The project drainage area is found in Figure 2. Pools 1, 2, and 3 have a combined drainage area of 202 square miles and provide storage for floodwaters from this area.

FIGURE 1. PROJECT LOCATION

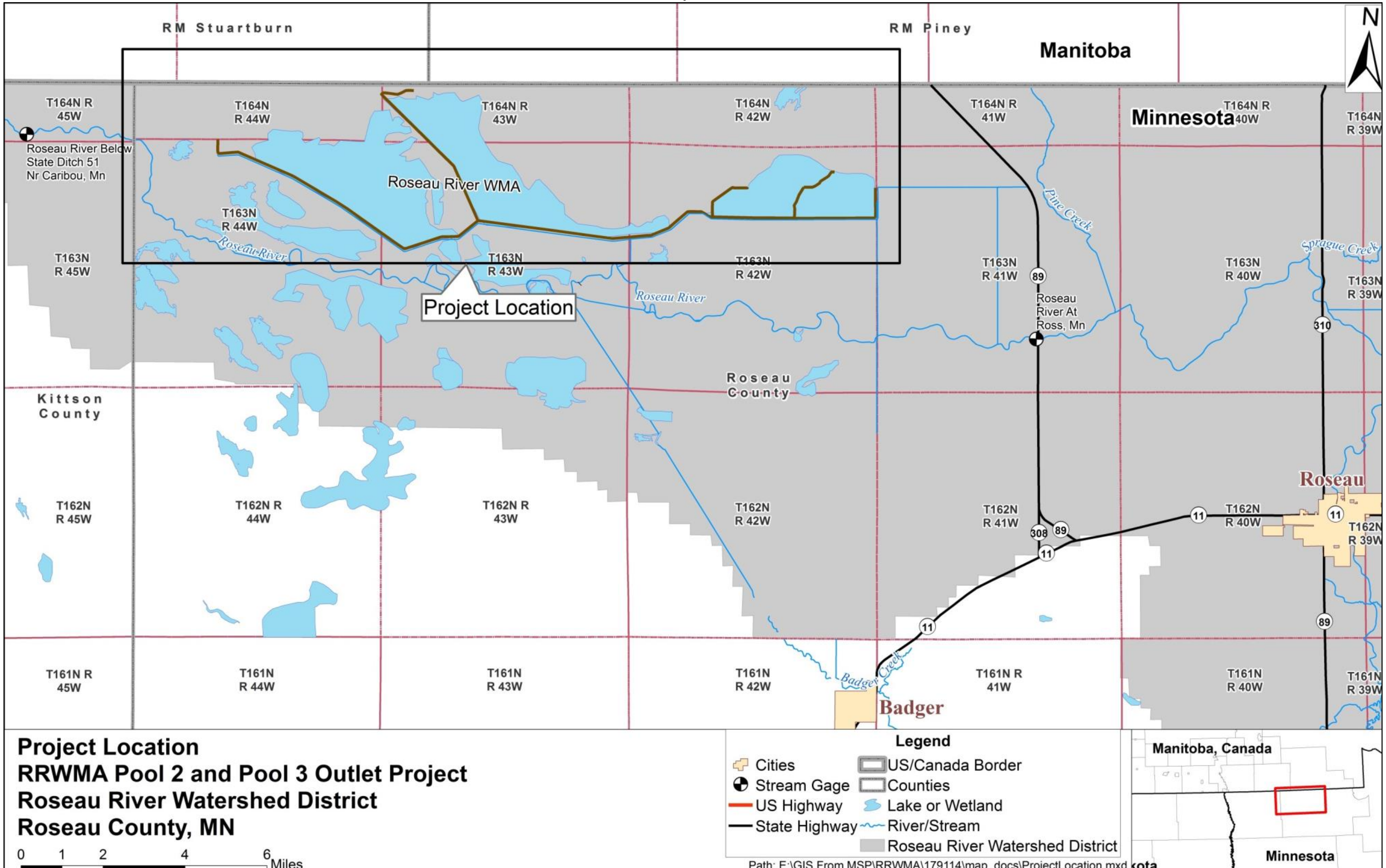
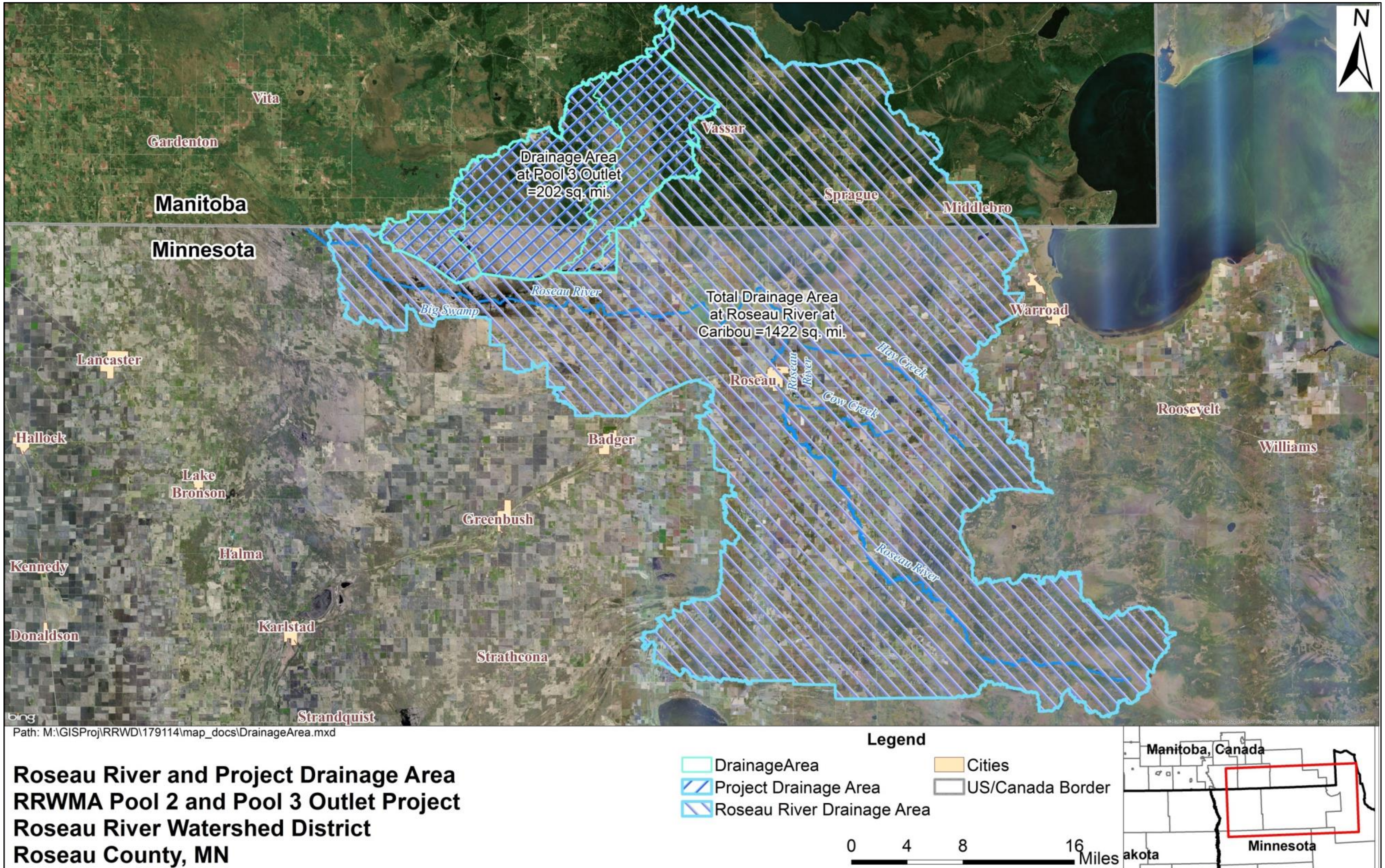


FIGURE 2. DRAINAGE AREA



4.0 PROJECT NEED

4.1 FREQUENCY OF FLOODING

The area is prone to frequent and damaging floods. The threshold for significant flood damages for the Roseau River near Caribou, MN is about 3,000 cubic feet per second (cfs). The largest runoff event recorded in the Roseau River watershed occurred in June 2002. This occurred after over nine (9) inches of rain fell across the watershed during the previous two weeks, which included a 6.8-inch 3-day duration rainfall event (National Oceanic and Atmospheric Administration, 2014). The 6.8-inch 3-day duration rainfall has a recurrence interval of somewhere between once in every 50 to 100 years. This event combined with other smaller events in the weeks surrounding it made for one very large runoff event. The peak discharge for this event at the Roseau River near Caribou gaging station was over 4,300 cfs. Table 1 lists the top twenty annual peak flood events on the Roseau River below State Ditch 51 near Caribou, MN (USGS Gage # 05112000).

TABLE 1. HISTORIC ANNUAL PEAK EVENTS AT ROSEAU RIVER BELOW STATE DITCH 51 NEAR CARIBOU, MN (USGS GAGE #05112000)

Date	River Stage (ft)	Peak Elevation (NAVD88) (ft)	Peak Flow (cfs)
June 24, 2002	11.91	1015.58	4,320
May 19, 1950	11.81	1015.48	4,080
May 31, 2004	10.78	1014.45	3,480
May 18, 1996	10.78	1014.45	3,350
May 8, 1997	10.74	1014.41	3,320
May 1, 2009	10.46	1014.13	3,240
May 24, 1927	N/A	N/A	3,170
April 28, 1966	10.34	1014.01	3,120
April 25, 2011	10.1	1013.77	3,000
May 2, 1923	N/A	N/A	2,980
May 8, 1979	10.11	1013.78	2,980
April 19, 2006	10.2	1013.87	2,970
May 15, 1970	10.05	1013.72	2,940
April 14, 2001	10.13	1013.80	2,920
May 14, 1974	9.68	1013.35	2,720
May 6, 1965	9.64	1013.31	2,690
April 22, 1999	9.6	1013.27	2,590
May 8, 1975	9.39	1013.06	2,540
May 26, 2014	9.43	1013.10	2,570
April 28, 1969	9.28	1012.95	2,480

Note: Datum of gage is 1003.67 (NAVD88)

HDR performed a Log-Pearson Type III analysis of maximum annual flood data from the past 95 years of recorded data at the Roseau River at Caribou, to determine the flood recurrence interval. Based on this data, the recurrence interval for significant flood damages at this location is approximately 1 in 10 years. A flow of 3,000 cfs has been surpassed three times in the past ten years, and suggests an increase in the frequency of significant flooding in recent years. See Table 2 for the results of the flood frequency analysis.

TABLE 2. FLOOD FREQUENCY AT ROSEAU RIVER BELOW STATE DITCH 51 NEAR CARIBOU, MN

Recurrence Interval (Year)	River Stage (ft)	River Water Surface Elevation (NAVD88) (ft)	Peak Flow (cfs)
200	12.1	1015.8	4,260
100	11.8	1015.5	4,030
50	11.5	1015.2	3,770
25	11.1	1014.8	3,460
10	10.4	1014.1	2,970
5	9.6	1013.3	2,510
2	8.0	1011.7	1,710

4.2 PROBLEMS WITH EXISTING PROJECT

The Roseau River Wildlife Management Area Preliminary Concept Report, by JOR Engineering (JOR Engineering, Inc., 2006), states that the current problems in the RRWMA are:

"Management of water levels is a critical element of the operation of the RRWMA. Management of water levels has implications for vegetation and habitat management and nesting success for waterfowl. The RRWMA pools also provide flood control benefits through diversion and storage of floodwaters".

"The capacity of the existing outlet structures is not adequate to control pool levels when major inflows occur. Excessive pool bounce during the productive season, can cause damage to over water nesting and nearby ground nesting. The ability to periodically draw down and maintain lower pool levels is also important for vegetation management. This includes the need to periodically control water levels well below the 'normal' pool level. By drawing down and then gradually raising pool levels over a period of years, vegetation can be more effectively managed to provide the essential diversity of habitats".

"The flood storage capacity of the pools is often used up prior to the occurrence of peak flow on the Roseau River below State Ditch 51 near Caribou, MN (USGS Gaging Station #05112000) and during a period when the river could easily handle additional outflow from the pools. This early storage provides much less flood control benefit than would result if storage were available during the peak flow period. The location of the existing outlets, which discharge into the Big Swamp, further delays the transport of released water to the Roseau River at Caribou".

"High flow in this reach of the Roseau River causes flooding problems in multiple areas. Flood damages occur downstream along the river at Caribou and in Canada, in the Two Rivers watershed due to breakout flows, and in agricultural areas upstream."

Table 3 provides the pre- and post-project impact on agricultural lands, county and township roads, and major bridges and culverts.

TABLE 3. 100-YEAR FLOODPLAIN, ROADWAYS, AND BRIDGES

Location/Description	Pre-Project	Post-Project
AGRICULTURAL LAND IN FLOODPLAIN (MI^2)	59.5	57.6
COUNTY AND TOWNSHIP ROADWAYS (MILES)	35.5	31.5
MAJOR BRIDGES & CULVERTS	5	5

4.3 SOLUTIONS

As referenced in the Roseau River Watershed District's FDR Grant Application (Roseau River Watershed District, 2011), the purpose of the project is to:

- Address the need to repair or replace the failing control structure between Pools 2 and 3;
- Improve water level management on the RRWMA for vegetation management;
- Control pool bounce on the RRWMA to improve nesting success;
- Provide more efficient flood storage on the RRWMA;
- Provide flood damage reduction downstream at Caribou by decreasing peak flows at Caribou;
- Manage storage and flow release in beneficial consideration of Red River peak flows;
- Provide flood damage reduction in the Two Rivers Watershed District by reducing Roseau River overflows over County Road 7 and into State Ditch 72 and overland flows in Juneberry and Polonia Townships and on Two Rivers;
- Provide flood damage reduction in agricultural areas upstream and south of the Big Swamp along the Roseau River in Moose, Soler, Dieter, and Pohlitz Townships.

Solutions include:

- Improve timing of water storage and release from the RRWMA to reduce peak flows on the Roseau River
- Provide an option to move outflows to the Roseau River downstream of the Big Swamp.
- Improve water transfer between Pools 2 and 3 by replacing and improving the control structures between Pools 2 and 3.
- Improve the water control on Pool 3 by constructing a new outlet from Pool 3.
- Develop an operating plan.

5.0 EXISTING PROJECT FEATURES

5.1 OUTLET STRUCTURES

The current project has several structures in place to transfer flows between pools or out of the system to the Roseau River, as shown in Figure 3. Two existing structures are located on the dike wall between Pools 2 and 3. The northern structure (Figure 3) has not been operated in years, and is considered to be no longer operable. The southern structure is a gate and stoplog bay located inside a 6-foot diameter riser pipe, that outlets through a 48-inch diameter corrugated steel pipe (CSP) (Figure 3). This structure has limited capacity to pass flow from Pool 2 to Pool 3. The existing Pool 2 Outlet Structure (Figure 3) is located approximately two miles from the upstream end of Pool 2. The existing Pool 3 Outlet Structure (Figure 3) is located at the southernmost corner of the Pool 3 dike, also near the upstream end of Pool 3. It consists of a combination of a gate, two stoplog bays, and a concrete spillway weir. Overall, the combination of structures are too undersized to be able to quickly discharge flows to provide significant flood timing and storage benefits. This is detrimental because of the inability to discharge significant flows ahead of the peak flow on the Roseau River.

5.2 OUTLET CHANNELS

The location of the existing Pool 3 Outlet Channel and Outlet Structure is unfavorable to providing flood control benefits. The channel is located near the upstream end of the pool, as shown in Figure 3. Water discharged at this location enters the Roseau River near the middle of the constricted Big Swamp area, increasing water surface elevations (WSE) and flooding in the rural populated areas upstream of the Big Swamp. Releasing flows to the Big Swamp before the peak period of flooding decreases the storage capacity of the Big Swamp. Releasing water at this location also exacerbates the amount of water that overflows to the Two Rivers watershed.

5.3 EMERGENCY SPILLWAYS

There are currently two emergency spillways on the Pool 2 dike, and one emergency spillway on the Pool 3 dike, as shown in Figure 3. The emergency spillways are earthen, with sheetpile placed parallel to and within the dike to prevent erosion. The emergency spillways have an approximately 15-foot crest width. They have varying crest lengths and elevations. This information is summarized in Table 4.

TABLE 4. EXISTING EMERGENCY SPILLWAYS

Location/Description	Crest Length (ft)	Elevation (ft) (NAVD88)
POOL 2 TO POOL 3	350	1031.35
POOL 2	350	1031.85
POOL 3	250	1025.85

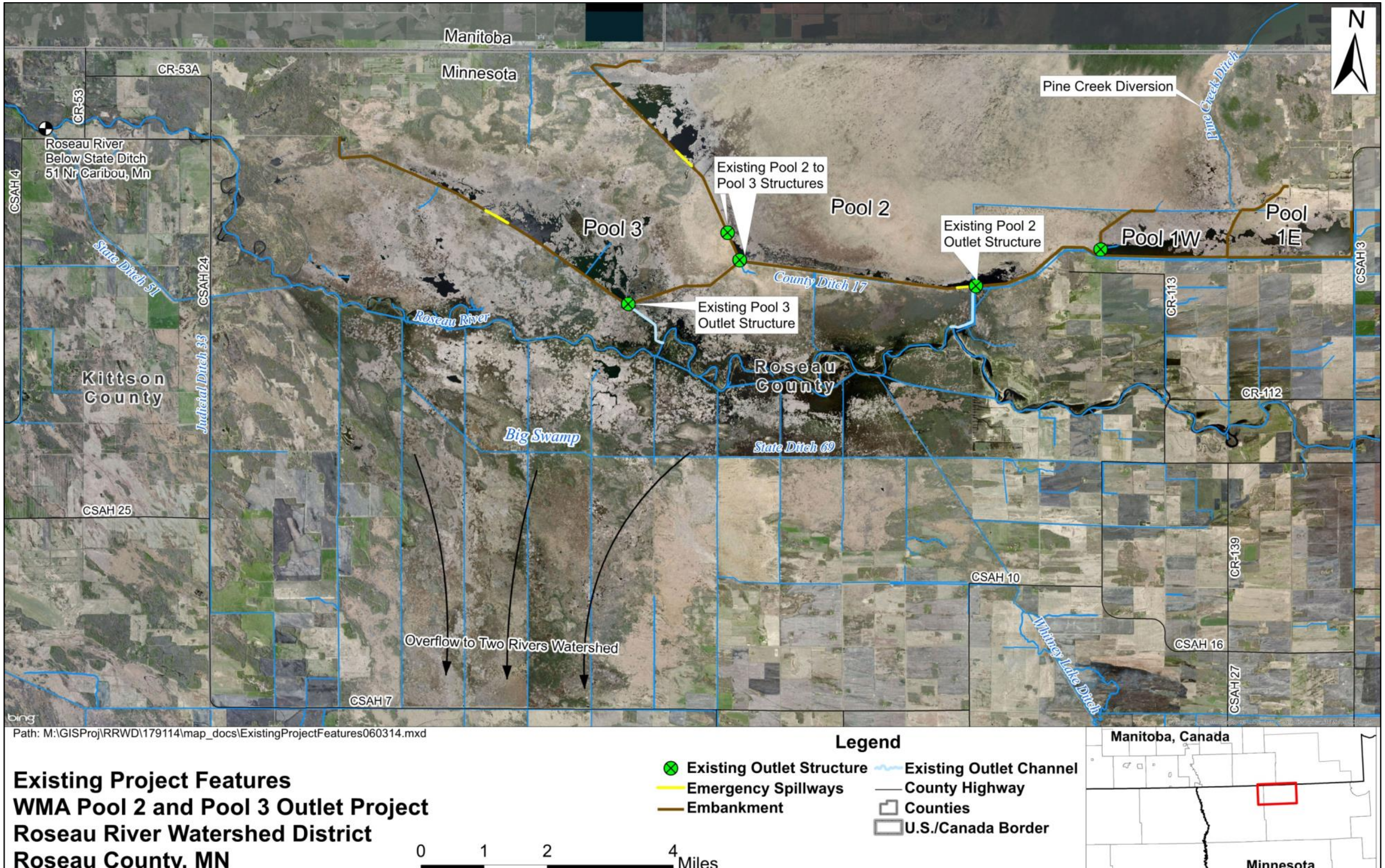
Source: (JOR Engineering, Inc., 2006)

TABLE 5. EXISTING PROJECT DESIGN SUMMARY

Feature	Pool Description	
	Pool 2	Pool 3
TOP OF EMBANKMENT (NAVD88) (FT)	1034.35	1029.35
NORMAL POOL ELEVATION (NAVD88) (FT)	1030.35	1025.35
POOL AREA (ACRE)	4,600	3,700
TOTAL CONTROLLED STORAGE (AC-FT)	12,800	4,500

Source: (JOR Engineering, Inc., 2006)

FIGURE 3. EXISTING PROJECT FEATURES



6.0 HYDROLOGY

6.1 HYDROLOGIC MODEL

JOR Engineering, Inc. developed a rainfall-runoff model for the existing conditions in the Roseau River Watershed District using the HEC-1 software. This model is referred to as the District Model. A HEC-HMS model of the watershed was developed by the USACE using the District Model as a reference along with recently acquired LiDAR and a consistent methodology with other Red River basin watershed models. The USACE HMS-Model was calibrated to storm events of 10-day and 24-hour durations and used to develop project hydrographs. The downstream portion of the RRWMA and Roseau River near the Caribou gage was converted to an EPA-SWMM (SWMM) model in order to compare existing and proposed hydraulic conditions. The reasons for using EPA-SWMM are described in section 7.1. All elevations from this model are reported in NAVD88 feet.

6.2 SUBWATERSHEDS

Figure 2 shows the watershed for the RRWMA and the entire Roseau River watershed to the Roseau River at Caribou. The majority of the Project's drainage area is in Canada and a large portion of the drainage area comes from a diversion of the Pine Creek. The total drainage area for the RRWMA is about 202 square miles. The contributing drainage areas are summarized in Table 6 below.

TABLE 6. CONTRIBUTING DRAINAGE AREAS AT SPECIFIC LOCATIONS

Location	Drainage Area (mi^2)
POOL 1W OUTLET	77.1
POOL 2 OUTLET	179.7
POOL 3 OUTLET	202.0
BIG SWAMP OUTLET	1431.4
ROSEAU RIVER AT CARIBOU	1458.7

6.3 DESIGN STORM EVENTS

The Project design is based on the 10-year 24-hour, 100-year 24-hour, and 100-year 10-day storms, which are used to evaluate the proposed features. Design storm rainfall depths are from Atlas 14 Volume 8 (2013). A gridded design storm rainfall depth was used to assign depths to various portions of the Roseau watershed. The design storm events were calculated in GIS using an average value of rainfall across the watershed. Average rainfall depths across the project watershed are presented in Table 7 below.

During the 100-year 10-day event, frost is assumed to still be in the ground, so there are no runoff losses, as described in Section 6.5. Due to this, and fact that the 100-year 10-day precipitation values from NOAA Atlas 14 are much greater than previous values used in the original District Model by JOR Engineering, the modeled USACE HEC-HMS peak flow on the Roseau River at Caribou is greater than any flow previously recorded at that location. As shown in Table 8, the 100-year 10-day event has a modeled peak flow of 4,728 cfs at Caribou. The largest flow recorded in the Roseau River Watershed, in June 2002, was 4,320 cfs at the Roseau River USGS Gage at Caribou. The reason the modeled flow is larger than the June 2002 event is because the 2002 event was a summer event, when there are significant runoff abstractions.

TABLE 7. DESIGN STORM EVENTS

Event	Precipitation (in.)
10-YEAR 24-HOUR	3.36
100-YEAR 24-HOUR	5.68
100-YEAR 10-DAY	8.32

Source: (National Oceanic and Atmospheric Administration, 2013)

6.4 DESIGN RAINFALL DISTRIBUTION

Since the release of NOAA Atlas 14, the SCS Type II rainfall distribution is no longer the recommended rainfall distribution. All storm events are distributed using the Atlas 14 rainfall distribution curve. The most frequent 50% probability 1^{st} quartile was used. While the 24-hour hyeotgraph was available in Atlas 14, a 10-day hyetograph was not provided in Atlas 14. The 96-hour hyetograph was scaled to obtain a 10-day hyetograph.

6.5 RUNOFF LOSSES

Losses are attributed to initial abstraction, infiltration, evaporation, and groundwater and surface water storage. Surface runoff is defined as the difference between total precipitation and total losses. Ten-day duration storms represent typical spring runoff events where most of the runoff is due to spring snow melt. Twenty-four hour duration storms represent typical summer storms and are not typically attributed to snowmelt runoff.

6.5.1 10-DAY EVENTS

Since it is assumed that the ground is fully saturated and frost is still in the ground, loss rates were set to zero.

6.5.2 24-HOUR EVENTS

Twenty-four hour duration storm events used the SCS Curve Number method. Factors affecting curve number values include hydrologic soil group, hydrologic condition and antecedent moisture condition, land cover, and cropping practice (Gupta, 2008). For 24-hour events, the USACE HEC-HMS model uses curve numbers ranging from 64 to 84. The median curve number across all subbasins is 75.

6.6 TIME OF CONCENTRATION

Time of concentration is defined as the travel time of a water drop from the hydraulically most remote point in the subbasin to its outflow location (Gupta, 2008). Its value is based on the physical characteristics of a watershed, in terms of basin slope, flow length, and roughness coefficient.

The initial time of concentration data in the USACE HEC-HMS model was developed using a Minnesota DNR GIS program that estimates travel times based on land slope, land use, and degree of channelization. The initial time of concentrations were then calibrated to several historic storm events. Time of concentration varies across subbasins from 6 to 70 hours. The median subbasin time of concentration is 20 hours.

6.7 UNIT HYDROGRAPH SHAPE

The District Model uses the Clark synthetic unit hydrograph transformation. This method requires time of concentration (T_c) and the storage coefficient (R) as inputs to this method. Studies have found that the storage coefficient, divided by the sum of the time of concentration and storage coefficient, is reasonably consistent over a region. A USACE study of various gages in the Red River Basin was used to estimate watershed ratios of R/(R+Tc) (U.S. Army Corps of Engineers - St. Paul District, 1990).

6.8 PEAK OUTFLOWS

Table 8 provides existing peak flows and total volumes of flow through various locations relevant to the Project. Peak flows and volumes are reduced from the Big Swamp to the downstream Caribou gage because of attenuation through the Big Swamp and flow transfer to the Two Rivers watershed. The 100-year 24-hour event peak flow of 2,956 cfs compares with the June 2002 peak flow of 4,320 cfs. This indicates the June 2002 event is reflective of a recurrence interval of once in more than 200 years. Hydrographs for existing conditions on the Roseau River near Caribou may be found in Figure 24 through Figure 26.

TABLE 8. MODELED EXISTING PEAK FLOWS AND TOTAL VOLUMES

Location	10-yr 24-hr Event		100-yr 24-hr Event		100-yr 10-day Event	
	Peak Flow (cfs)	Total Volume (ac-ft)	Peak Flow (cfs)	Total Volume (ac-ft)	Peak Flow (cfs)	Total Volume (ac-ft)
POOL 1 INFLOW	921	13,442	792	11,757	1,541	30,714
POOL 2 INFLOW	1,742	24,390	1,560	22,958	3,494	65,662
POOL 3 INFLOW	476	8,060	1,347	27,676	2,776	64,483
ROSEAU RIVER AT BIG SWAMP INFLOW	1,510	72,943	4,528	248,820	11,351	649,048
ROSEAU RIVER AT CARIBOU INFLOW	1,428	75,728	2,956	234,962	4,728	481,498

Note: All values are from the EPA-SWMM model, with the exception of Pool 1 inflow values, which are from the existing USACE HEC-HMS model.

6.9 EXISTING CONDITIONS PEAK POOL ELEVATION AND VOLUME

Peak water surface elevations in Pools 1, 2, and 3 for the existing storm events are summarized in Table 9 below. Pool storage volumes associated with these peak water surface elevations are also shown in the table.

TABLE 9. MODELED EXISTING PEAK WATER SURFACE ELEVATIONS

Location	10-yr 24-hr Event		100-yr 24-hr Event		100-yr 10-day Event	
	Peak Water Surface Elevation (NAVD88) (ft)	Peak Pool Storage (ac-ft)	Peak Water Surface Elevation (NAVD88) (ft)	Peak Pool Storage (ac-ft)	Peak Water Surface Elevation (NAVD88) (ft)	Peak Pool Storage (ac-ft)
POOL 1	1,038.51	3,274	1,038.42	3,089	1,038.90	4,089
POOL 2	1,030.49	5,184	1031.20	8,470	1031.90	12,485
POOL 3	1,026.15	5,559	1027.06	10,525	1028.10	17,625

7.0 HYDRAULICS

7.1 HYDRAULIC MODEL

HDR created a proposed conditions hydraulic model using EPA-SWMM version 5.0 with runoff hydrographs from the USACE HEC-HMS model used as hydrologic inputs. EPA-SWMM was selected due to its ability to efficiently model different operating conditions, including opening and closure of gated structures. HDR also converted the downstream portion of the USACE HEC-HMS model of the existing conditions to EPA-SWMM in order to make a proper comparison. All of the results presented in this report are from EPA-SWMM 5.0 in NAVD88.

7.2 PROPOSED HYDRAULIC FEATURES

The proposed Project is to consist of four main Project features. Each of the Project features has three alternatives. Locations of the Project features is illustrated in Figure 4. The Project features are:

- Remove and replace the Pool 2 to Pool 3 Structure
- Construct a new Pool 3 Outlet Structure
- Improve and deepen existing Conveyance Channel at west end of Pool 3
- Construct a new Outlet Channel from the new Pool 3 Outlet Structure to the Roseau River

7.2.1 POOL 2 TO POOL 3 STRUCTURE

A new structure is proposed to replace the existing deteriorating structure between Pools 2 and 3. The structure size may vary based on the alternative selected, but may contain two openings through which to discharge flows. One opening is a sluice gate, while the other is a stoplog bay. This allows maximum control over pool elevations during dry periods and during flood events. It also helps meet the goal of needing to periodically draw down and maintain lower pool levels for effective vegetation management. A conceptual figure of the proposed structure is shown in Figure 5 and Figure 7. Capacities for the three alternatives for this structure are outlined in Table 11.

7.2.2 POOL 3 OUTLET STRUCTURE

A new structure is proposed at the west end of Pool 3 to supplement the existing Pool 3 Outlet Structure and may contain up to four openings through which to discharge flows. Two of these openings would be stoplog bays, while two would be stainless steel sluice gates. The two stoplog bay inverts will be at an elevation two feet lower than the invert of the sluice gates, providing maximum flexibility to de-water, raise, or maintain water surface elevation inside Pool 3. See Figure 6 and Figure 8 for the design concept. Discharge capacities for each of the three alternatives are summarized in Table 11.

FIGURE 4. PROPOSED PROJECT FEATURES

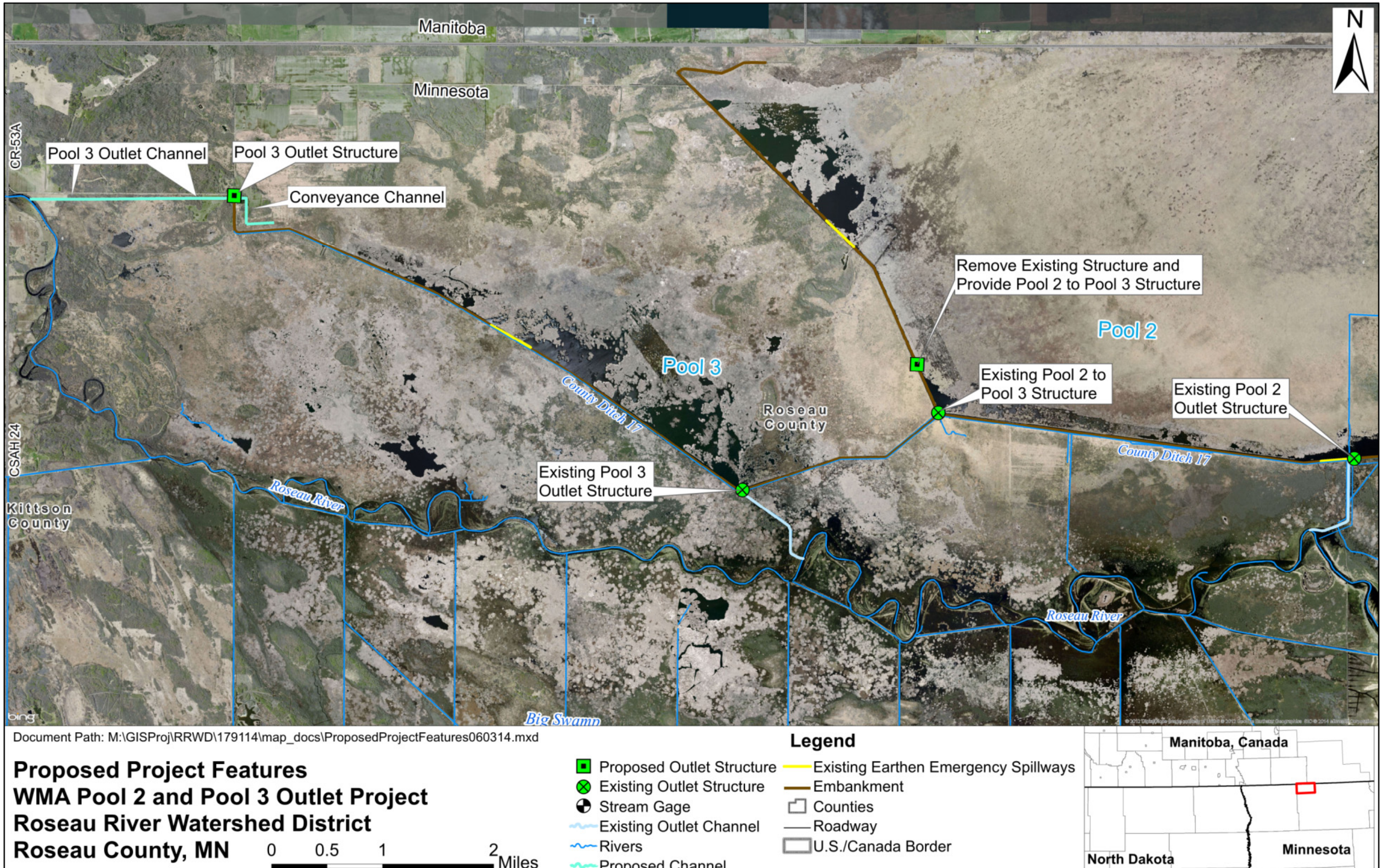


FIGURE 5. POOL 2 TO POOL 3 STRUCTURE ELEVATION

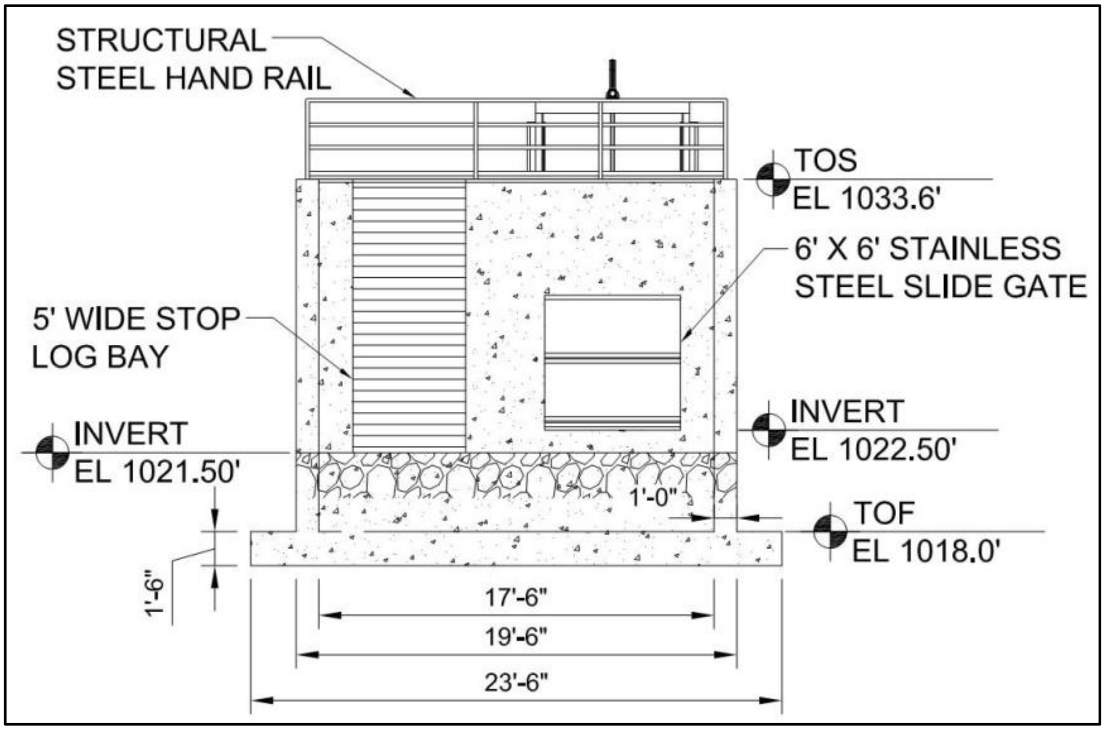


FIGURE 6. POOL 3 OUTLET STRUCTURE ELEVATION

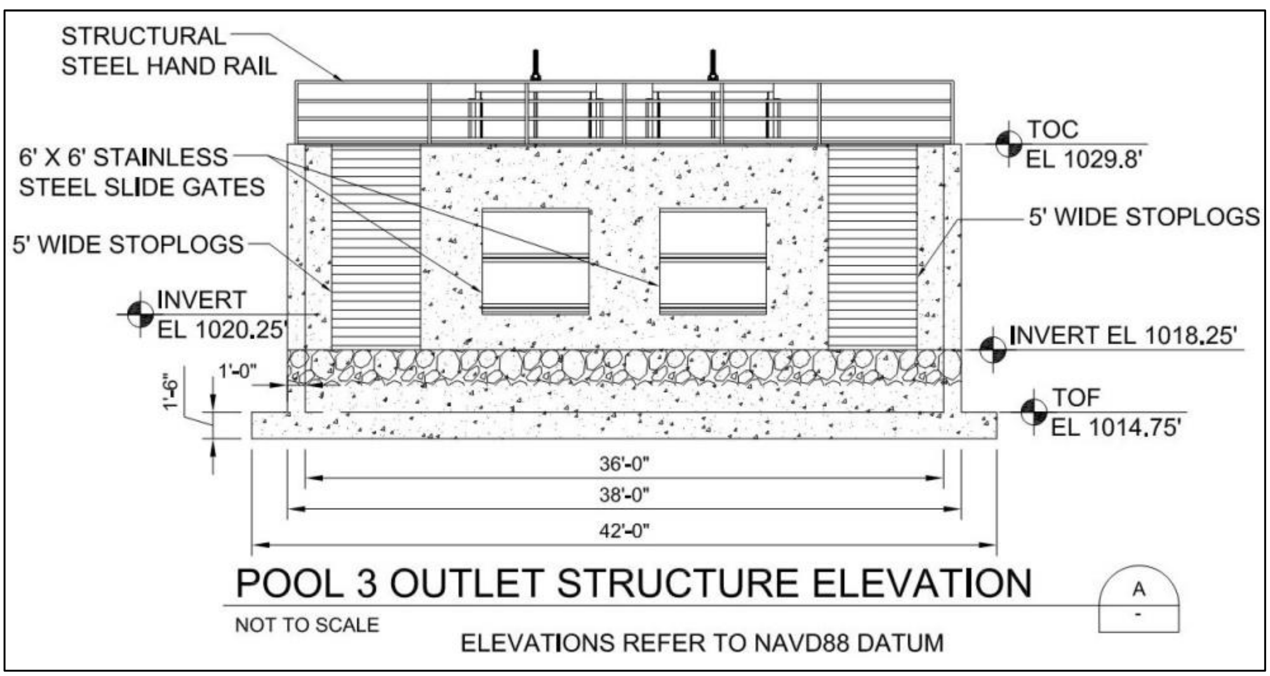


FIGURE 7. POOL 2 TO POOL 3 STRUCTURE PLAN

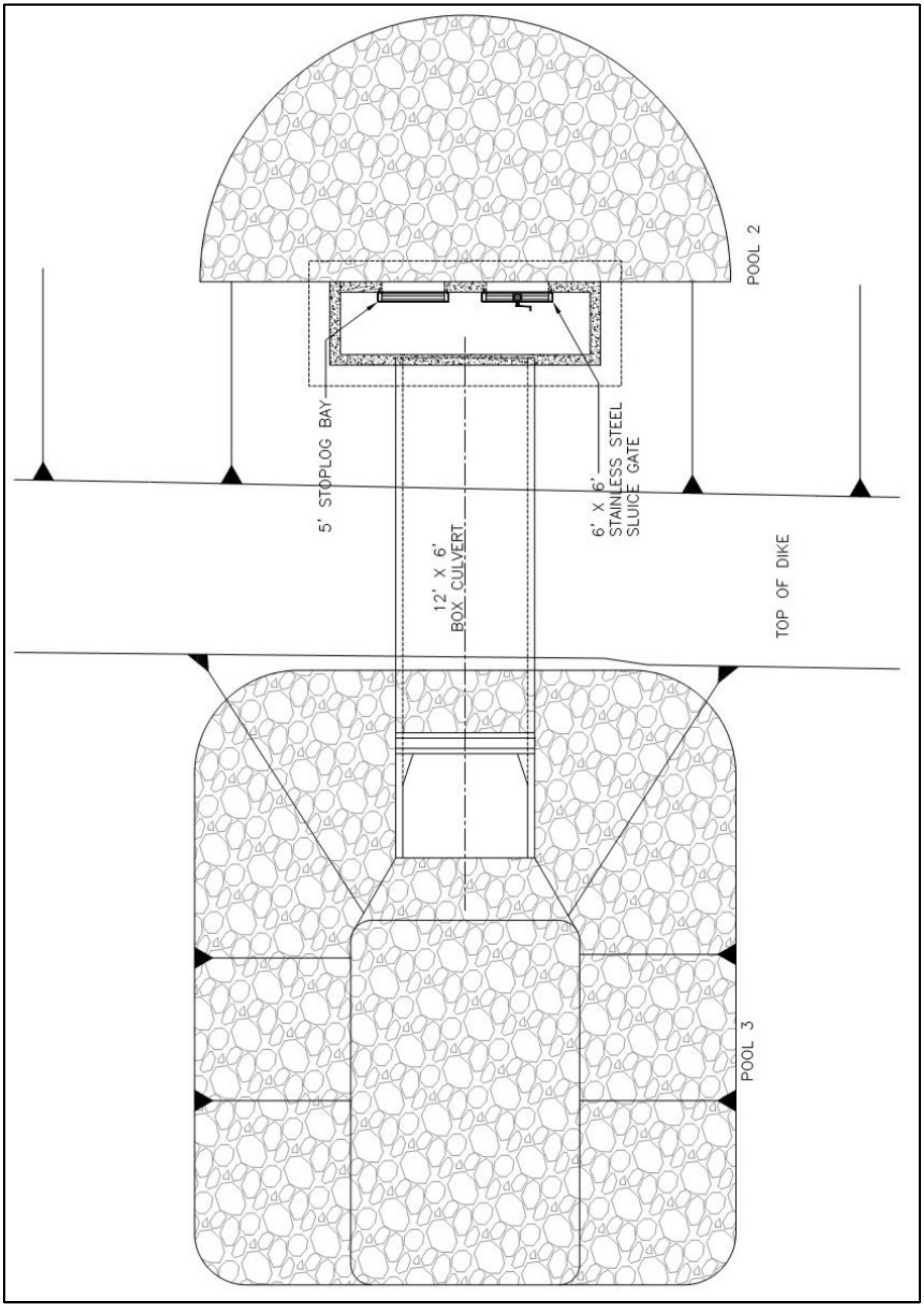
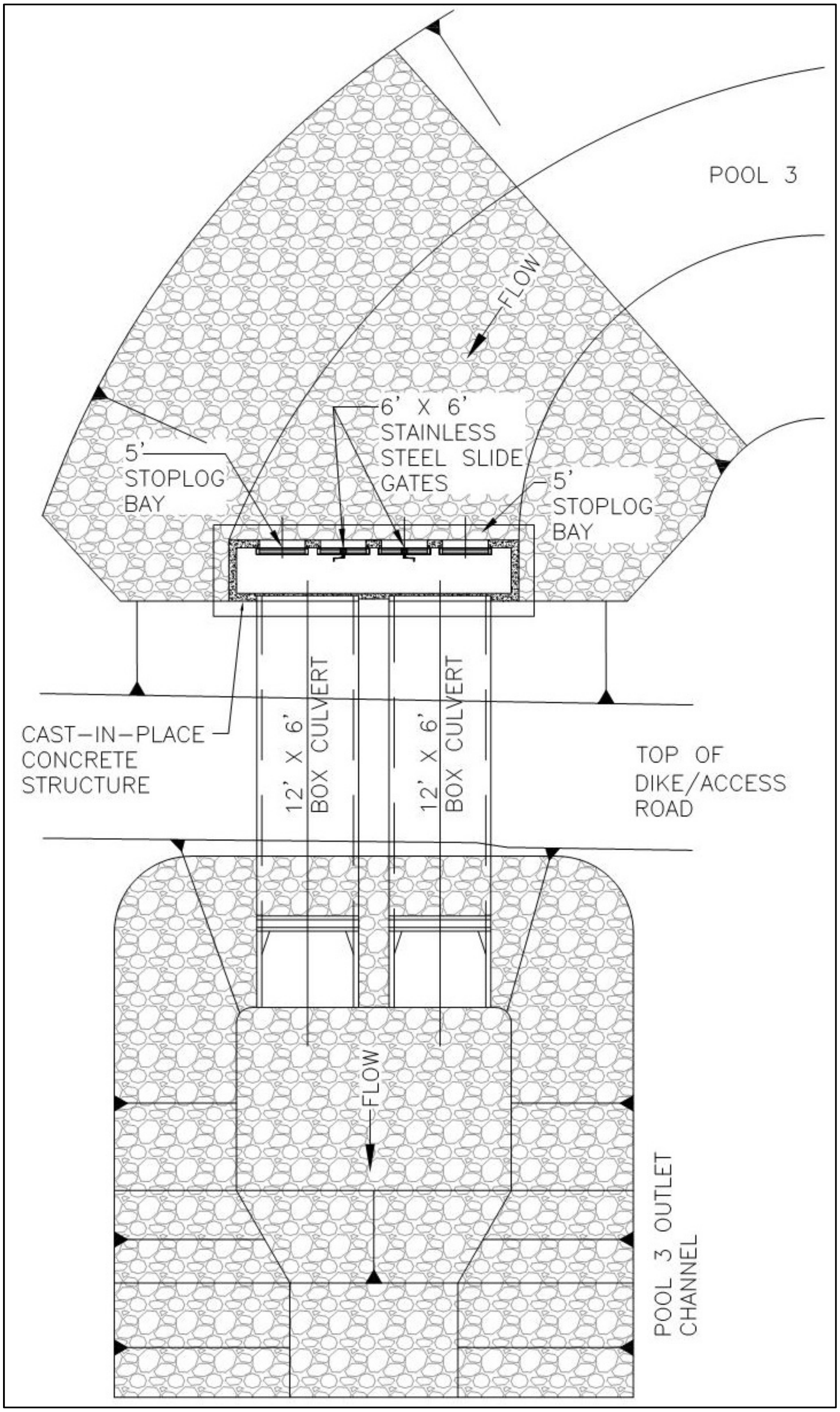


FIGURE 8. POOL 3 STRUCTURE PLAN



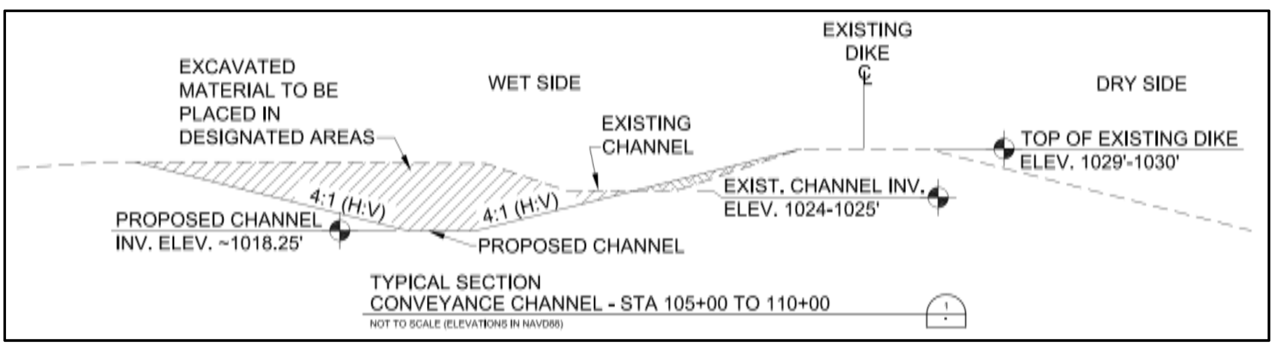
7.2.3 CONVEYANCE CHANNEL

The existing drainage channel inside and adjacent to the existing Pool 3 dike is referred to as the Conveyance Channel. Upstream of the new Pool 3 Outlet Structure, the Conveyance Channel will be excavated deeper to convey water inside Pool 3 to the new Pool 3 Outlet Structure. The limits of the channel excavation will extend approximately 2,200 feet upstream from the new Pool 3 Outlet Structure. The Conveyance Channel allows the Project to convey early floodwaters through the new Pool 3 outlet, downstream of the Big Swamp, before peak flows occur on the Roseau River. The location of the Conveyance Channel is shown in Figure 4.

Excavated material from the channel will be placed on the side slope of the existing dike slope, in the Pool 3 Outlet Channel spoil pile, or in the 400th street roadway raise. Material placed on the side slope of the existing dike helps to increase the slope stability factor of safety of the dike. The side slopes of the Conveyance Channel will be 4:1 (H:V) per recommendations from the USACE's Preliminary Geotechnical Report (U.S. Army Corps of Engineers, 2013).

The Conveyance Channel is sized to convey the capacity discharging through the Pool 3 Outlet Structure. A typical Conveyance Channel section is illustrated in Figure 9. Conveyance Channel dimensions for each alternative are found in Table 11.

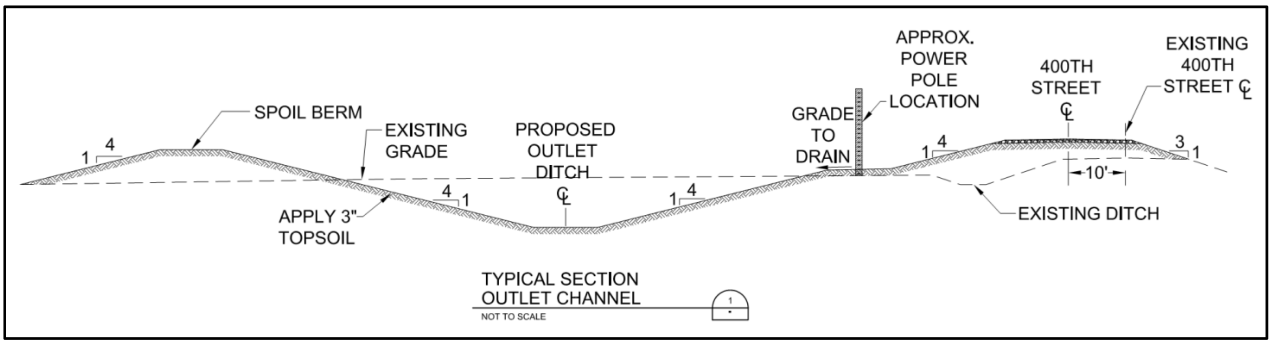
FIGURE 9. CONVEYANCE CHANNEL TYPICAL SECTION



7.2.4 OUTLET CHANNEL

A new Outlet Channel is proposed from the new Pool 3 Outlet Structure west to the Roseau River. The channel is located parallel and adjacent to 400th Street. The Pool 3 Outlet Channel may be located either on the south or north side of 400th Street, depending on the selected alternative. The location of the Outlet Channel may be found in Figure 4. This channel is sized based on the maximum Pool 3 Outlet Structure capacity. A riprap outfall from the channel is proposed for energy dissipation and to increase dissolved oxygen concentrations downstream. A typical section of the Outlet Channel is illustrated in Figure 10.

FIGURE 10. OUTLET CHANNEL TYPICAL SECTION



7.2.4.1 Stable Channel Velocity and Erosion Prevention

Six soil borings were taken in the vicinity of the Outlet Channel in June 2012 (U.S. Army Corps of Engineers, 2013). The proposed Outlet Channel profile was overlaid with the soil boring logs to determine the soil texture at the invert of the Outlet Channel. The surface soil texture in five of the six soil borings at the proposed Outlet Channel are soft, fat clays (CH) while one of the six borings indicated a soil texture of lean clay with gravel (CL).

Unvegetated clayey soils can withstand water velocities of 3 ft/sec before significant erosion occurs (Fischenich, 2001). However, the Outlet Channel will be seeded and become vegetated, since it is elevated above the ordinary high water level of the Roseau River, and discharges from the Pool 3 outlet will not be permitted during the turf establishment period. A conservative assumption is that the channel is vegetated with native-type grasses that are expected to withstand water velocities of 3.5 – 4.0 ft/second (NRCS 2007). The channel bottom width, side slope, and longitudinal slope were designed to result in a maximum channel velocity of 3.5 ft/second. The Outlet Channel dimensions and slope for each alternative can be found in Table 11.

7.2.4.2 Riprap Outfall at Roseau River

To maintain non-erodible velocities in the Outlet Channel, the grade of the Outlet Channel must be minimized. It is also beneficial to reduce the extent and period of time that the Outlet Channel is inundated with backwater from the Roseau River. These factors result in the need for a riprapped outfall with an elevation drop of about 4 to 5 feet between the downstream end of the Outlet Channel and the invert of the Roseau River. The riprap outfall is designed to prevent erosion and dissipate energy at the convergence of the Outlet Channel and the Roseau River.

The general operation of the Pool 3 Outlet Structure dictates how the Outlet Channel is utilized. During significantly high flows on the Roseau River, the gates on the Pool 3 Outlet Structure will be closed. Once flows at the USGS Caribou Gage fall to the trigger point, the Pool 3 Outlet Structure gates may be gradually opened to discharge flows down the Outlet Channel. This equates to approximately a 2- to 5-year recurrence interval, with a tailwater elevation on the Roseau River between 1011.7 and 1013.3 (NAVD88). The riprap outfall is sized for the design peak discharge from the Pool 3 Outlet Structure and Outlet Channel, and the riprap outfall layout is illustrated in Figure 11 and Figure 12.

FIGURE 11. RIPRAP OUTFALL PLAN

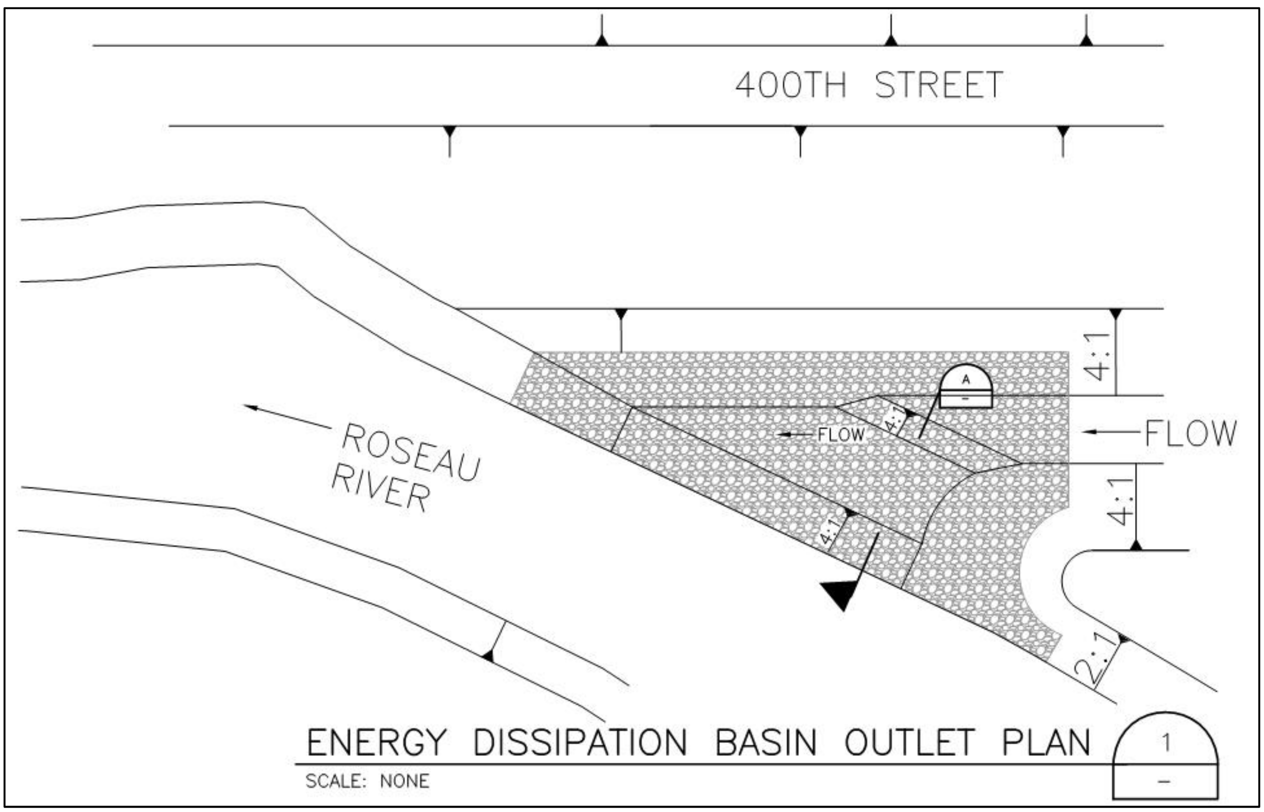
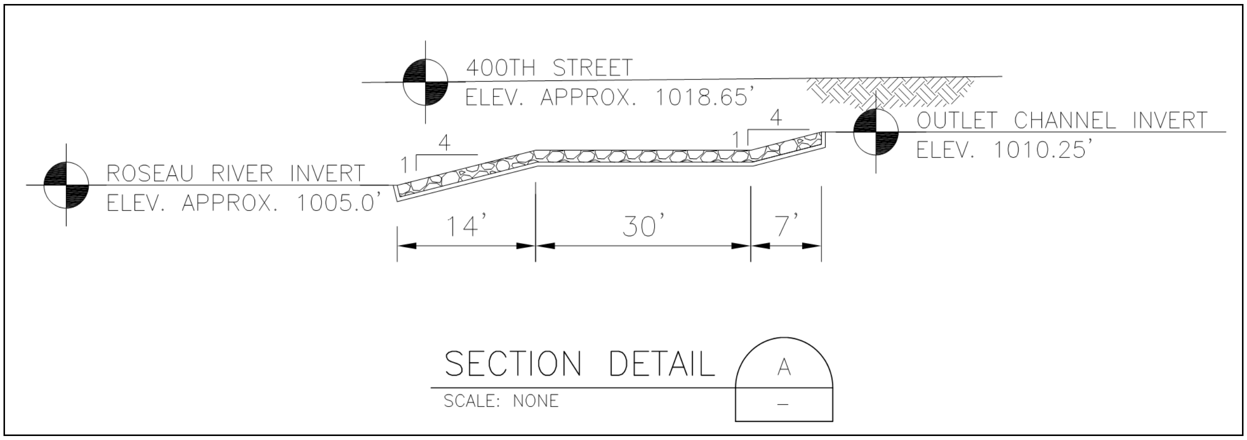


FIGURE 12. RIPRAP OUTFALL PROFILE



7.3 PROJECT ALTERNATIVES

The Project features each have three different alternatives, with differing flow capacities that affect the size of the features discussed in Section 7.2. Alternative 1 is the lowest capacity alternative that closely matches the existing capacity of the system. Alternative 3 is the highest capacity alternative that is financially and operationally feasible. Alternative 2 has a flow capacity between Alternatives 1 and 3. Each alternative also has a suffix of "A" or "B", describing the location of the Pool 3 Outlet Channel. Alternatives with a suffix of "A" locate the Pool 3 Outlet Channel along the south side of 400th Street. Alternatives with a suffix of "B" locate the Pool 3 Outlet Channel along the north side of 400th Street. A summary of the alternatives is found in Table 10. The alternatives are evaluated for the benefits they provide in reducing downstream peak flows, flexibility in pool bounce, and reducing flow transfer between the Roseau River and Two Rivers watersheds. They are also evaluated for construction costs and environmental impacts and benefits. The Minnesota DNR, Roseau River Watershed District, and other Project stakeholders will make a determination of the desired alternative based on a combination of these factors. The proposed alternatives are discussed in detail below.

7.3.1 ALTERNATIVE 1

Alternative 1 is designed with hydraulic features having the ability to convey approximately 30% of the maximum flow of Alternative 3 or 330 cfs at the Pool 3 outlet.

7.3.2 ALTERNATIVE 2

Alternative 2 is designed with hydraulic features having the ability to convey approximately 65% of the maximum flow of Alternative 3 or 770 cfs at the Pool 3 outlet.

7.3.3 ALTERNATIVE 3

Alternative 3 is the maximum flow alternative. It is designed to convey a maximum of 1,200 cfs from the Pool 3 Outlet Structure to the Roseau River.

TABLE 10. ALTERNATIVE SUMMARY

1A – 30% of Alternative 3 Capacity with Pool 3 Outlet Channel on south side of 400th Street	**2A** – 65% of Alternative 3 Capacity with Pool 3 Outlet Channel on south side of 400th Street	**3A** – Maximum Flow Alternative with Pool 3 Outlet Channel on south side of 400th Street
1B – 30% of Alternative 3 Capacity with Pool 3 Outlet Channel on north side of 400th Street	**2B –** 65% of Alternative 3 Capacity with Pool 3 Outlet Channel on north side of 400th Street	**3B –** Maximum Flow Alternative with Pool 3 Outlet Channel on north side of 400th Street

TABLE 11. HYDRAULIC FEATURES AND ALTERNATIVES

Project Feature	Alternatives		
	#1	#2	#3
POOL 2 TO POOL 3 STRUCTURE CAPACITY (CFS)	205	425	660
POOL 3 OUTLET STRUCTURE CAPACITY (CFS)	330	770	1,200
POOL 3 CONVEYANCE CHANNEL DIMENSIONS	V-ditch - 3:1 Side Slopes	6 ft Bottom Width 3.5:1 Side Slopes	10 ft Bottom Width 4:1 Side Slopes
POOL 3 OUTLET CHANNEL DIMENSIONS	V-ditch - 3:1 Side Slopes	6 ft Bottom Width 3.5:1 Side Slopes	10 ft Bottom Width 4:1 Side Slopes
POOL 3 OUTLET CHANNEL SLOPE (%)	0.08%	0.08%	0.08%

7.4 OPERATING PLAN

7.4.1 OPERATIONAL GOALS

The goals of the operating plan are to reduce peak flows on the Roseau River downstream of the Project area, reduce flow transfer between the Roseau River and Two Rivers watersheds, provide the ability to efficiently store floodwaters within Pools 2 and 3, and control pool bounce more effectively to improve wildlife nesting success. The proposed operating plan provides a general instruction on how to maximize flood control benefits by identifying trigger points at which to operate the gates on the new control structures to start filling Pools 2 and 3.

7.4.2 SUMMARY OF PROJECT ELEMENTS

The Project consists of a new structure between Pools 2 and 3, a new Pool 3 Outlet Structure, a deeper Conveyance Channel near the west (downstream) end of Pool 3, a new Outlet Channel downstream of the Pool 3 Outlet Structure, and a change in the timing of how the Outlet Structure gates are operated. Each pool has offsite drainage areas that contribute runoff. Under existing conditions, when offsite flow enters the pools, portions of Pool 2 outflows discharge to both Pool 3 and the Roseau River, and Pool 3 outflows discharge to the Roseau River. In the proposed conditions, during the initial stages of the hydrograph, the existing Pool 2 outlet structure to the Roseau River is closed, and flows are allowed to discharge through the existing and proposed Pool 2 to Pool 3 Structures. The existing Pool 3 Outlet Structure is also closed and flows are allowed to discharge through the proposed Pool 3 Outlet Structure at the west end of Pool 3. During large events, water surface elevations may be high enough to discharge over the earthen emergency spillways in either Pool.

7.4.3 PROPOSED OPERATION

7.4.3.1 General Operation

Generally, in the fall, stoplogs are removed from the existing structures to de-water the pools to one foot below the normal summer pool level. The proposed structures would also operate under this assumption. De-watering the pools to one foot below their normal summer level allows for storage of floodwaters during spring runoff. As the late winter and early spring snowmelt begins, the Project operation should minimize discharge from the existing Outlet Structures and open the proposed Pool 2 and Pool 3 Outlet Structure gates and stoplogs to allow flow from Pools 2 and 3 to bypass the Big Swamp. Then, based upon flows on the Roseau River at Caribou, the proposed Pool 2 and Pool 3 Outlet Structure gates are closed and stoplogs are put in place to allow the pools to fill. During larger events, the existing emergency spillways and Outlet Structures would allow discharge once the Pools fill up. When Roseau River flows fall below the chosen trigger point, the proposed

Pool 2 and Pool 3 Outlet Structure gates and stoplogs may be opened at the operator's discretion to slowly discharge from the RRWMA until the target pool elevations are reached.

7.4.3.2 Trigger Points

At some point during significant runoff events, the proposed Pool 2 to Pool 3 Structure and Pool 3 Outlet Structure gates and stoplogs should be closed in order to begin storing water in the RRWMA Pools and to reduce flows in the Roseau River. The point at which this operation occurs is referred to as the trigger point. HDR conducted an analysis to determine the ideal trigger points to operate the structures to optimally reduce peak flows on the Roseau River. For the 100-year events, this equates to allowing some discharges from the RRWMA during lower-stage flooding (1,800 – 2,750 cfs) to achieve this reduction.

Forecasted flows are inferred by looking at upstream river gage peaks, predicted peak flow estimates from the National Weather Service (NWS) on the Roseau River at Roseau, and rainfall values over the watershed. Once the estimated event is determined, the operator uses Table 12 and peak flow information for the USGS Roseau River near Caribou gage to determine the appropriate trigger point to close the proposed Pool 2 and Pool 3 Outlet Structure gates and stoplogs. For events between the 10-year and a 100-year event, the peak flow at which the gates are operated could be interpolated between the events listed in the table.

When the gates are closed at the trigger point, the flow on the Roseau River may temporarily be reduced as the flow contribution from the RRWMA is removed. For the 10-day duration events, a two-stage trigger operation is more beneficial for Roseau River peak flow reduction and RRWMA pool bounce reduction than a single-stage operation in which the gates and stoplogs are closed at once. Under the two-stage trigger, the RRWMA gates are closed 50% when the first trigger is reached, which immediately decreases the flow at the Caribou gage. As flows at Caribou increase, some flow is still being released from the RRWMA. Once the second trigger stage is reached, the gates are completely closed, stopping the discharge from Pool 3.

For the Alternative 3 100-year 10-day event in which peak flows on the Roseau River at Caribou are 4,651 cfs, discharges will not be allowed from the proposed Pool 3 Outlet Structure once flows at Caribou reach 2,750 cfs. For the Alternative 3 100-year 24-hour event in which the peak flow at Caribou is 2,813 cfs, discharges will not be allowed from the proposed Pool 3 Outlet Structure once flows at Caribou reach 2,450 cfs. Trigger points corresponding to Roseau River flows at Caribou are shown in Figures 25 and 26. For all events smaller than a 100-year recurrence, the Pool 3 Outlet gates will be closed before the Roseau River at Caribou reaches these higher flow rates. For the Alternative 3 100-year 24-hour event, the proposed RRWMA outlet gates and stoplogs should be closed approximately 18 days before the peak flood flow arrives at the USGS Caribou gage.

TABLE 12. TRIGGER POINTS FOR OUTLET STRUCTURE GATE CLOSURE

Alternative	Peak Flow on the Roseau River near Caribou Gage at which to close the Proposed Outlet Gates (cfs)					
	100-Year 10-Day Event		100-Year 24-Hour Event		10-Year 24-Hour Event	
	50% Closure	Full Closure	50% Closure	Full Closure	50% Closure	Full Closure
1	2,700	2,900	2,650	2,700	1,150	1,200
2	2,700	2,850	2,550	2,650	700	1,150
3	2,600	2,750	1,800	2,450	800	900

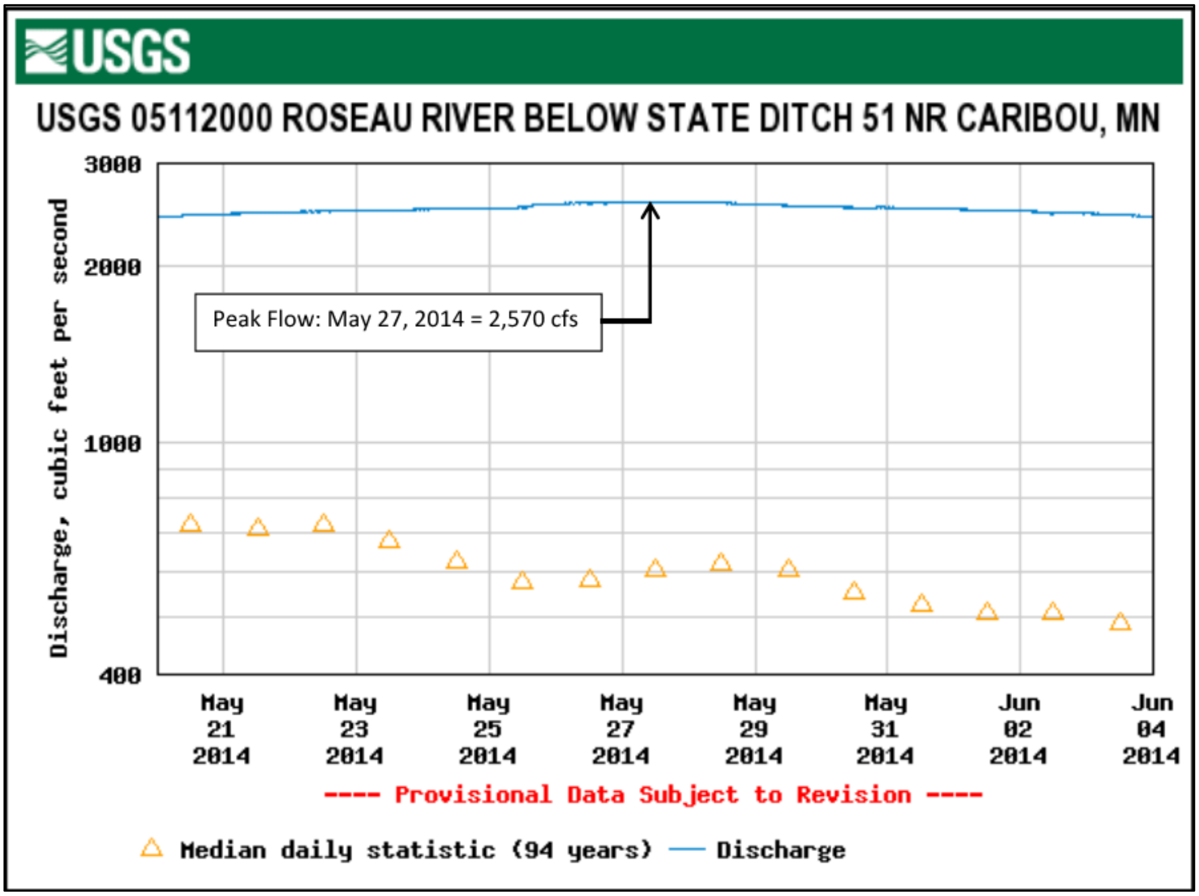
7.4.4 EFFECTS OF OPERATION

7.4.4.1 Recent High Flow Events

High flows are occurring with increasing frequency on the Roseau River. In ten of the last 20 years, the annual peak flow on the Roseau River at Caribou has exceeded 2,500 cfs (U.S. Geologic Survey, 2014). Recently, the USGS Gage at Caribou indicated that the peak flow reached 2,570 cfs near the end of May 2014 (See Figure 13).

For the 100-year 10-day event, as shown in Table 12 and Figure 17 through Figure 19, once the flow at Caribou reaches 2,750 cfs, the proposed Pool 3 Outlet Structure gates and stoplogs will be fully closed. The modeled 100-year 10-day event flow rate of 4,651 cfs has never been recorded on the Roseau River at Caribou. For every other smaller runoff event, including the 100-year 24-hour event, the proposed Pool 3 Outlet Structure gates and stoplogs will be completely closed prior to the flow at Caribou reaching 2,500 cfs.

FIGURE 13. RECENT HIGH FLOWS ON ROSEAU RIVER AT CARIBOU



7.4.4.2 Duration of High Flows

By allowing more flows out of the proposed Pool 3 Outlet Structure early in the runoff event, the length of time that Roseau River flows are above certain flood stages can be reduced. Duration of flooding is an important factor in the amount of flood damages that occur, and any reduction in flood duration is a welcomed benefit. Alternative 3 generally provides the greatest reduction in high flow duration during flooding events. For the Alternative 3 100-year 10-day event, the duration of time that flows at Caribou are above 3,200 cfs is reduced by four (4) days compared with existing conditions. For the Alternative 3 10-year 24-hour event, the duration of time that flows at Caribou are above 1,300 cfs is reduced by 3.75 days compared with existing conditions. See Figures 14 through 16 as an illustration of this point.

FIGURE 14. DURATION OF HIGH FLOWS FOR THE 100-YEAR 10-DAY EVENT

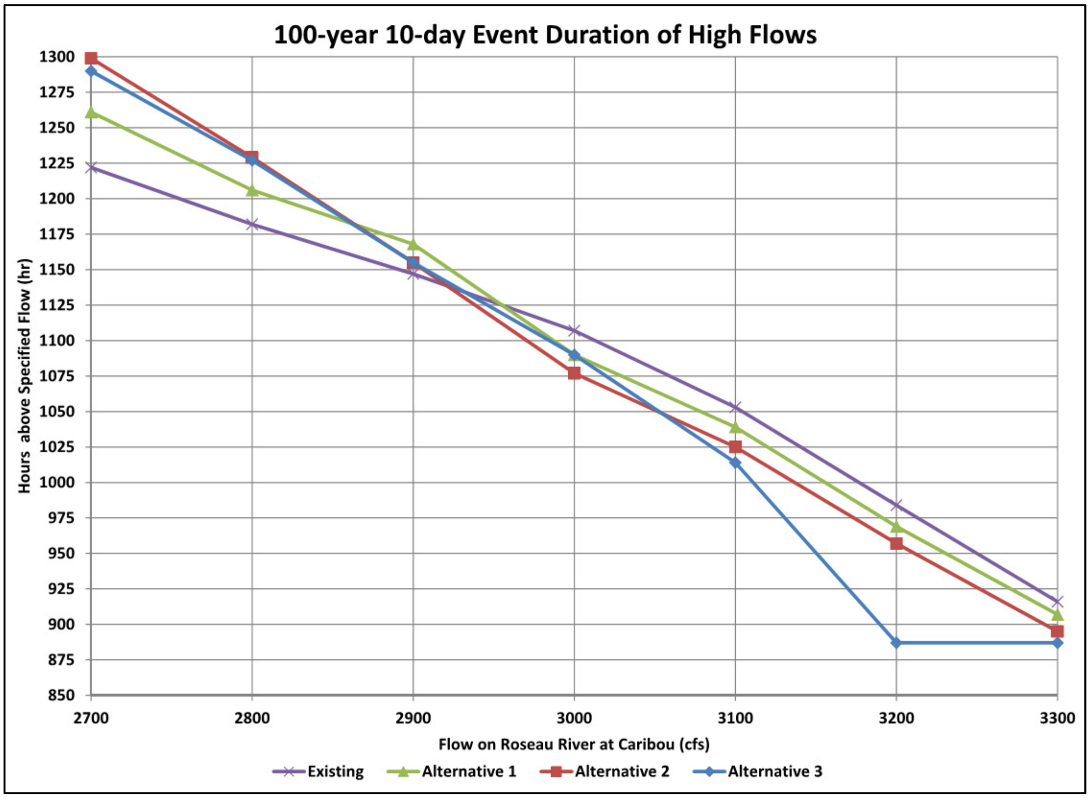


FIGURE 15. DURATION OF HIGH FLOWS FOR THE 100-YEAR 24-HOUR

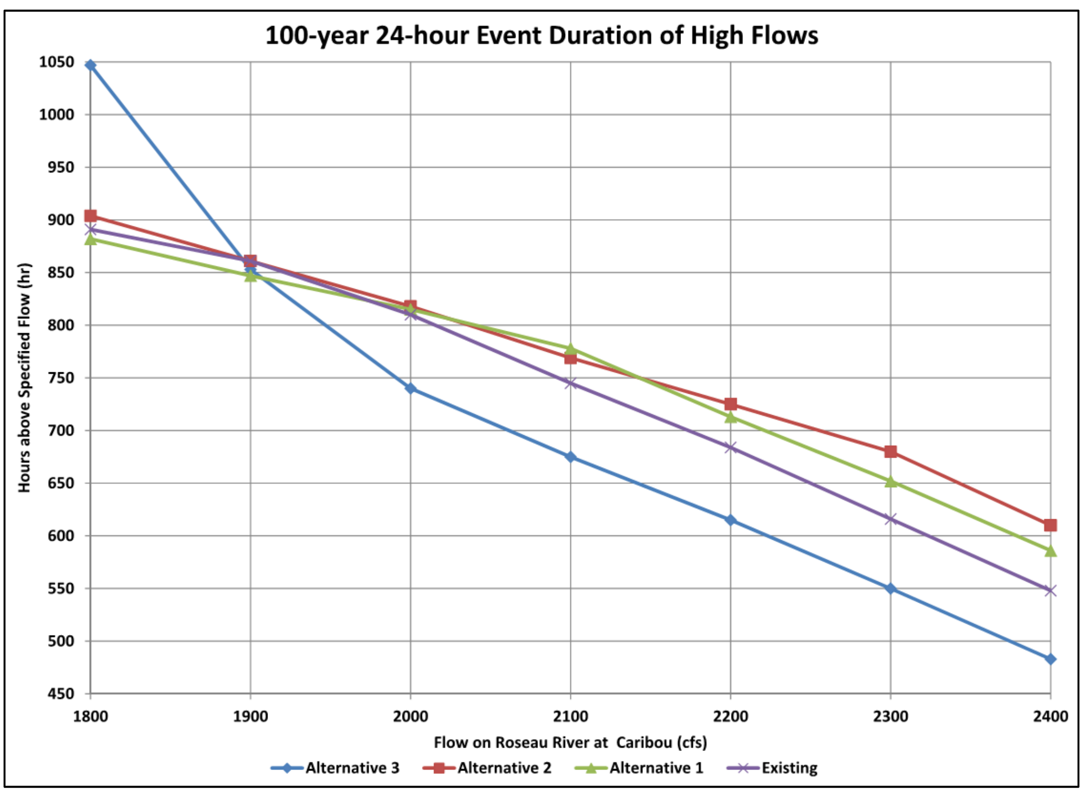
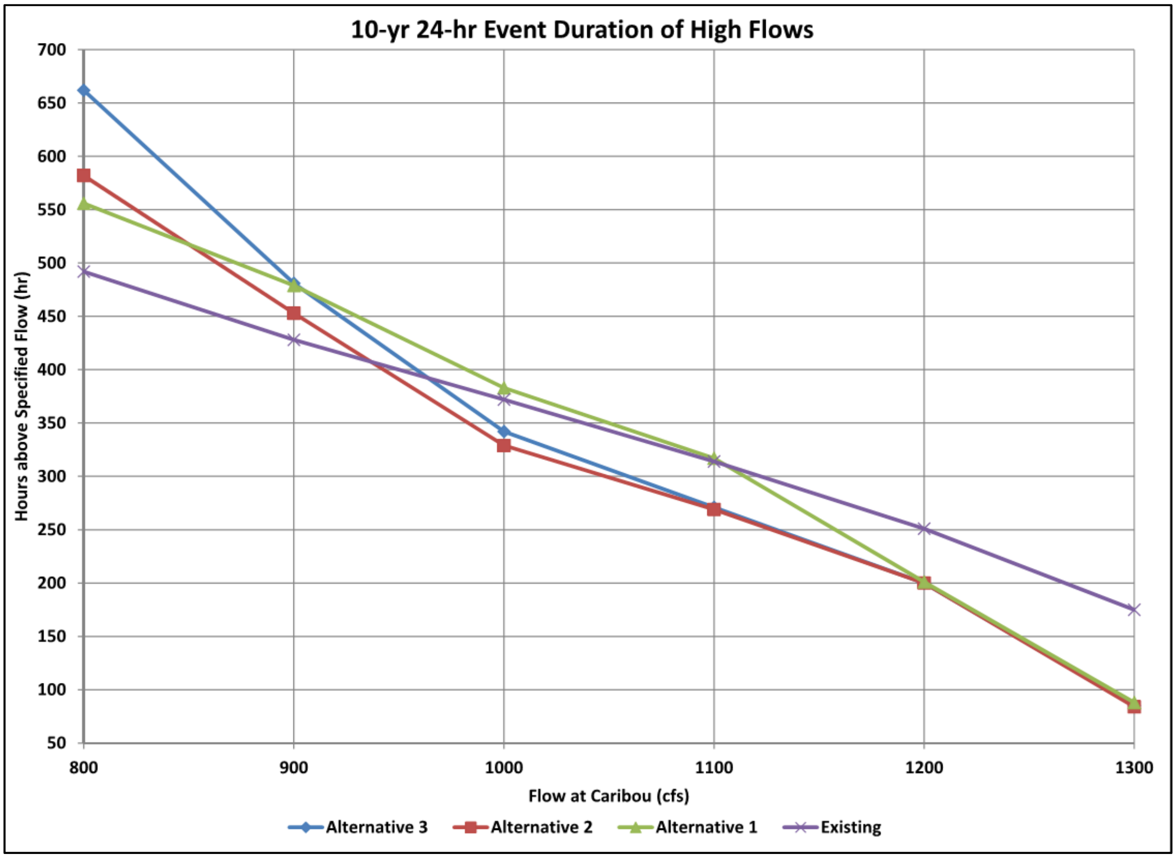


FIGURE 16. DURATION OF HIGH FLOWS FOR THE 10-YEAR 24-HOUR



7.4.4.3 Pool 3 Outlet Discharges versus Roseau River Flow at Caribou

During the early stages of the hydrograph of large runoff events, Pool 3 discharges may make up a significant portion of overall flow rates on the Roseau River at Caribou. These discharges vary depending on the alternative constructed. Early discharges from the proposed Pool 3 Outlet Structure are the main contributor to reducing overall peak flow rates and the duration of high flows on the Roseau River. Discharges from the proposed Pool 3 Outlet Structure are larger for Alternative 3 than they are for Alternatives 1 and 2, but the gates and stoplogs are allowed to close earlier for Alternative 3 than for Alternatives 1 and 2. See Figure 18 through Figure 23 for proposed Pool 3 Outlet Structure discharges expressed as flow rates and as percentages of the overall flow rate on the Roseau River at Caribou. For the 100-year events (10-day and 24-hour), the Alternative 3 Pool 3 Outlet discharges generally make up 35-55% of the overall flow rate on the Roseau River at Caribou in the early portions of the hydrograph. Then, the outlet structures are closed, with no discharges allowed until after the flow on the Roseau River recedes to below the trigger point.

FIGURE 17. POOL 3 OUTLET DISCHARGE VS. FLOW AT CARIBOU FOR THE 100-YEAR 10-DAY EVENT

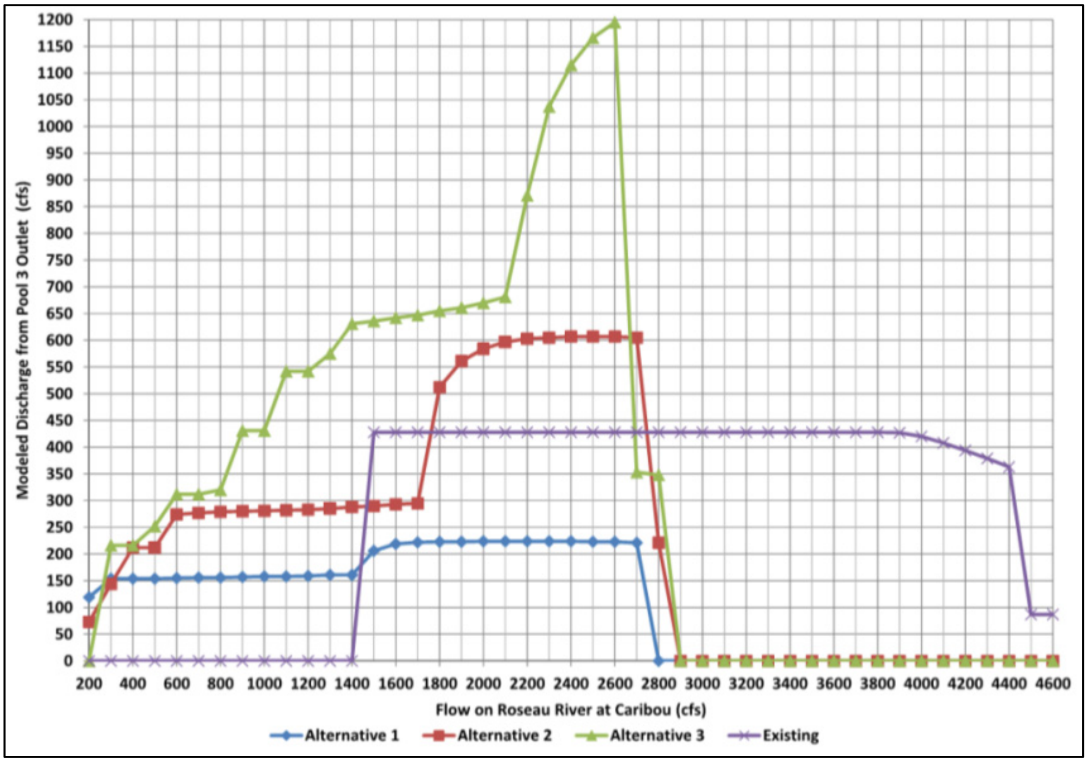


FIGURE 18. POOL 3 OUTLET DISCHARGE VS. FLOW AT CARIBOU FOR THE 100-YEAR 24-HOUR EVENT

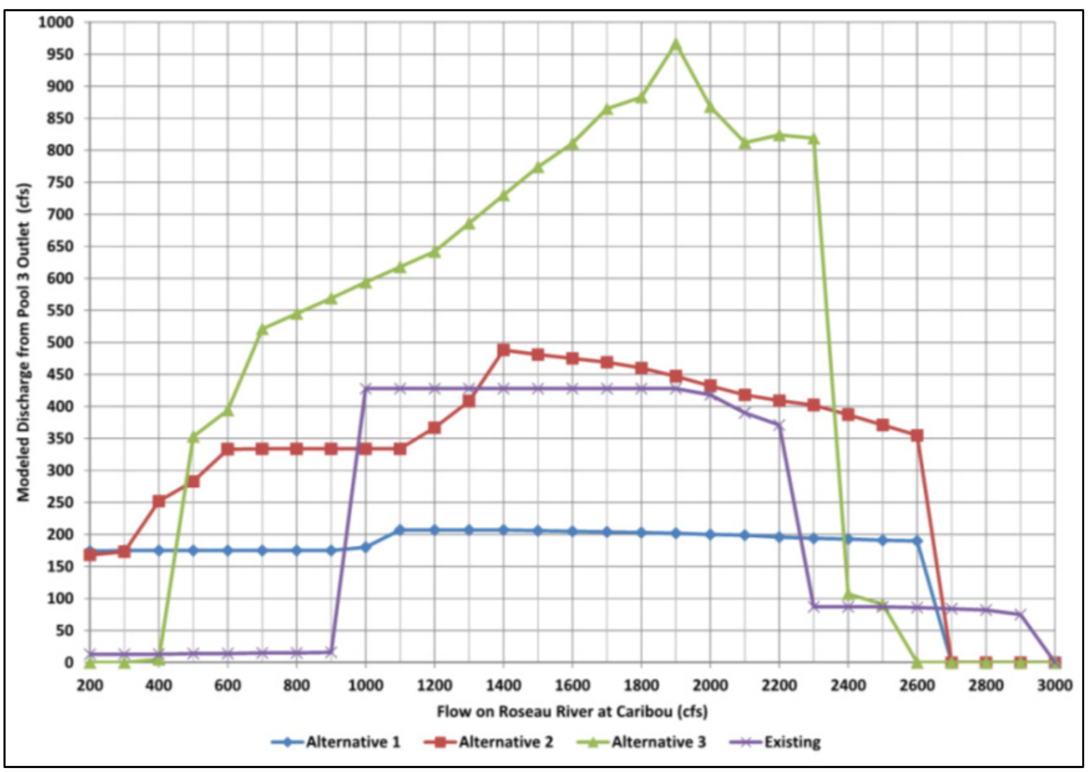


FIGURE 19. POOL 3 OUTLET DISCHARGE VS. FLOW AT CARIBOU FOR THE 10-YEAR 24-HOUR EVENT

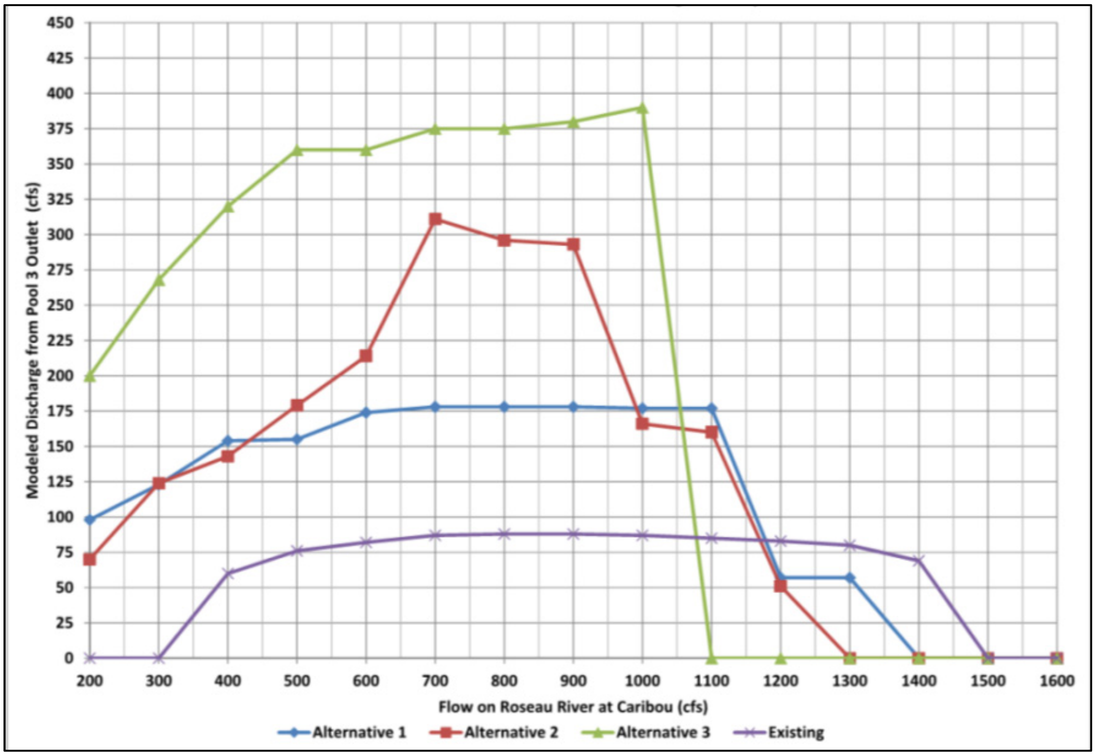


FIGURE 20. 100-YEAR 10-DAY PORTION OF FLOW AT CARIBOU FROM PROPOSED POOL 3 OUTLET STRUCTURE

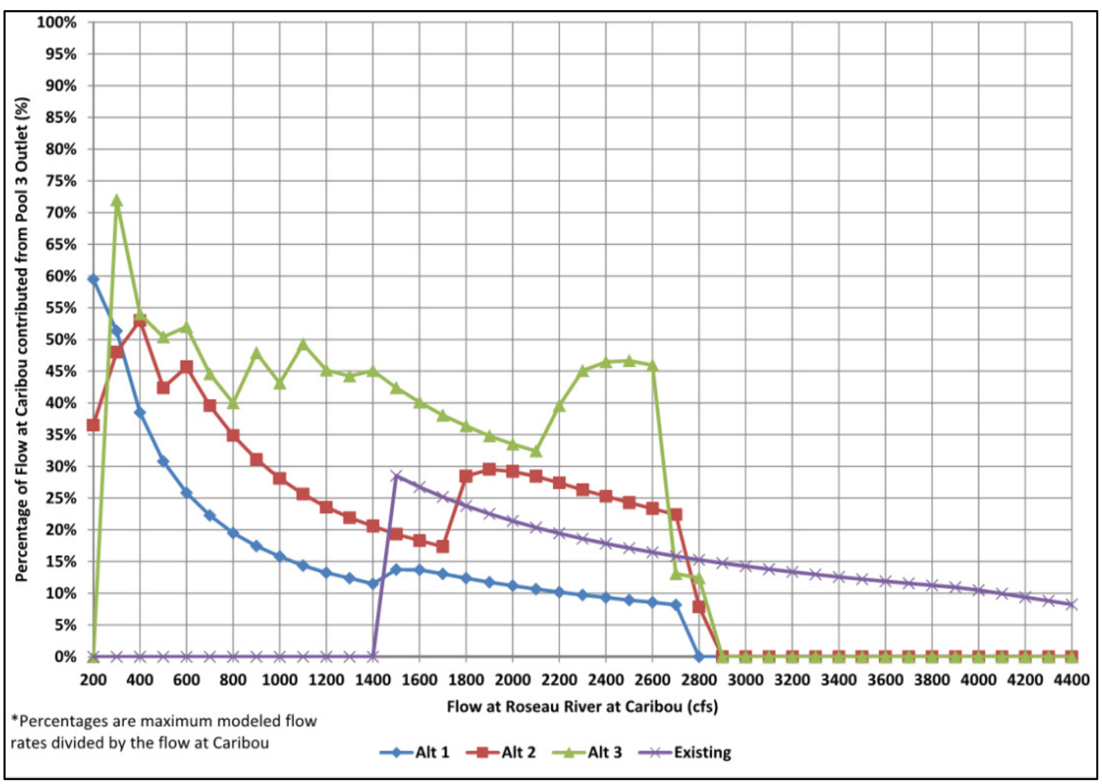


FIGURE 21. 100-YEAR 24-HOUR PORTION OF FLOW AT CARIBOU FROM PROPOSED POOL 3 OUTLET STRUCTURE

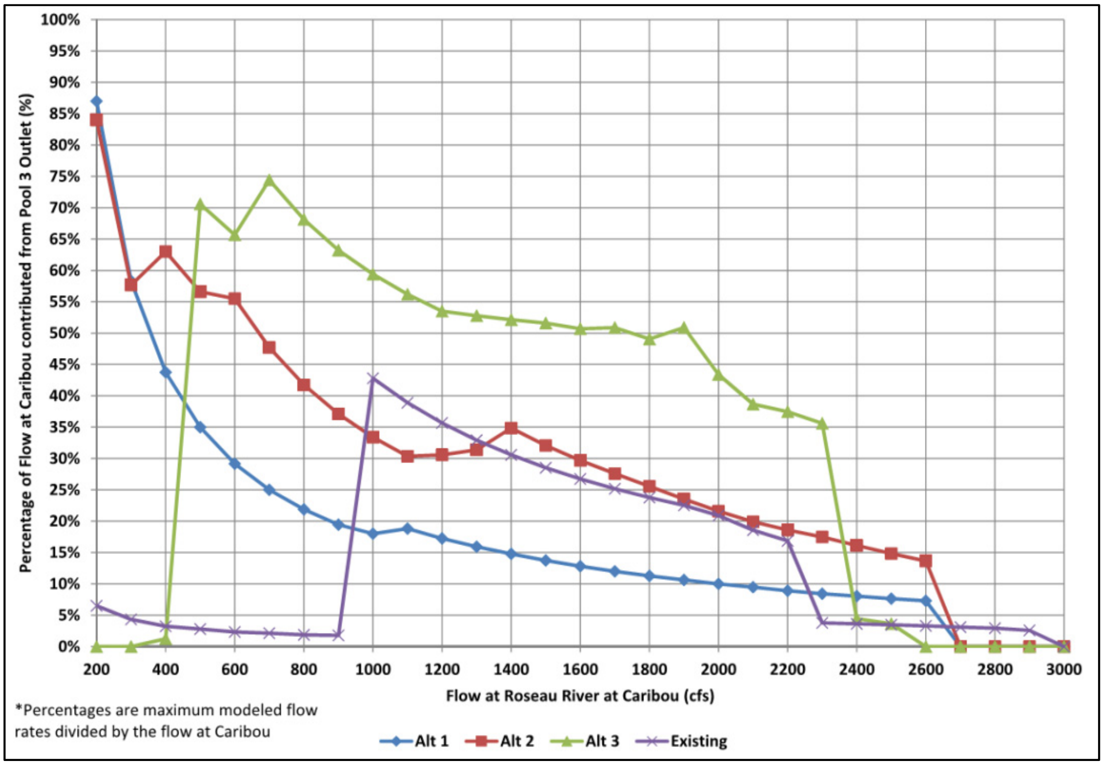
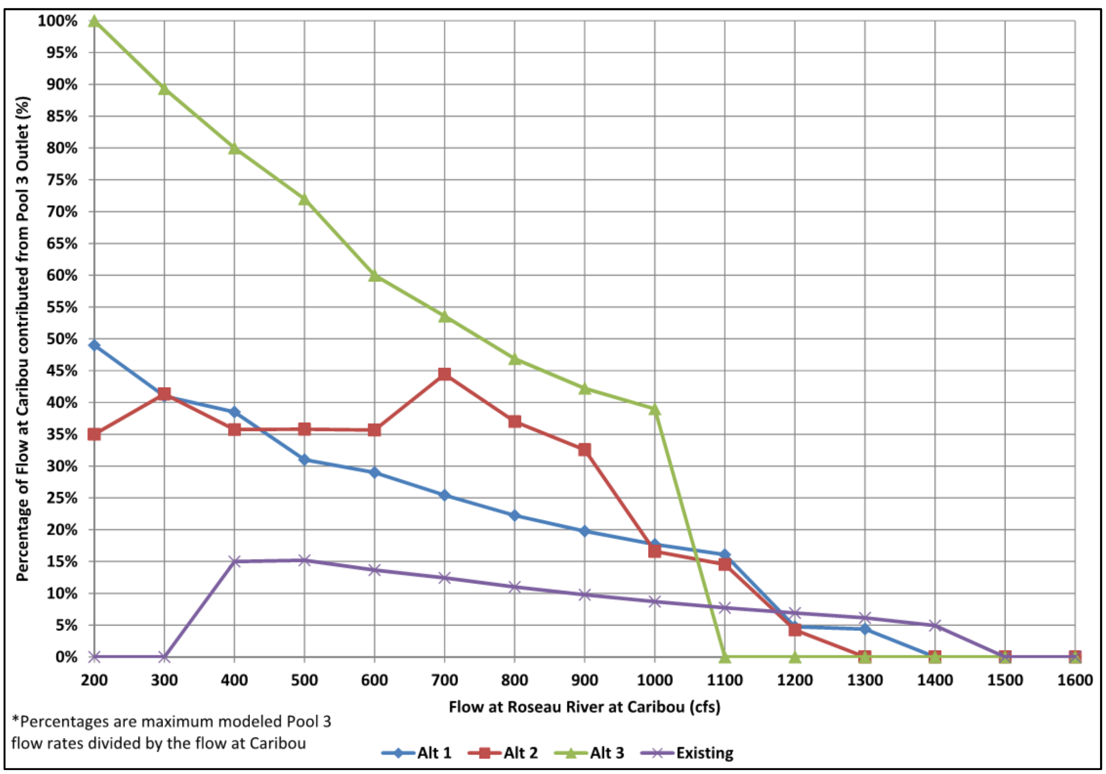


FIGURE 22. 10-YEAR 24-HOUR PORTION OF FLOW AT CARIBOU FROM PROPOSED POOL 3 OUTLET STRUCTURE



7.4.5 OPERATING PLAN SUMMARY

Peak flow rates on the Roseau River and flow transfer to the Two Rivers watershed may be reduced by utilizing an operating plan. This includes allowing stoplog and gate structures to be opened at the start of the runoff event, then operating the proposed Outlet Structure gates and stoplogs at the trigger points indicated in Table 12.

For landowners in the vicinity and downstream of the RRWMA, Alternative 3 provides the best benefit and lowest trigger points. The lower trigger points of Alternative 3 provide the greatest benefit to landowners by closing the Pool 3 Outlet Structure gates earlier in the hydrograph than for the other alternatives. This eliminates the RRWMA's contribution to Roseau River flows at the earliest possible point.

Utilizing the operation plan also reduces the duration of time that the Roseau River is at higher flows. The amount of flood damage is reduced when the length of time of land inundation is reduced. Alternative 3 provides the greatest reduction in the duration of high flows on the Roseau River.

During early portions of the modeled hydrograph, the RRWMA contributes a significant portion of the overall flow rate on the Roseau River at Caribou. While the Alternative 3 Pool 3 Outlet Structure provides the greatest percentage of the overall Roseau River flow rate, it also provides the greatest reduction in the peak flow on the Roseau River.

The hydraulic results in Section 7.5 further describe the magnitude of the benefits that are obtained by correctly operating the Project. If the Project is not operated in accordance with the operating plan, the benefits may change accordingly. The trigger points identified herein represent three possible scenarios with which to operate the project, and other benefits may be gained with other runoff events as operational experience is gained. The MN/DNR and the RRWD reserve the right to modify the operational parameters of the trigger points as experience is gained.

7.5 HYDRAULIC RESULTS

The hydraulics of the proposed Project are evaluated based on the goals of the Project. Desired hydraulic results of the Project include the following:

- Reducing peak flows on the Roseau River downstream of the RRWMA, at the Caribou gage
- Reducing overflows from the Roseau River watershed to the Two Rivers watershed
- Flexible and reasonable control of pool bounce during flooding events and more frequent events to control vegetation and wildlife habitat
- Augmenting downstream flow during dry periods by slowly releasing water from the pools

The results of these hydraulic criteria are summarized in the following sections.

7.5.1 PEAK FLOW REDUCTION

One of the most important goals of this Project is to reduce peak flows on the Roseau River. Well-timed early discharge of water from Pools 2 and 3, combined with adherence to an operation plan to close the structures will aid in accomplishing this goal. Modeled peak flows at the Caribou gage are summarized in Table 13, for each alternative. Existing and proposed Alternative 3 hydrographs for the 100-year 24-hour event at the Caribou gage and the Big Swamp inflows are shown in Figure 23 as an illustration of the attenuation and storage that the Big Swamp provides. Hydrographs for the 100-year 10-day, 100-year 24-hour, and 10-year 24-hour event at the Caribou gage, are shown in Figure 24 through Figure 26.

TABLE 13. MODELED PEAK FLOW RATES ON ROSEAU RIVER NEAR CARIBOU

Storm Event	Peak Flow Rate (cfs)						
	Existing	Alt. 1	Alt. 1 % Change	Alt. 2	Alt. 2 % Change	Alt. 3	Alt. 3 % Change
100-YEAR 10-DAY	4,728	4,696	-0.7%	4,673	-1.2%	4,651	-1.6%
100-YEAR 24-HOUR	2,956	2,852	-3.5%	2,819	-4.6%	2,813	-4.8%
10-YEAR 24-HOUR	1,428	1,371	-4.0%	1,367	-4.3%	1,367	-4.3%

Peak flows on the Roseau River at Caribou may be reduced by 80 cfs or about 2% during the 100-year 10-day event, for Alternative 3. Peak flows are reduced by about 145 cfs, or 5%, during the 100-year 24-hour event, for Alternative 3. The modeling results indicate that Alternative 3 provides the greatest reduction in peak flow rates on the Roseau River. This is because the proposed Alternative 3 Pool 3 Outlet Structure is capable of discharging the most flow downstream ahead of the peak flow on the Roseau River. Peak flows can be decreased by a greater percentage during smaller events. For the 10-year 24-hour storm event, the entire volume from the RRWMA that contributes to the peak flow at Caribou can be contained in the RRWMA system, with no difference between the different potential outlet configuration. This is the reason all three alternatives have similar peak flow reductions for the 10-year 24-hour event.

FIGURE 23. 100-YEAR 24-HOUR PROPOSED FEATURES AND HYDROGRAPHS

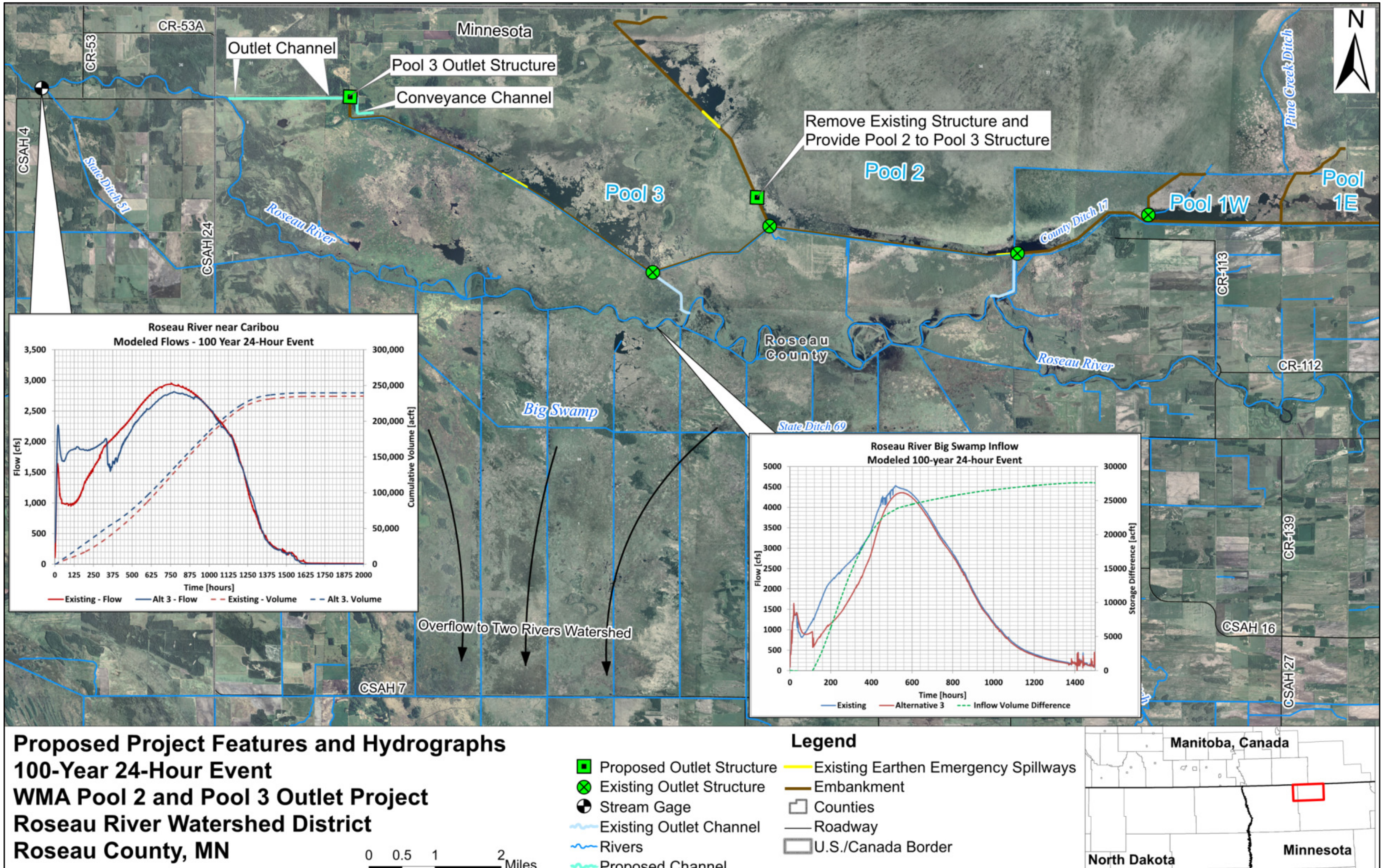


FIGURE 24. MODELED 100-YEAR 10-DAY HYDROGRAPHS AT CARIBOU

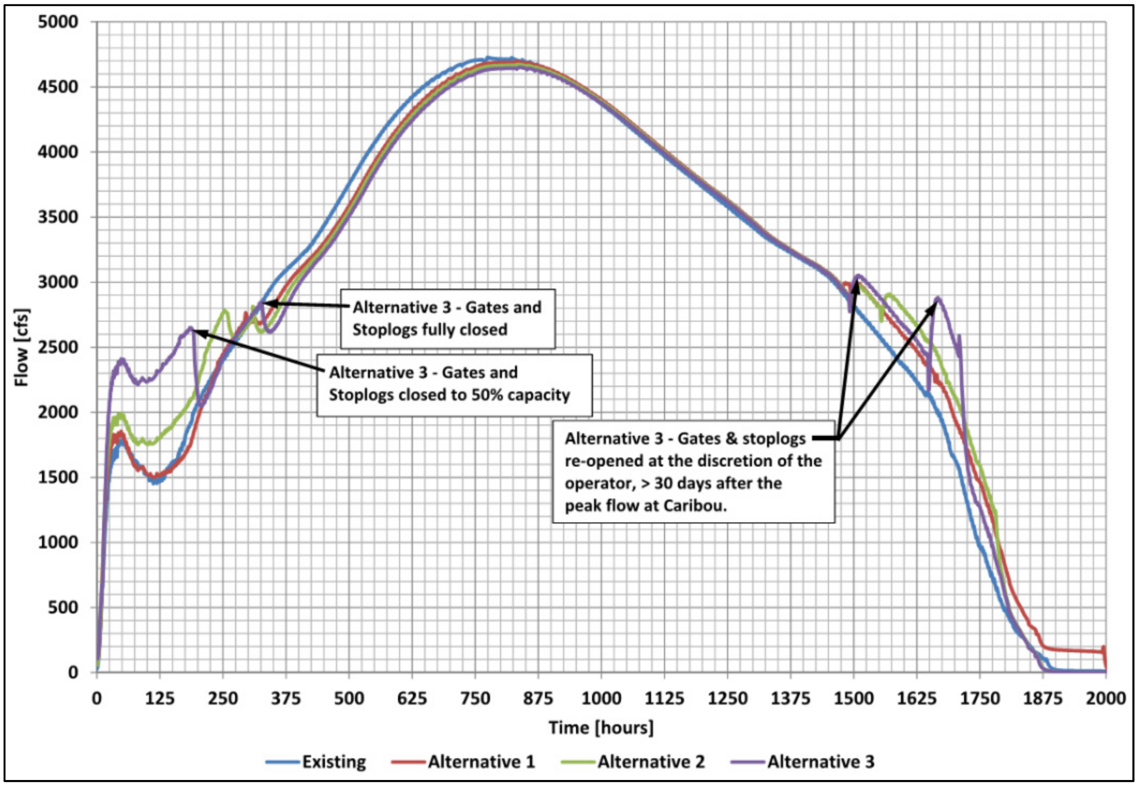


FIGURE 25. MODELED 100-YEAR 24-HOUR HYDROGRAPHS AT CARIBOU

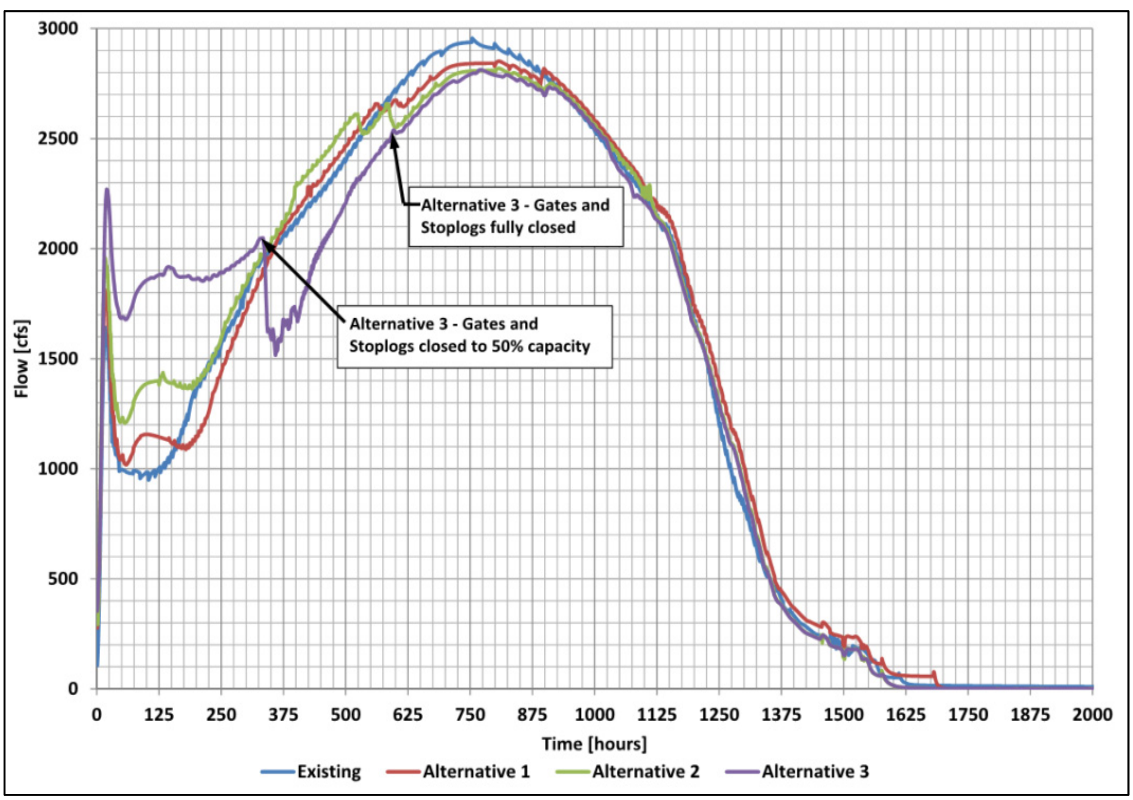
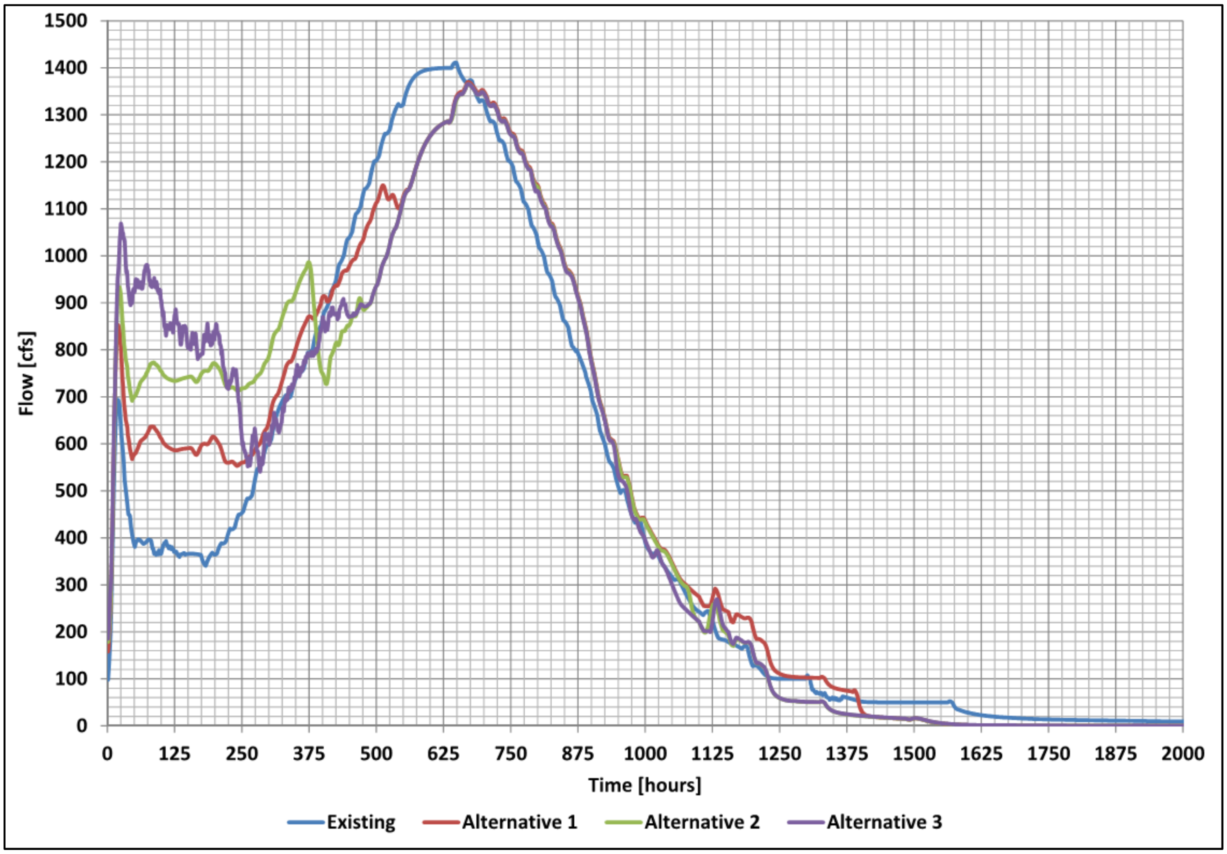


FIGURE 26. MODELED 10-YEAR 24-HOUR HYDROGRAPHS AT CARIBOU



7.5.2 BIG SWAMP EFFECTS

The Big Swamp has an attenuating effect on Roseau River flows because the large amount of storage in the Big Swamp decreases peak flow rates and delays the timing of peak flows on the Roseau River. The Big Swamp is modeled with a storage-discharge relationship provided in the original District HEC-1 model. If a significant amount of Big Swamp storage is available, then the peak flow leaving the Big Swamp is reduced.

The current configuration of the Pool 2 and Pool 3 outlets exacerbate the timing problem with the RRWMA. The RRWMA currently discharges flow directly into the Big Swamp, which fills the available storage early, slows down and backs up subsequent flows, and causes flows to spill over County Road 7, located six miles south of Pool 3, into the Two Rivers watershed.

A proposed new Pool 3 outlet approximately five miles west-northwest of the current Pool 3 outlet will help improve the RRWMA outflow timing and optimize Big Swamp storage. This configuration allows Pool 3 outflows to discharge downstream of the Big Swamp to the Roseau River before the peak flow from remainder of the Roseau River watershed arrives at this location. Bypassing the Big

Swamp keeps more storage available for larger flows upstream, resulting in approximately 22,000 ac-ft of additional potential (better-timed) storage available throughout the entire 100-year 10-day runoff event. Big Swamp peak flows, timing, and the difference in volume of water stored between the existing and proposed conditions, are illustrated in Figure 27 through Figure 29.

The increased early available storage in the Big Swamp allows the Big Swamp to fill up later. As shown in the figures below, there is negligible delay in the peak flows entering Big Swamp for the 100-year 10-day and 10-year 24-hour events. The peak flow delay is about 30 hours for the 100-year 24-hour event.

FIGURE 27. MODELED BIG SWAMP HYDROGRAPH – 100-YEAR 10-DAY EVENT

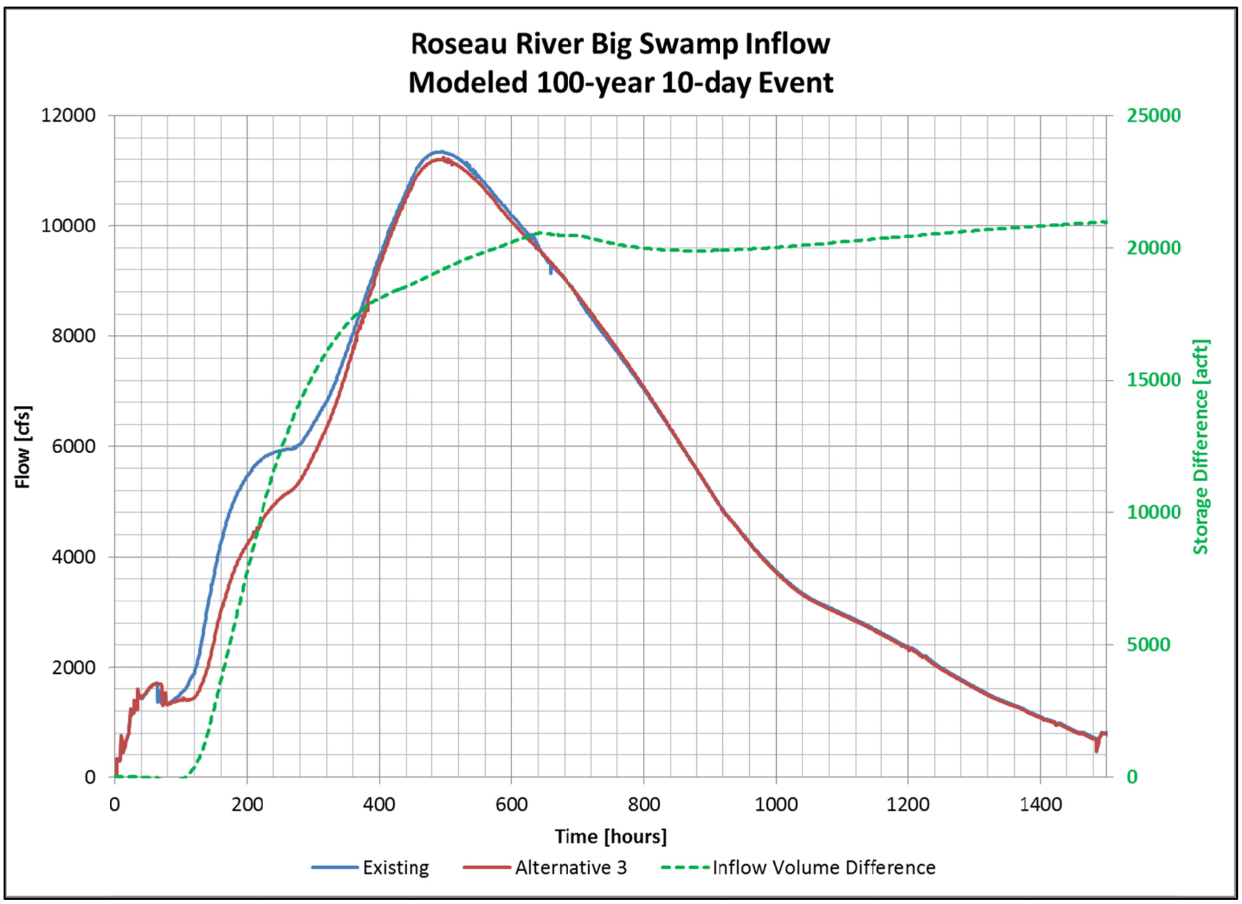


FIGURE 28. MODELED BIG SWAMP HYDROGRAPH – 100-YEAR 24-HOUR EVENT

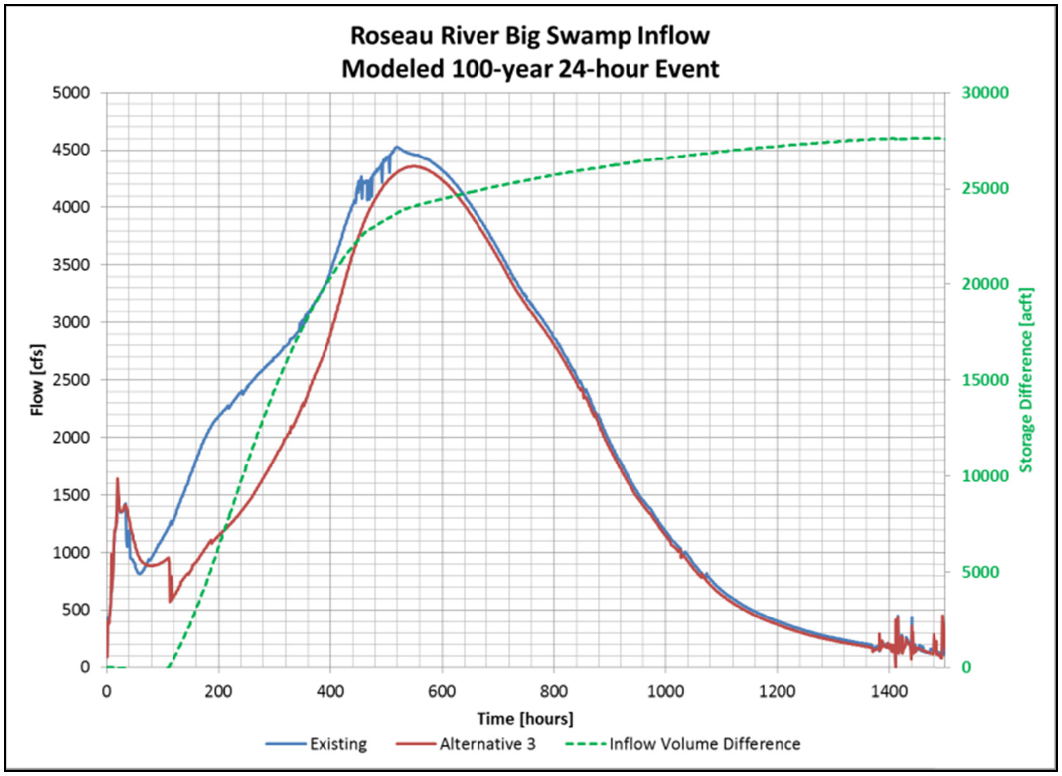
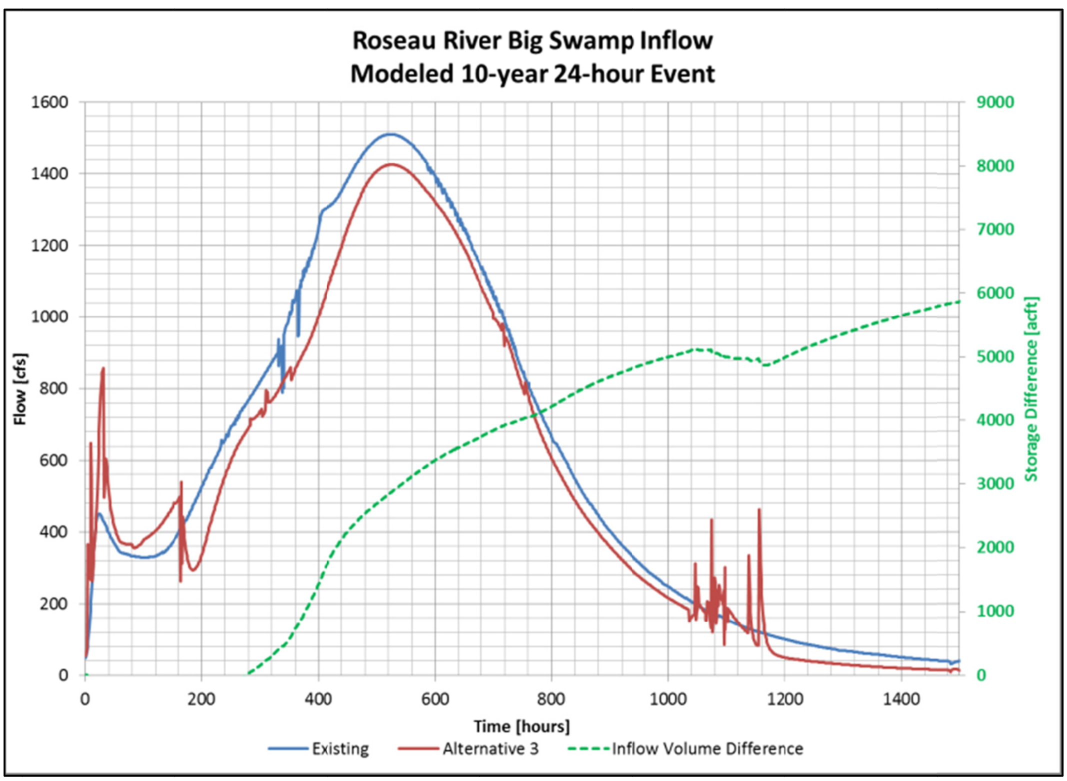


FIGURE 29. MODELED BIG SWAMP HYDROGRAPH – 10-YEAR 24-HOUR EVENT



7.5.3 OVERFLOW TO TWO RIVERS WATERSHED

When flows in the Big Swamp area of the Roseau River reach approximately 2,000 cfs, water starts flowing over County Road 7, six miles south of Pool 3, and into the Two Rivers Watershed. By discharging RRWMA inflows downstream of the Big Swamp through the proposed Pool 3 outlet, the amount of flow transferring to the Two Rivers Watershed can be greatly reduced.

Reducing total volumes and peak flows from transferring to the Two Rivers watershed will impact downstream watersheds. Since the Roseau River Watershed is downstream of the Two Rivers Watershed, along the Red River, keeping more volume and flow in the Roseau River Watershed will result in flows getting to the Red River more quickly than if they passed through the Two Rivers Watershed.

This can be beneficial to flooding concerns on the Red River if the RRWMA structures are operated according to the operating plan. The benefit comes from the optimal timing of storage of the RRWMA, and discharges that are only permitted once Roseau River flows are below flood stage.

Reducing the volume and flow that is transferred to the Two Rivers Watershed could also be detrimental if the RRWMA structures are operated using the wrong timing. If RRWMA Pools 2 and 3 are allowed to fill prematurely, by closing the gates and stoplogs too early, the RRWMA will be discharging over the emergency spillways during the peak flows on the Roseau River, exacerbating the existing problem.

During the 10-year 24-hour event, no flow is transferred to the Two Rivers Watershed. For the 100-year events, total volume and peak overflows transferring to the Two Rivers Watershed are shown in Table 14 and Table 15. Alternative 3 has the greatest reduction in peak flows and volumes to the Two Rivers Watershed because it allows the most flow to discharge downstream of the Big Swamp, ahead of the peak Roseau River flows. The reduction in volume to the Big Swamp also reduces the duration of peak flows to the Two Rivers Watershed.

TABLE 14. MODELED TOTAL VOLUME TRANSFERRED TO TWO RIVERS WATERSHED

	Scenario	100-Year 10-Day		100-Year 24-Hour	
			% Reduction		% Reduction
TOTAL VOLUME (AC-FT)	Existing	180,667	---	20,719	---
	Alt. 1	177,005	-2.0%	18,115	-12.6%
	Alt. 2	174,228	-3.6%	16,684	-19.5%
	Alt. 3	171,177	-5.3%	15,867	-23.4%

Notes: Volume calculated from 45-days (24-hour event) to 70-days (10-day event) after start of storm event

TABLE 15. MODELED PEAK FLOW INTO TWO RIVERS WATERSHED

Scenario	100-Year 10-Day		100-Year 24-Hour	
	Peak Flow (cfs)	% Reduction	Peak Flow (cfs)	% Reduction
Existing	2,816	---	511	---
Alt. 1	2,761	-2.0%	458	-10.4%
Alt. 2	2,733	-2.9%	440	-13.9%
Alt. 3	2,706	-3.9%	440	-13.9%

7.5.4 POOL WATER SURFACE ELEVATION AND BOUNCE

The DNR's operational goals include obtaining the ability to efficiently improve water level management within the RRWMA for vegetation management and control pool bounce to improve success of wildlife nesting.

During normal periods, not during significant runoff events, the DNR may operate the pools as they normally would. This may include drawing the pools down using stoplogs to manage vegetation and nesting habitat, as well as raising pool levels for various reasons.

The proposed higher capacity structures allow greater flexibility in controlling pool bounce. However, pool bounce is entirely dependent on how these structures are operated.

Table 16 illustrates an example of the pool bounce and peak water surface elevation inside the pools, for various runoff events. Additionally, several specific 24-hour summer storm events were examined which produce a given Pool 3 bounce using the Alternative 3 structure configuration (Table 16). A 4.75-inch storm event, simulating the June 2011 event, was selected that produced a

20-inch bounce in Pool 3 under proposed conditions and a 22-inch bounce under existing conditions. A 3.7-inch storm produced a 5-inch Pool 3 bounce under proposed conditions compared to nearly 12 inches under existing conditions. A 2.8-inch storm produced no bounce in Pool 3-Alternative 3, but a 9.5-inch bounce under existing conditions. These events had similar reductions in bounce in Pool 2.

A small change in pool bounce may have a large impact on the area of land that is inundated with water inside the pools. For example, in Pool 3, during a 100-year 10-day event, the bounce is reduced by about 1 inch with Alternative 3, compared with existing conditions. This small change in bounce reduces the inundated area by more than 80 acres. The remaining results of inundated areas is shown in Table 16.

TABLE 16. MODELED PEAK POOL WSE, INUNDATED AREAS, AND BOUNCE

Storm Event		Pool 2				Pool 3			
		Existing	Alt #1	Alt #2	Alt #3	Existing	Alt #1	Alt #2	Alt #3
100-Year 10-Day	Peak WSE (ft)	1,031.90	1,031.84	1,031.78	1,031.72	1,028.10	1,028.27	1,028.07	1,028.02
	Peak Inundated Area [ac]	7,372	7,319	7,265	7,212	7,112	7,285	7,082	7,031
	Pool Bounce (ft)	2.54	2.48	2.42	2.36	3.74	3.91	3.71	3.66
100-Year 24-Hour	Peak WSE (ft)	1,031.20	1,031.10	1,031.00	1,030.92	1,027.06	1,027.26	1,027.03	1,026.37
	Peak Inundated Area [ac]	6,749	6,660	6,570	6,499	6,058	6,260	6,027	5,358
	Pool Bounce (ft)	0.84	0.74	0.64	0.56	1.70	1.90	1.67	1.01
10-Year 24-Hour	Peak WSE (ft)	1,030.49	1,030.26	1,029.72	1,029.68	1,026.15	1,025.60	1,025.39	1,024.87
	Peak Inundated Area [ac]	6,116	5,911	5,430	5,394	5,135	4,577	4,364	3,837
	Pool Bounce (ft)	1.13	0.90	0.36	0.32	1.79	1.24	1.03	0.51
2011 Summer Event - 4.75-in over 24 hours	Peak WSE (ft)	1,030.95	-	-	1,030.43	1,027.18	-	-	1,027.02
	Peak Inundated Area [ac]	6,526	-	-	6,063	6,179	-	-	6,017
	Pool Bounce (ft)	0.59	-	-	0.07	1.82	-	-	1.66
2.80-in over 24 hours	Peak WSE (ft)	1,030.49	-	-	1,030.06	1,026.15	-	-	1,025.36
	Peak Inundated Area [ac]	6,116	-	-	5,733	5,135	-	-	4,334
	Pool Bounce (ft)	0.13	-	-	-0.30	0.79	-	-	0.00
3.70-in over 24 hours	Peak WSE (ft)	1,030.67	-	-	1,030.47	1,026.31	-	-	1,025.76
	Peak Inundated Area [ac]	6,276	-	-	6,098	5,297	-	-	4,740
	Pool Bounce (ft)	0.31	-	-	0.11	0.95	-	-	0.40

7.5.5 FLOW AUGMENTATION

Flooding is often associated with the Red River of the North and its tributaries. However, there are many instances, normally between the months of August and November, when flows on the Roseau River decrease to as little as 5-20 cfs. In these instances, the DNR may decide to augment flows on the Roseau River with waters stored in the RRWMA pools to increase dissolved oxygen for fish habitat and provide additional river base flow. Additional flows of 2 to 10 cfs may be the expected range of augmented flows. Flows are augmented by holding water inside the pools during large runoff events and releasing it slowly later in the season. Relationships between augmentation, duration, and associated storage requirements for various augmented flow rates are provided in Table 17.

TABLE 17. FLOW AUGMENTATION

Flow Rate (cfs)	Augmentation Duration (weeks)	Storage Required (acre-feet)
2	4	111
	24	666
6	4	333
	24	1,999
10	4	555
	24	3,332

8.0 OTHER CONSIDERATIONS

8.1 WATER QUALITY AND WETLAND ASSESSMENT

8.1.1 WATER QUALITY MONITORING DATA ANALYSIS

Water quality monitoring has taken place downstream of the Project at the County Road 53 crossing of the Roseau River, near Caribou, as well as upstream of the Project at the County Road 113 crossing of the Roseau River (Transgrud Bridge). Data was collected in the years of 1967, 1968, 1982, and 2002 through 2012. Measurements of temperature, dissolved oxygen, total phosphorus, turbidity, and fecal coliform have consistently been taken over the past 11 years. A summary of the existing available data is shown in Table 18.

TABLE 18. EXISTING WATER QUALITY MONITORING DATA

Year	Water Quality Parameter*										
	Temp	BOD	Chl(a)	DO	TKN	NO_3-N	TP	TSS	Turbidity	Fecal Coliform	E. Coli
2012	x			x		x	x		x		x
2011	x			x		x	x		x		x
2010	x			x		x	x		x		x
2009	x			x		x	x		x		x
2008	x			x		x	x		x	x	
2007	x			x		x	x		x	x	
2006	x			x		x	x	x	x	x	
2005	x			x		x	x		x	x	
2004	x		x	x		x	x	x	x	x	
2003	x		x	x	x	x	x	x	x	x	
2002	x	x	x	x	x		x	x	x		
1982	x	x		x	x	x	x	x		x	
1968	x	x		x		x	x	x	x	x	
1967	x	x		x		x	x	x	x	x	

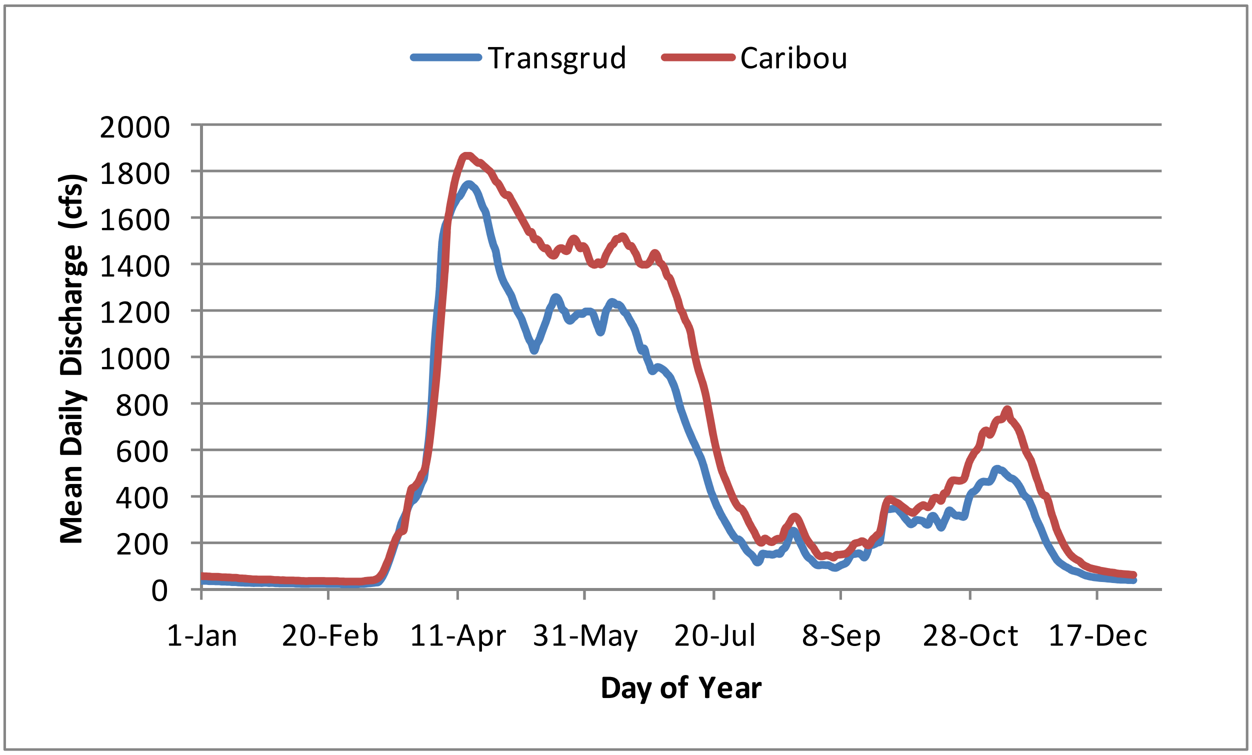
*Years noted are applicable to both monitoring locations cited in the text.

Source: (Environmental Data Access: Minnesota Pollution Control Agency, 2012)

The 2003 to 2012 period was chosen for further analysis because these years included the early spring period (2002 did not). Discharge measurements for the Caribou station were taken from the onsite USGS gage. There is no gaging station at the Transgrud station, so discharge values at the Ross USGS gage station a few miles upstream were utilized by adding 2% to the mean daily discharge value (based on Roseau River H&H modeling results).

HDR's approach to water quality data analysis consists of examining data from common sampling dates for these two sampling stations during the 2003 to 2012 period. Averages for the mean daily discharge values for the water years 2003 through 2012 are shown in Figure 30. Increases in discharge at the beginning of the spring runoff period typically take place in early March and peak about mid-April. By late July, discharges typically decrease significantly, as the drier second half of summer arrives. A smaller discharge peak typically occurs in mid-November.

FIGURE 30. MEAN DAILY DISCHARGES AT CARIBOU AND TRANSGRUD USGS GAGES



For the water quality analysis, only data collected during the months of April and May were evaluated because those months best represent the period of time when the Project would typically operate. As shown in Table 19, there is no statistical difference (alpha = 0.05) between several upstream (Transgrud) and downstream (Caribou) comparisons between water quality parameters. A similar set of comparisons, using April to October common dates, also yielded no statistically significant differences.

TABLE 19. COMPARISON OF WATER QUALITY MEANS, APRIL TO MAY*

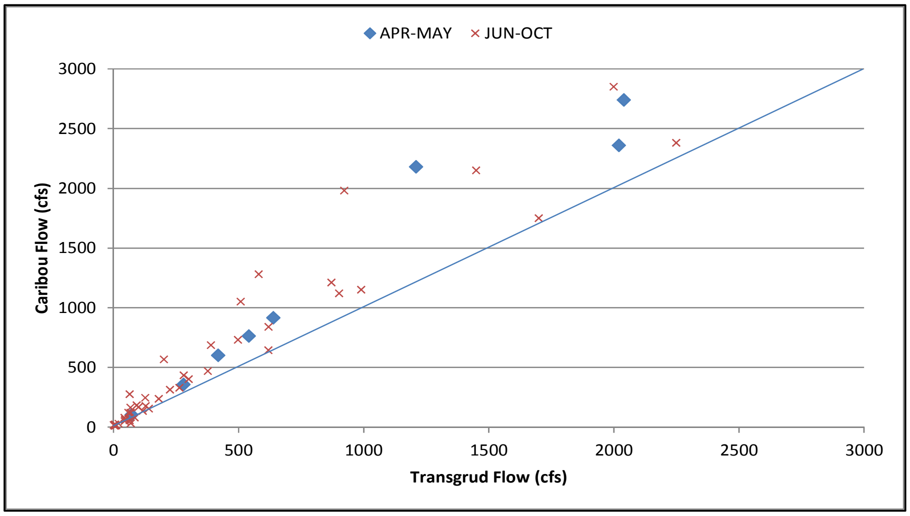
Variable	Units	# of common dates	Transgrud (upstream station) Mean	Transgrud (upstream station) Standard Deviation	Caribou (downstream station) Mean	Caribou (downstream station) Standard Deviation	Statistical Significance
FLOW	cfs	8	903	770	1,252	1,014	Not Significant
DISSOLVED OXYGEN	mg/L	6	8.7	1.6	8.2	2.3	Not Significant
E. COLI	#/100mL	4	8	5	5	4	Not Significant
FECAL COLIFORMS	#/100mL	4	3	2	5	4	Not Significant
NITRATE-N	mg/L	8	0.026	0.020	0.028	0.031	Not Significant
PH	None	6	7.88	0.17	7.75	0.28	Not Significant
TEMPERATURE	Deg C	7	14.6	3.8	13.1	2.8	Not Significant
TOTAL PHOSPHORUS	mg/L	8	0.070	0.027	0.065	0.031	Not Significant
TURBIDITY	NTU	8	13.3	8.1	12.4	9.0	Not Significant

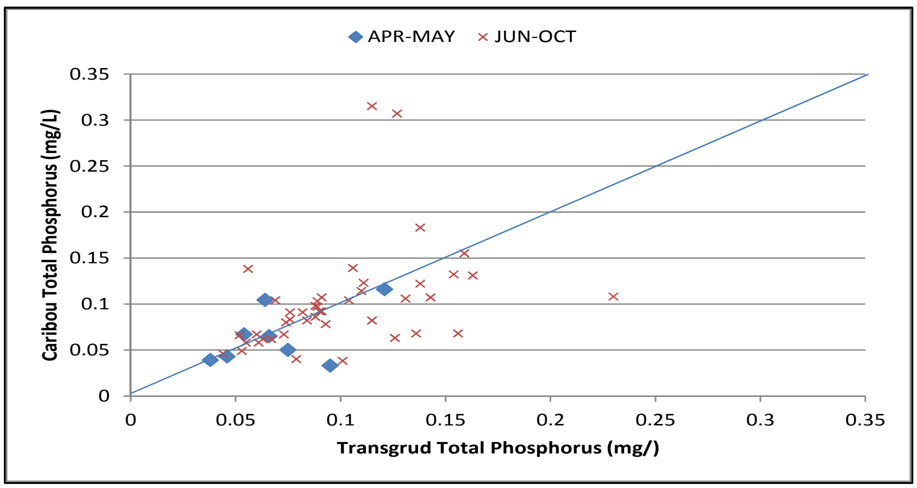
*Samples collected on common dates (April and May, 2003-2012) for Transgrud and Caribou sampling locations. Statistical significance determined using ANOVA, alpha = 0.05

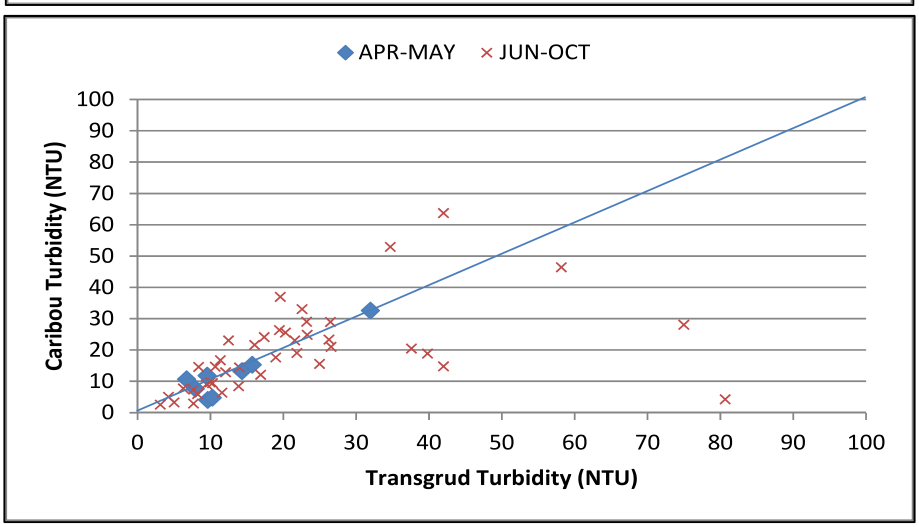
Graphical comparison between water quality parameters showed some interesting results for flow, total phosphorus (TP), and turbidity (Figure 31). One can gather that discharges increase between the Transgrud (upstream) and Caribou (downstream) sampling locations. With the exception of a few outliers for TP (e.g. TP > 0.3 mg/L), more of the values tended to fall below the 1:1 line, suggesting that TP concentrations tend to decrease from upstream to downstream. A similar but less prominent pattern is seen for turbidity.

In summary, it appears that although discharges tend to increase in the Roseau River from a location above the proposed Project (Transgrud) to a location below the proposed Project (Caribou), total phosphorus and turbidity concentrations tend to decrease. This behavior suggests that water entering the River between the two locations, including water from the RRWMA, improves water quality in the Roseau River. Thus, there is no evidence that a change in the timing of outflows from the RRWMA will cause an adverse impact to water quality.

FIGURE 31. SELECTED RELATIONSHIPS BETWEEN ROSEAU RIVER SAMPLING LOCATIONS





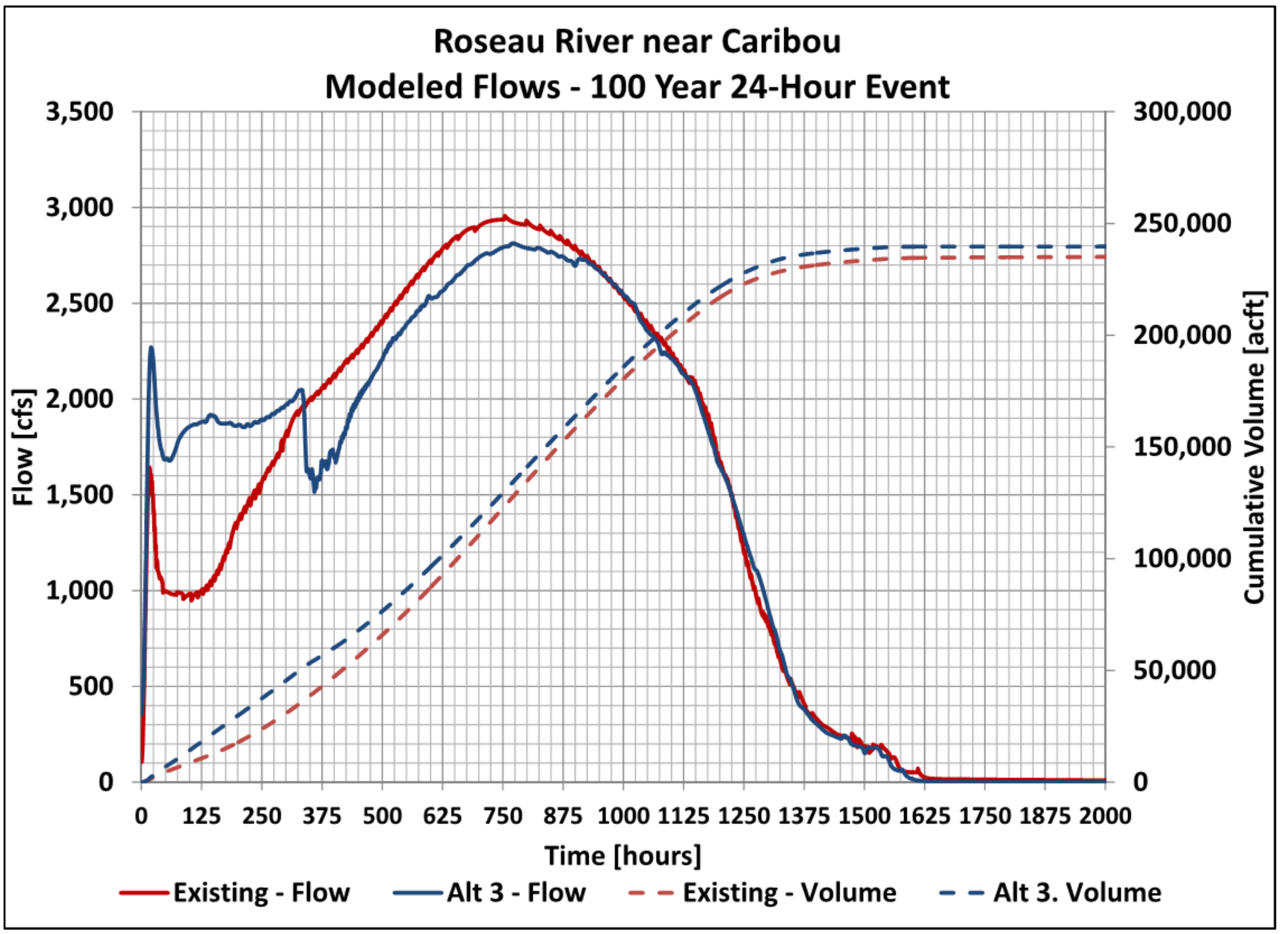


1:1 lines shown in blue for comparison between sampling locations.

Pre- and Post-Project Water Quality Loading, Discharge, and Volume

Figure 32 illustrates the modeled existing and proposed 100-year 24-hour storm, on the Roseau River at Caribou. While proposed discharges increase over existing conditions during the first 13 days of the event, during the middle of the event (approximately Day 13 through Day 39) discharges for proposed conditions are lower than existing conditions. The cumulative total volume of water discharged from the Project is 2% more (about 4,500 acre-feet) for proposed conditions, compared with existing conditions. This is due to the fact that the proposed Pool 3 Alternative greatly reduces the volume of flow transferring to the Two Rivers Watershed. Because the total volume of flow and water quality concentrations discharged from the Project does not significantly change pre- to post-Project, the total loading of phosphorus, turbidity, nitrate-N, and fecal coliforms to the Roseau River will also remain unchanged.

FIGURE 32. ROSEAU RIVER AT CARIBOU VOLUME AND DISCHARGE



8.1.2 NUTRIENT FLUSHING AND IMPACTS ON RRWMA POOLS

Water Velocities inside Pools Related to Nutrient Flushing

Currently, the Pool Outlet Structures have limited capacities. The new higher-capacity Outlet Structures mean that flow through the pools will increase. Since flows are increased, water velocities will likely increase. There is cause for concern that any water velocity increase may cause detrimental effects to the health of the wetland habitat inside the pools.

The following analysis calculates velocities inside the pool by determining flow area at radial cross-sections of 100 feet, 1,000 feet, and up to 15,000 feet from each pool's Outlet Structure. Flow area is determined by finding the area between an ArcGIS cross-section of the raw topographic surface, and the 100-year 10-day water surface elevation, for each alternative. Intuitively, at 15,000 feet from the Outlet Structure, water traveling towards the Outlet Structure has velocity of close to zero. Conversely, as water moves toward the Outlet Structure, it will increase in velocity due to the smaller cross-sectional area. See Table 20 and Table 21 below for existing and proposed velocity of water moving towards the Outlet Structures in each pool. See Figure 33 and Figure 34 for an illustration of corresponding cross-section locations.

TABLE 20. POOL 2 WATER VELOCITIES AT VARYING CROSS-SECTIONS

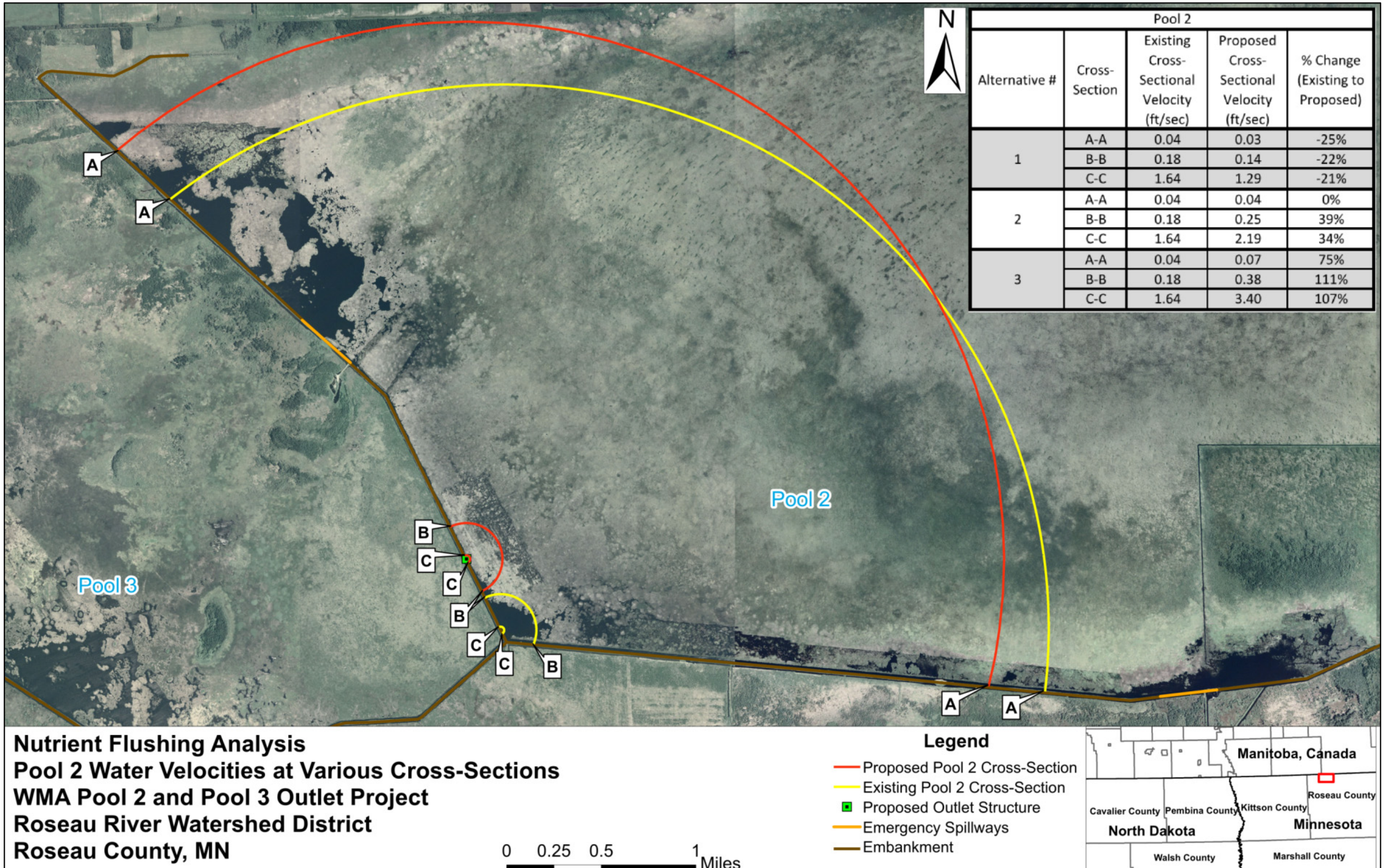
Alt #	Cross-Section	Distance from Outlet Structure (ft)	Existing Flow Area (ft^2)	Proposed Flow Area (ft^2)	Existing Flow (cfs)	Proposed Flow (cfs)	100-Yr 10-Day Existing Velocity (ft/sec)	100-Yr 10-Day Proposed Velocity (ft/sec)	Velocity Increase (ft/sec)
1	A-A	15,000	6,760	9,631	250	250	0.04	0.03	-0.01
	B-B	1,000	1,388	1,734			0.18	0.14	-0.04
	C-C	100	153	194			1.64	1.29	-0.35
2	A-A	15,000	6,760	9,631	250	425	0.04	0.04	0.0
	B-B	1,000	1,388	1,734			0.18	0.25	0.07
	C-C	100	153	194			1.64	2.19	0.55
3	A-A	15,000	6,760	9,631	250	660	0.04	0.07	0.03
	B-B	1,000	1,388	1,734			0.18	0.38	0.20
	C-C	100	153	194			1.64	3.40	1.76

TABLE 21. POOL 3 WATER VELOCITIES AT VARYING CROSS-SECTIONS

Alt #	Cross-Section	Distance from Outlet Structure (ft)	Existing Flow Area (ft^2)	Proposed Flow Area (ft^2)	Existing Flow (cfs)	Proposed Flow (cfs)	100-Yr 10-Day Existing Velocity (ft/sec)	100-Yr 10-Day Proposed Velocity (ft/sec)	Velocity Increase (ft/sec)
1	A-A	Up to 15,000	12,511	12,518	250	330	0.02	0.03	0.01
	B-B	1,000	1,435	1,553			0.17	0.21	0.04
	C-C	100	149	286			1.68	1.15	-0.53
2	A-A	Up to 15,000	12,511	12,559	250	770	0.02	0.06	0.04
	B-B	1,000	1,435	1,600			0.17	0.48	0.31
	C-C	100	149	335			1.68	2.30	0.62
3	A-A	Up to 15,000	12,511	12,610	250	1,200	0.02	0.10	0.08
	B-B	1,000	1,435	1,658			0.17	0.72	0.55
	C-C	100	149	396			1.68	3.03	1.35

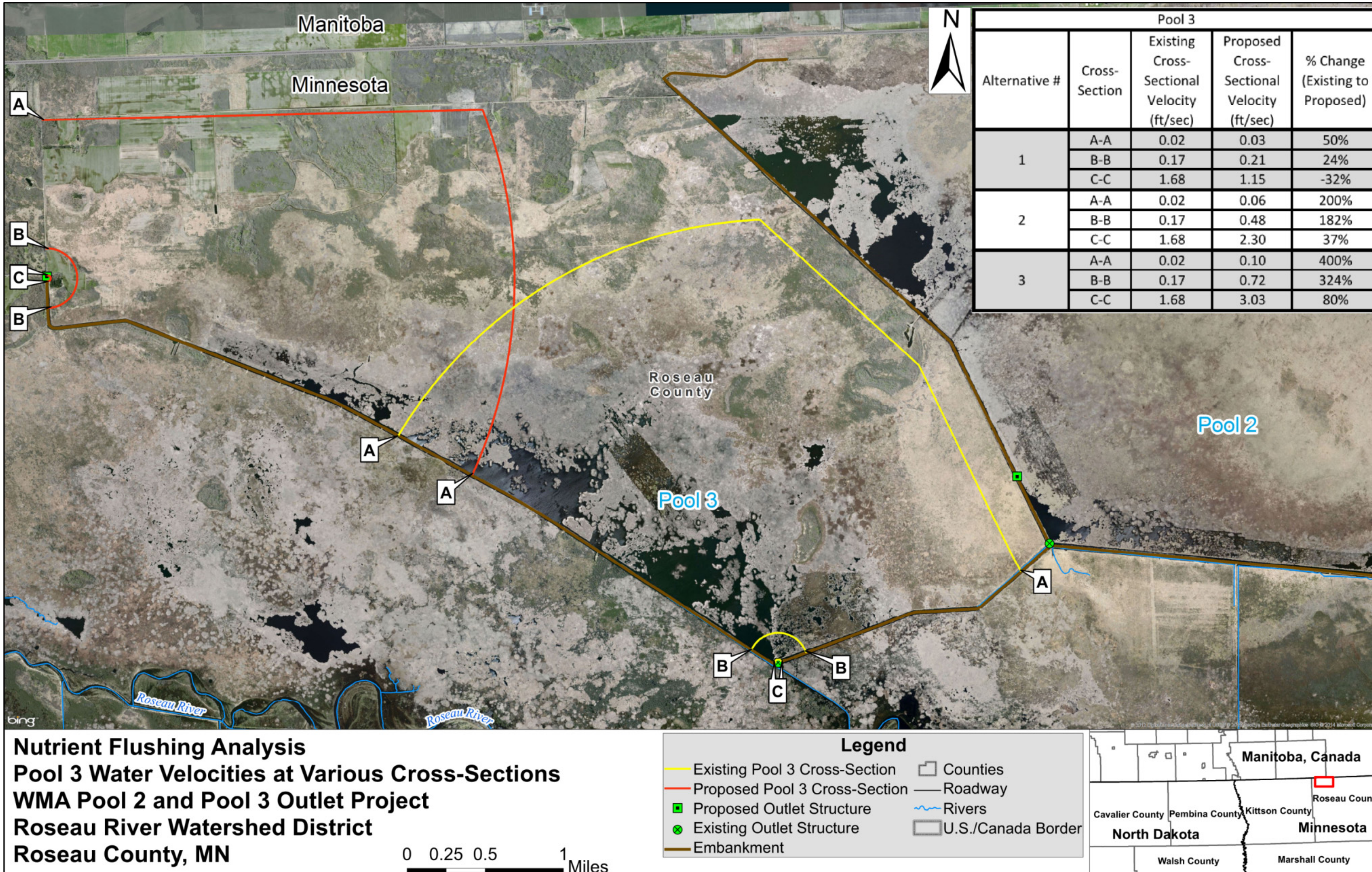
Under existing conditions, water in the middle of each pool moves towards the Outlet Structure at less than 0.1 ft/sec. during a large flood event. With the proposed conditions, water velocities in the middle of each pool are also less than 0.1 ft/sec, but may experience a slight increase. Regardless of the increase, this velocity is not large enough to flush nutrients and/or vegetation from the pools. During large runoff events, within 100 feet of the Outlet Structure, water is moving at about 1.7 ft/sec. For the proposed Project, velocity may increase by up to 1.5 ft/sec. near the pool 3 outlet(s). Near the existing Outlet Structures, nutrient accumulation is already inhibited due to velocities and the appearance of open water. Velocities are generally not high enough to scour nutrients or vegetation off the bottom of the pool from the Outlet Structure at a distance of 1,000 feet or more.

FIGURE 33. POOL 2 CROSS-SECTIONAL VELOCITIES



Pool 2				
Alternative #	Cross-Section	Existing Cross-Sectional Velocity (ft/sec)	Proposed Cross-Sectional Velocity (ft/sec)	% Change (Existing to Proposed)
1	A-A	0.04	0.03	-25%
	B-B	0.18	0.14	-22%
	C-C	1.64	1.29	-21%
2	A-A	0.04	0.04	0%
	B-B	0.18	0.25	39%
	C-C	1.64	2.19	34%
3	A-A	0.04	0.07	75%
	B-B	0.18	0.38	111%
	C-C	1.64	3.40	107%

FIGURE 34. POOL 3 CROSS-SECTIONAL VELOCITIES



Pool 3				
Alternative #	Cross-Section	Existing Cross-Sectional Velocity (ft/sec)	Proposed Cross-Sectional Velocity (ft/sec)	% Change (Existing to Proposed)
1	A-A	0.02	0.03	50%
	B-B	0.17	0.21	24%
	C-C	1.68	1.15	-32%
2	A-A	0.02	0.06	200%
	B-B	0.17	0.48	182%
	C-C	1.68	2.30	37%
3	A-A	0.02	0.10	400%
	B-B	0.17	0.72	324%
	C-C	1.68	3.03	80%

Water Shear Stress and Nutrient Scouring

The biggest factor in analyzing whether the proposed Project will "flush" nutrients out of the RRWMA is the shear stress between the water and the bottom of the channel or pool.

The shear stress of water is the force of water moving against the bed of the channel. If this force is large enough, it will pick up sediment and/or vegetation from the bed of the channel and deposit it downstream where the shear stress decreases accordingly. Different soil types have different abilities to resist shear stress. In the case of the RRWMA, most of the surface soils are muck or peat. Peat has a low ability to resist shear forces, due to its light weight, high water content, and small particle sizes.

Shear stresses inside Pool 3 were examined to determine whether the proposed Project would have negative impacts the health of the ecosystem in the RRWMA. A hydraulic model was developed, using HEC-RAS to perform this analysis. Surveyed existing cross-sections of the channel next to the dike wall were used to develop the existing conditions model. The proposed Alternative 3 Pool 3 Conveyance Channel was used as the proposed conditions model geometry. Existing flow in the channel adjacent to the pool 3 dike was assumed to be 250 cfs, or one-half of the total estimated capacity of the existing RRWMA pool 2 and 3 structures. The existing pool 2 Outlet Structure is assumed to discharge the other half of this flow. The flow used in the proposed conditions model is 660 cfs, the modeled peak flow in the proposed Conveyance Channel. HEC-RAS was used to perform shear stress calculations at every modeled cross-section. See Table 22 for the results of existing and proposed shear stresses in the pool 3 channel.

TABLE 22. CHANNEL SHEAR STRESS – EXISTING AND PROPOSED

Shear Stress (lb/ft^2)	Existing Conditions	Proposed Conditions – Alternative #3
AVERAGE SHEAR STRESS (LB/FT^2)	0.049	0.045
MINIMUM SHEAR STRESS (LB/FT^2)	0.019	0.033
MAXIMUM SHEAR STRESS (LB/FT^2)	0.072	0.091

As described in the table above, the proposed Alternative 3 conditions slightly decrease overall average shear stress in the Conveyance Channel. Near the new Pool 3 Outlet Structure, shear stresses slightly increase due to the increased flow at the upstream side of the Pool 3 Outlet Structure. In some locations within the Conveyance Channel, proposed shear stresses may increase over existing conditions, but these increases remain below the maximum shear stresses just upstream of the proposed Pool 3 Outlet Structure. Since average shear in the Conveyance Channel is slightly decreased compared with existing conditions, channel scour and nutrient flushing should not increase due to the proposed Project.

8.1.3 WETLAND HEALTH AND HABITAT

Inundation Depth and Duration during Flood Events

Due to water quality and wetland inundation concerns, the period of time that floodwaters are detained inside the pools is important. For purposes of this analysis, the period of inundation is defined by the period of time that the water surface elevation inside Pools 2 and 3 exceeds 0.1 ft above the normal pool elevation. This period of inundation is entirely dependent on how the Project's outlets are operated. By following the operation plan, inundation time inside the pools may be reduced with the proposed Project due to the increased capacity in the Outlet Structure sizes. See Table 23 and Table 24 for a comparison of pre- and post-Project inundation periods. Inundation times are shown for a modeling iteration where the new hydraulic structures are allowed to discharge up to the operation plan trigger point. Alternative 3 has the greatest effect on reducing the period of inundation in pools 2 and 3.

The depth of inundation in Pools 2 and 3 varies depending on the alternative and the runoff event. Pool 2 vegetation may see inundation depths decrease by 2 – 3.5 inches during large 100-year storm events. The Pool 2 period of inundation is also decreased by 30-40% for Alternative 3 during the 100-year events. Pool 3 vegetation may see a decrease in the depth of inundation by up to 1 – 8 inches during 100-year storm events of various durations. In addition to the reduced depth of inundation during storm events, the Pool 3 period of inundation may be reduced by 23% for the 100-year 10-day and 71% for the 100-year 24-hour event. See Table 25 for pool bounce changes between existing and proposed conditions. The net result of the proposed Project is an overall benefit to the wetland communities inside Pools 2 and 3 due to the decreased depths and duration of inundation over wetland vegetation.

TABLE 23. POOL 2 PRE- AND POST-PROJECT PERIOD OF INUNDATION

Event	Existing	Alternative 1		Alternative 2		Alternative 3	
	Detention Time (hr)	Detention Time (hr)	% Decrease	Detention Time (hr)	% Decrease	Detention Time (hr)	% Decrease
100-YEAR 10-DAY	2,158	1,572	27%	1,526	29%	1,505	30%
100-YEAR 24-HOUR	317	253	20%	214	32%	186	41%
10-YEAR 24-HOUR	2,154	464	78%	163	92%	149	93%

Note: Detention times are the number of hours the pool is above elevation 1029.45 ft (NAVD88) for spring events and 1030.45 ft (NAVD88) for summer events. This elevation is just above normal pool elevation and was selected because using normal pool elevation provides unreasonable results.

TABLE 24. POOL 3 PRE- AND POST-PROJECT PERIOD OF INUNDATION

Event	Existing	Alternative 1		Alternative 2		Alternative 3	
	Detention Time (hr)	Detention Time (hr)	% Decrease	Detention Time (hr)	% Decrease	Detention Time (hr)	% Decrease
100-YEAR 10-DAY	2,178	1,979	9%	1,763	19%	1,687	23%
100-YEAR 24-HOUR	1,616	1,579	2%	982	39%	467	71%
10-YEAR 24-HOUR	2,184	1,370	37%	966	56%	397	82%

Note: Detention times are the number of hours the pool is above elevation 1024.45 ft (NAVD88) for spring events and 1025.45 ft (NAVD88) for summer events. This elevation is just above normal pool elevation and was selected because using normal pool elevation provides unreasonable results.

TABLE 25. DIFFERENCE IN DEPTH OF INUNDATION

Storm Event		Pool 2				Pool 3			
		Existing	Alt #1	Alt #2	Alt #3	Existing	Alt #1	Alt #2	Alt #3
100-Year 10-Day	Peak WSE (NAVD 88) (ft)	1031.90	1031.84	1031.78	1031.72	1028.10	1028.27	1028.07	1028.02
	Pool Bounce (ft)	2.54	2.48	2.42	2.36	3.74	3.91	3.71	3.66
	Change (+/-)	---	-0.06	-0.12	-0.18	---	0.17	-0.03	-0.08
100-Year 24-Hour	Peak WSE (NAVD 88) (ft)	1,031.20	1031.10	1031.00	1030.92	1027.06	1027.26	1027.03	1026.37
	Pool Bounce (ft)	0.84	0.74	0.64	0.56	1.70	1.90	1.67	1.01
	Change (+/-)	---	-0.10	-0.20	-0.28	---	0.20	-0.03	-0.69
10-Year 24-Hour	Peak WSE (NAVD 88) (ft)	1,030.49	1030.26	1029.72	1029.68	1026.15	1025.60	1025.39	1024.87
	Pool Bounce (ft)	1.13	0.90	0.36	0.32	1.79	1.24	1.03	0.51
	Change (+/-)	---	-0.23	-0.77	-0.81	---	-0.55	-0.76	-1.28

Wetland Modeling to determine Impacts

The Ecosystem Functions Model (HEC-EFM) was used to determine the potential habitat impacts due to the proposed RRWMA Pool 2 and Pool 3 Outlet Project. HDR ran the HEC-EFM program using project hydrology and hydraulic information to determine the general ecosystem responses due to the project. The U.S. Army Corps of Engineers (USACE) developed HEC-EFM software is a statistical analysis of relationships between hydrology, hydraulics, and ecology. This program output was used to infer general nutrient impacts potentially due to the project.

Hydrologic Data

Rainfall records were downloaded from the National Climatic Data Center for the Pembina, ND, Warroad, MN, and Thief Lake Refuge, MN hourly precipitation gages. These records go back as far as August 10, 1948. Pembina was the primary record used for the continuous simulation model primarily because of its proximity to the project location (approximately 40 miles due west of Roseau, MN). The Warroad and Thief Lake Refuge gages were used to supplement the Pembina record where the Pembina data was missing. Snowpack accumulation and snowmelt were not modeled due to lack of available data. The modified rainfall record was input into HEC-HMS and run for 10 years (January 1, 1980 to December 31, 1989). This decade was chosen because it represented several average years including a few high and low rainfall years.

Hydraulic Data

In order to develop input data for the HEC-EFM model, flows were first modeled in HEC-HMS and input into the EPA-SWMM model to analyze the Alternative 3 outlet configurations. Alternative 3 was chosen because it has the largest flow rate increase through the RRWMA and is most likely to influence the nutrients and habitat throughout the RRWMA system. Alternative 3 includes a new Outlet Structure with four gates or stoplog bays at the Pool 3 outlet and a Conveyance Channel near the outlet end of Pool 3. In order to perform use HEC-EFM to perform the habitat analysis, inflow and outflow records are required. Only Pool 3 has both inflow and outflow changes. The Pool 2 inflows are unchanged between existing and proposed conditions, so only Pool 3 was analyzed for habitat differences.

Ecologic Data

Wild rice was used as an indicator species of overall wetland health and function since many wildlife species depend on it for food; its preference for relatively healthy ecosystems with colder, clear water; and sensitivity to nitrogen availability. The Natural Resources Conservation Service (NRCS) suggests wild rice populations have a boom and bust cycle of every 3 to 5 years. For the purposes of this modeling, HDR assumed the population is in the middle of a boom cycle, and the inflow and climatological contributions of nutrients remained consistent with historical trends for the area.

Below are the basic requirements for native wild rice to grow in Northern Minnesota:

- Growing Season: May - September
- Water Depth: 0.5- to 3-feet of water, mid-range is optimal
- Water Flow: stagnant water is undesirable; rivers or lakes with inlet and outlet are preferred
- Water Clarity: clear water preferred, but moderately stained water with depth of less than or equal to 2 feet okay
- pH: 6.0 – 8.0
- Water Fluctuations: Water levels during growing season should be stable or gradually receding; daily fluctuation of less than six inches throughout the growing season

- Waves: seedlings are buoyant and areas subject to winds and high wave action from heavy watercraft activity are unsuitable as the plants can be uprooted from soft sediments by high wind or waves
- Soils: Several inches of soft, organic muck is optimal. Extremely soft or flocculent bottoms are unsuitable as it creates a nitrogen sink
- Winter: seeds need 3 to 4 months under freezing/near-freezing conditions for germination

Wetland Health and Water Surface Elevation Changes

Wild rice seeds sprout under water in late April to early May, by mid-June, they have reached the "floating-leaf stage" where the leaves are floating on the surface, but roots are loosely attached to the sediment below water. During this stage, the plant can be drowned due to any rapid increase in water levels and could collapse if the water levels were to drop. During this growth stage, wild rice prefers stable to gradual water surface changes, with no more than six inches of fluctuation per day. This was input into the HEC-EFM model using the following relationship data:

- Season: May 15 to June 30
- Duration: 4 days
- Rate of Change: No more than 1-foot (absolute) per every four days
- Percent Exceedance: 10% (10-year) flow frequency

This relationship between change in water surface elevations and success of wild rice seedlings has been documented by the NRCS in 2004. HDR assigned this as the highest confidence (more stars equals more confidence) relationship for the modeling, as shown in Table 26. This analysis analyzes long-term effects on water surface elevations. Short-term pool bounce and periods of inundation, during flood events, may be found in Table 23 through Table 25.

Vegetative Competition

Another relationship modeled was the competition from perennial vegetation such as sedges and canary grass. Perennial vegetation can outcompete wild rice, if annual water levels are kept too stable year-to-year. Higher than normal water levels during moderate storm events can be beneficial to wild rice because it drowns out competing emergent vegetation.

This relationship was modeled in HEC-EFM using the following criteria:

- Season: May 1 to August 15
- Duration: 14 days
- Rate of Change: No more than 1-foot (absolute) per every fourteen days
- Percent Exceedance: 50% (2-year) flow frequency

This relationship is based on guidance in *Wild Rice Seeding Guidelines (644) Biology Jobsheet #14* by the NRCS published in December 2004 (Natural Resources Conservation Service (NRCS), 2004); however it is not an exact scientific relationship, so caution should be used when interpreting the results. Reducing perennial vegetation competition is entirely within the gate operator's control. It simply requires periodic adjustment of the gates every few years to create higher than normal water surface elevations to drown out competing vegetation.

Water Exchange and Wetland Health

Finally, wetland health, based on water exchange rates was analyzed. This analysis looked at the flows through the wetland. It was assumed exchange rates in the pools are especially important during mid-May to mid-September and that, in general, increasing flow transfer within the RRWMA 30% of the time will be beneficial to wetland water quality and wild rice by providing a brief influx of nutrients and fresh water. This relationship was included for qualitative informational purposes only.

Analysis

The 10-year hydrologic cycle, EPA-SWMM flows, and wild rice relationships were entered into the HEC-EFM model to conduct a statistical analysis of the relationships between hydrology, hydraulics, and ecology. The model output was used to determine the general ecosystem responses to flow regime changes in Pool 3. Changes in ecosystem response are tied to nutrients within the pools.

Results

The results shown in Table 26 are not the same as the modeled stage for a given design storm discussed in Section 8.1.3 because these are based on long-term duration mean daily stage. The results shown in Table 26 represent an assumed condition where the increase in flow capacities in the proposed project allow for quicker pool drawdown and result in lower average pool levels during and after inundation events.

TABLE 26. HEC-EFM RELATIONSHIP RESULTS

Relationship	Confidence	Existing Conditions	Alternative 3	Proposed Project Influence on Wild Rice
		Stage, ft (NAVD88)	Stage, ft (NAVD88)	
Wild Rice Inundation	****	1025.11	1024.11	Positive
Perennial Vegetation Competition	**	1024.51	1024.11	Negative
Wetland Health	n/a	1024.01	1024.11	Positive

HEC-EFM indicates that Alternative 3 could provide some habitat benefits to wild rice by reducing the duration of high water surface elevations during the growing season. Table 26 shows a potential negative impact on wild rice, due to competition with perennial vegetation, and should be considered in the RRWMA's vegetation management plan.

Conclusions of Ecological Functions Model

Wild rice was used as an indicator species of overall wetland health and function since many wildlife species depend on it for food; its preference for relatively healthy ecosystems with colder, clear water; and its sensitivity to nitrogen availability. It is assumed that a positive response for wild rice would correspond to a positive response for overall wetland health and function. The HEC-EFM results indicate a positive response for wild rice development during its critical spring period for the proposed conditions.

In general, wetlands serve as a natural nutrient sink and are conducive to prolific vegetative growth and nutrient cycling. Each spring, wetlands switch from a sink to a nutrient source as snowmelt runoff flushes built-up nutrients released from vegetative senescence from the previous fall, along with over-winter internal loading of phosphorous (Mitsch & Gosselink, 2000).

Based on the HEC-EFM analysis, no negative impact is expected for the ecology indicator species, which is dependent on wetland nutrients to thrive. In addition, the proposed project does not alter the natural nutrient inflows, thus the project is not expected to adversely affect the RRWMA system.

8.1.4 CONCLUSIONS FOR WATER QUALITY AND WETLAND HABITAT

In summary, the following conclusions can be inferred from HDR's analysis of the proposed project's effect on the RRWMA:

1) Existing water quality data indicates that water discharging from the RRWMA is approximately the same, or better, in quality, than water in the Roseau River. Therefore, changes to the timing of discharges from the RRWMA should not cause adverse water quality impacts.

2) While discharges from the RRWMA may increase during the upper limb of a flood hydrograph, the total volume of flow from the RRWMA remains the same. This means that long-term (seasonal) water quality loading of total phosphorus, turbidity, nitrate-N, and fecal coliforms from the RRWMA to the Roseau River will remain mostly unchanged.

3) Water velocities in the middle of the pools may slightly increase in the proposed project, due to the increased flows. However, water velocities remain reasonable, not enough to scour the pool or channel bottom.

4) The average shear stress in the Conveyance Channel for the proposed project is less than the average shear stress in the existing condition. Channel scour and nutrient flushing in the Conveyance Channel, adjacent to the dike, should not increase due to the proposed project.

5) The duration and depth of inundation over wetland vegetation will be lessened.

6) Based on the ecological functions model, no negative impact is expected for the ecological indicator species. The health of the indicator species is a strong gauge of overall wetland health. Thus, the project is not expected to cause an adverse affect on wetland habitat within the RRWMA.

Overall, with consistent operation of Outlet Structure gates, the proposed project is not expected to change water quality within and downstream of the RRWMA or negatively impact the wetland health and habitat of the RRWMA.

8.2 WETLAND AVOIDANCE & MITIGATION

Any wetland disturbed by construction equipment, excavation, or fill material must be permitted in accordance with the BWSR's Wetland Conservation Act (WCA) and Section 404 of the USACE's Clean Water Act (CWA). Wetland disturbance should be avoided if possible. Much of the wetland disturbance on this project is avoided by utilizing the existing conveyance ditch that is adjacent to the Pool 3 dike, instead of excavating a new Conveyance Channel through Pool 3. The proposed Pool 3 Outlet Channel alignment should also be vetted so as to minimize wetland disturbance. However, the benefits of avoiding the most wetland acres will be weighed with the additional right-of-way and construction cost.

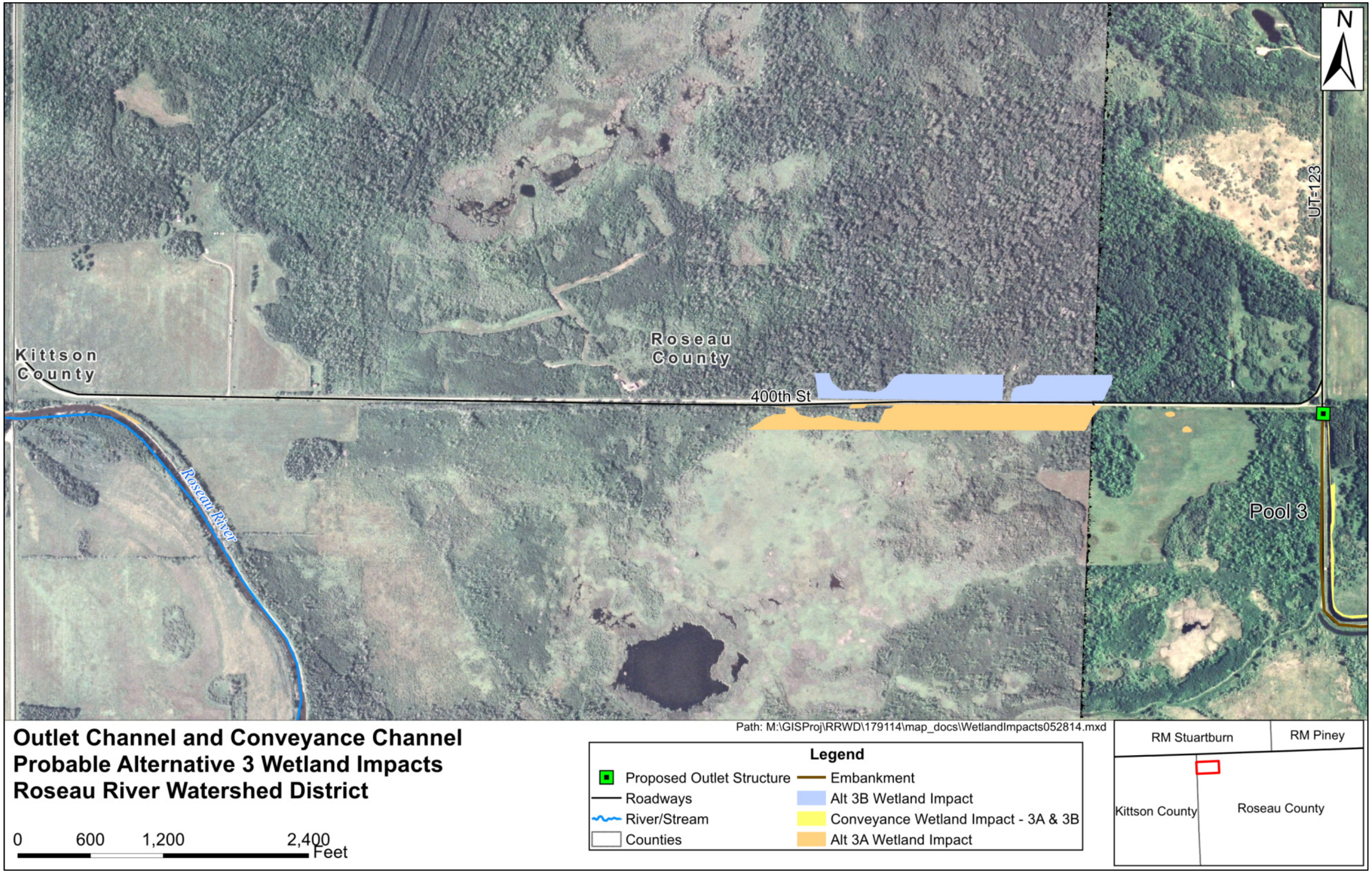
A wetland delineation, permit application, and mitigation plan will be developed prior to construction. Wetland mitigation can be accomplished through the creation, enhancement, or restoration of wetlands. A common way to create additional wetland acreage is through scraping existing vegetation, grading of small berms, planting native vegetation, and placement of ditch plugs and/or spillways. In the Roseau River Watershed, the creation of additional wetlands to mitigate wetland losses can be expected to cost approximately $2,000 - $10,000 per acre of wetland created.

Roseau River Watershed District staff performed a wetland delineation along the proposed alignments between August – October 2013 (Roseau River Watershed District, 2013). This data was overlaid with the limits of construction to provide the estimated amount of wetland impacts for each project alternative. The estimated area of wetland disturbance by each project alternative is summarized in Table 27. An illustration of this estimated area of disturbance is shown in Figure 35.

TABLE 27. APPROXIMATE WETLAND DISTURBANCE

Alternative #	Wetland Area Affected by Project Footprint (acres)
1A	7.6
1B	7.8
2A	9.4
2B	9.0
3A	12.3
3B	10.6

FIGURE 35. PROBABLE WETLAND IMPACTS



8.3 INVASIVE SPECIES

Northern pike are abundant in the RRWMA pool areas, near the Outlet Structures. It is desired to maintain the current northern pike population without introducing more rough fish (carp, sucker, bullhead, etc.) in the RRWMA. Currently, fish passage from the Roseau River to the RRWMA is not prevented.

In the future, it may be difficult to completely prevent fish passage, but some steps can be taken to reduce the likelihood of fish passage. Riprapped outfalls are planned for each of the proposed structures. The downstream invert of the Outlet Channel is 1010.25 (NAVD88) (Table 28). The Roseau River reaches that peak WSE approximately once every one to two years. Thus, water infrequently backs up into the Outlet Channel from the Roseau River.

When the Pool 3 Outlet Structures gates are open, water will be traveling through them at velocities of about 15 feet/second. This considerably reduces the probability of fish migrating through the Outlet Structure gates, as this is fast enough to deter fish migration into the RRWMA pools.

In order for fish to migrate into the pools over the top of the stoplogs, tailwater elevations on the downstream side of the stoplogs would need to be high enough for fish to swim or jump over the top stoplog. However, with normal operation during flood events, the stoplogs will be set at an elevation well above the tailwater elevation.

The instance in which fish passage into the RRWMA pools is most likely is when headwater in the pools is low (i.e. when pools are being de-watered), and tailwater on the Roseau River is high, during a significant runoff event from the remainder of the watershed. This creates a situation in which water velocities discharging through the RRWMA gates or stoplog bays are low enough to allow fish to migrate into the pools. Therefore, it is recommended that the pools should not be de-watered during periods of time when Roseau River stages are above a 2-year event.

TABLE 28. OUTLET CHANNEL INVERT ELEVATION

Alternative #	Outlet Channel Invert (NAVD88) (ft)	Roseau River 1-year WSE (NAVD88) (ft)	Roseau River 2-Year WSE (NAVD88) (ft)
1	1010.25	1008.4	1011.7
2	1010.25		
3	1010.25		

8.4 LAND OWNERSHIP, LAND USE, AND RIGHT-OF-WAY

Figure 36 shows the current land ownership for the area in the vicinity of the project. The area inside the RRWMA is owned and managed by the MnDNR. The MnDNR also owns much of the land in the Big Swamp area, south of the RRWMA. Public land is abundant in the area, with many parcels owned by Roseau County and the Nature Conservancy. Various privately owned agricultural lands are held in the Conservation Reserve Program (CRP). In Figure 36, private land is identified as the land that is not labeled as public lands.

The proposed Pool 3 Outlet Channel is located parallel to 400th Street, either on the north or south side, as discussed in Section 7.3. As shown in Figure 37, all of the land south of 400th Street is owned by the DNR, while land directly north of 400th Street is owned by several entities, including four separate private landowners. Locating the Pool 3 Outlet Channel north of 400th Street requires the purchase of additional right-of-way and the removal or relocation of two or three structures, due to their close proximity to 400th Street. An estimate of the right-of-way that would need to be purchased for the proposed Pool 3 Outlet Channel varies depending on the alternative selected, and is summarized in Table 29.

TABLE 29. RIGHT-OF-WAY FOR POOL 3 OUTLET CHANNEL

Alternative	Additional Right-of-Way Area (acres)
1A	0.0
1B	33.3
2A	0.0
2B	40.2
3A	0.0
3B	50.5

Current land use in the RRWMA pools consists of open water, emergent and woody wetlands as shown on Figure 38. Row crops, small grains, and pasture surround the RRWMA, with deciduous forest scattered along the north and west edges of Pool 3.

FIGURE 36. PUBLIC LAND OWNERSHIP AND PUBLIC WATERS

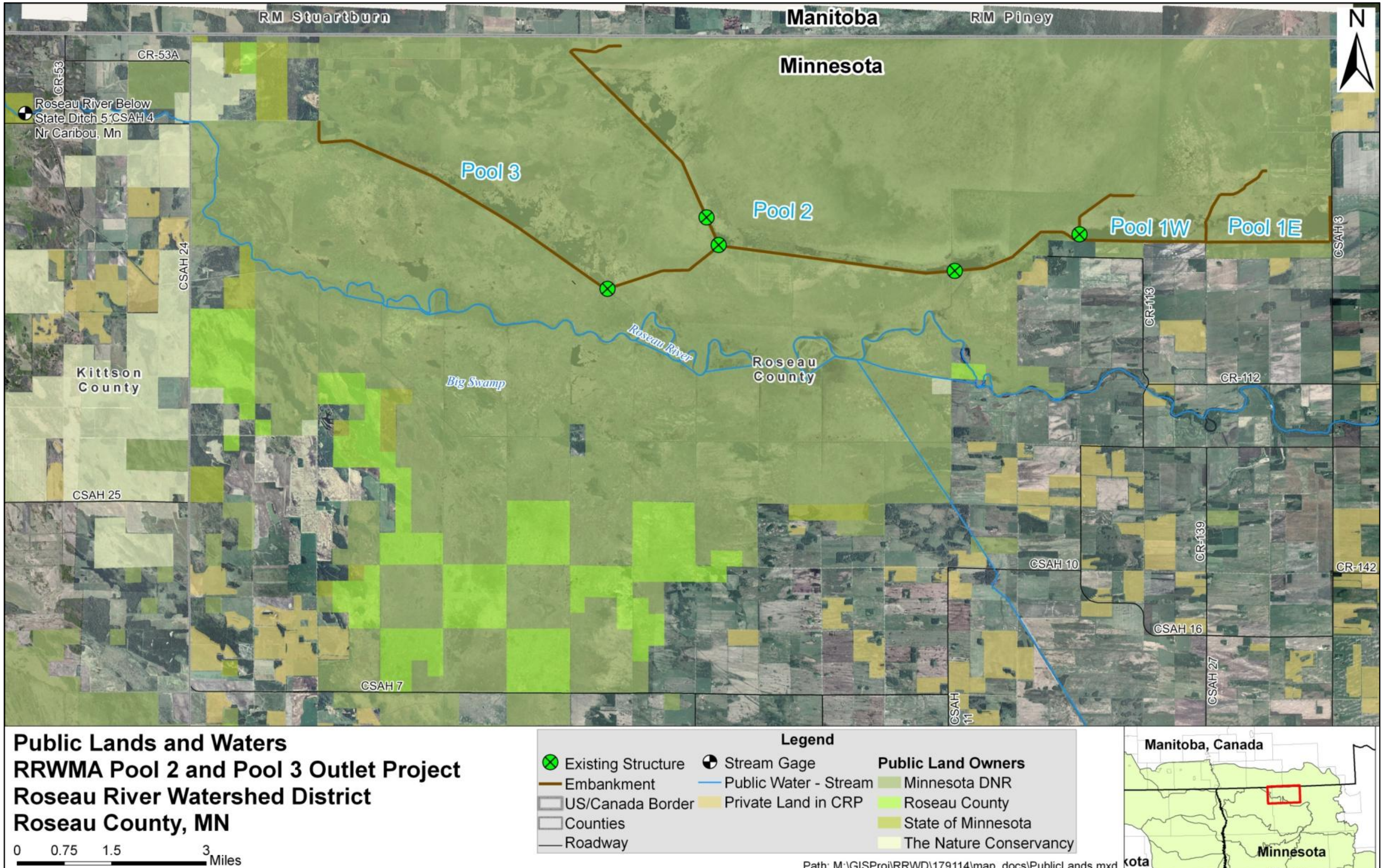
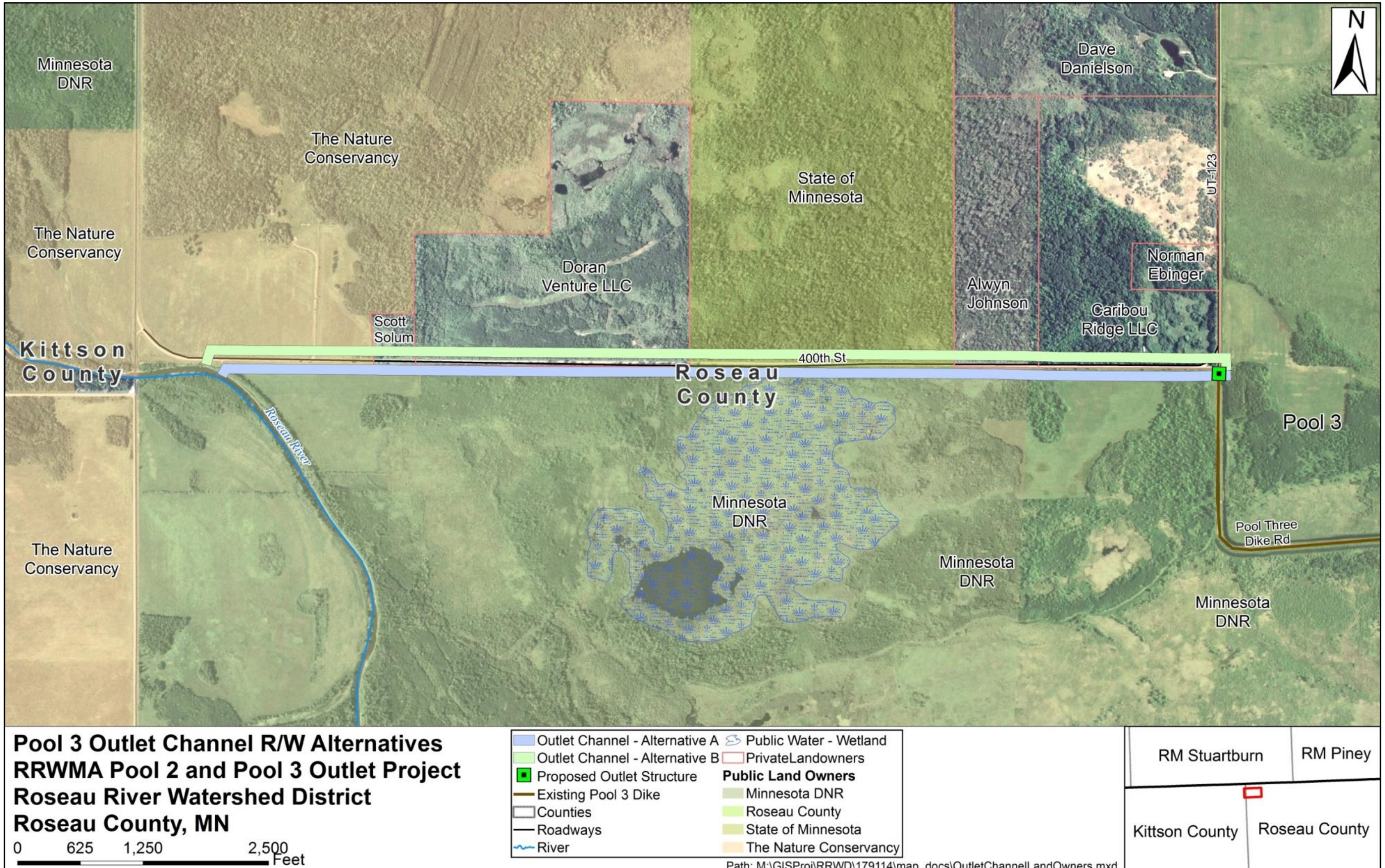
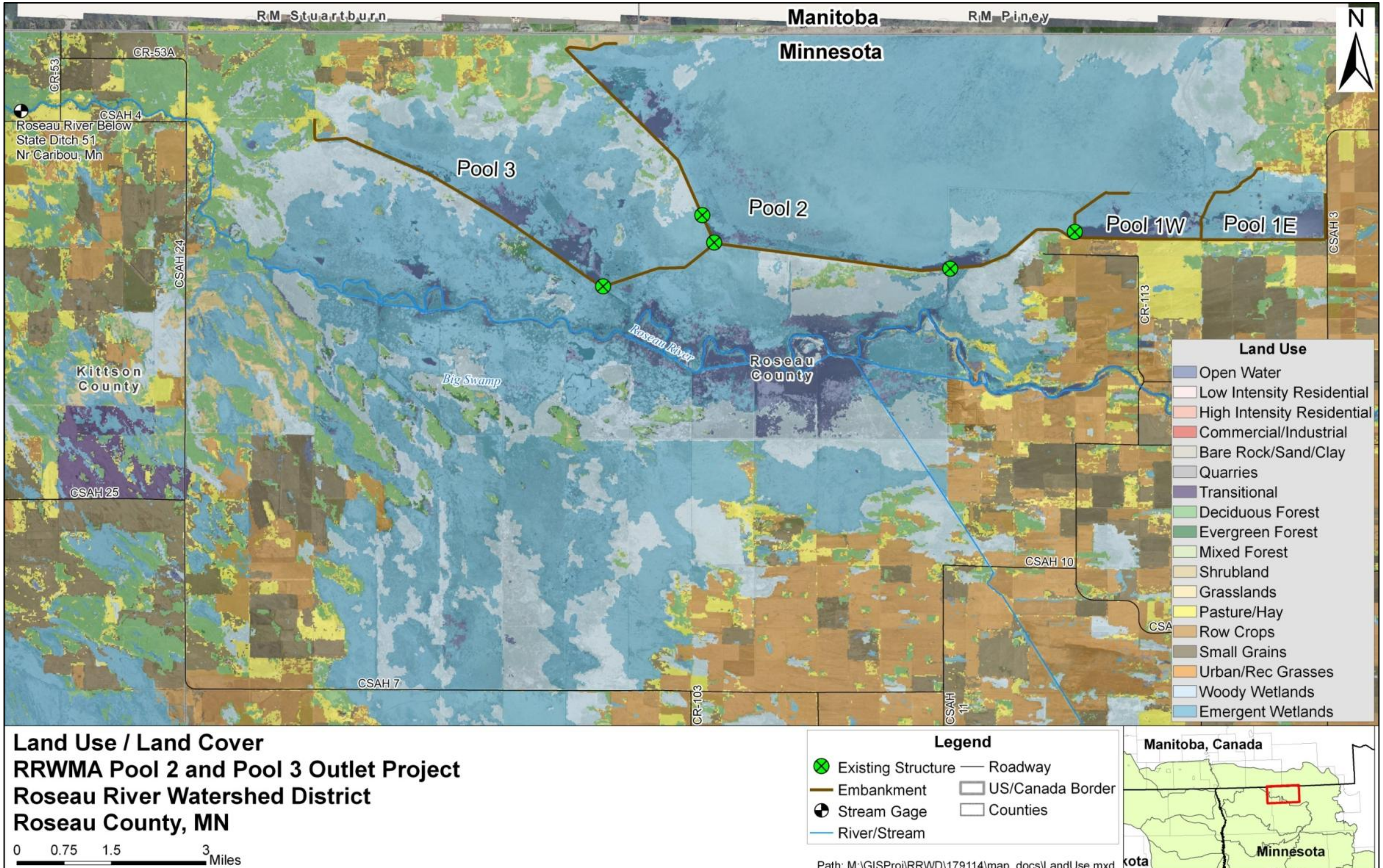


FIGURE 37. POOL 3 OUTLET CHANNEL LANDOWNERS & RIGHT-OF-WAY



Source: Roseau County Online Atlas

FIGURE 38. LAND USE



8.5 GEOTECHNICAL

8.5.1 HISTORY

The geology of the RRWMA is a product of Pleistocene and recent sedimentation and erosion. Glaciers advanced over the area several times during the Pleistocene Epoch and deposited a thick mantle of drift estimated to be over 150-200 feet thick. The last glacial period ended approximately 9,000 years ago with the retreat of the last glacier and draining of glacial Lake Agassiz, which occupied most of northwestern Minnesota, northeastern North Dakota, and central Canada. Since the recession of Lake Agassiz, streams such as the Roseau River established meandering courses over the relatively flat till and lake plain, eroding and depositing alluvial sediments; and shallow depressions filled with organic deposits to create marshes and expansive peat lands typical of the pre-drainage area of the RRWMA.

The dikes have experienced settling since they were constructed in the 1950's. Due to this settlement, in the late 1980's, approximately 1.5 – 2 feet of fill was placed to increase the top elevation of the dikes. Geotechnical documents by Midwest Testing Laboratory (now Terracon) in 1990 indicate a 300-foot long section of the Pool 2 dike failed. Temporary repairs were made to fill the failure surface and Midwest Testing Laboratory was hired to perform geotechnical investigations and provide dike repair recommendations. The recommendations included adding lightweight fill to the Pool 2 dike, placing longitudinal culvert sections into the embankment to displace soil, or provide sheet piling along the embankment to prevent rotational shear (Midwest Testing Laboratory, Inc., 1990). Sheet piling has been placed along failed portions of the dike, as the piling would cross the failure surface, providing resistance to slippage by forcing a new failure plane to develop at a lower elevation.

8.5.2 INVESTIGATIONS AND RECOMMENDATIONS

The US Army Corps of Engineers (USACE) has completed a Preliminary Geotechnical Report for the RRWMA project (U.S. Army Corps of Engineers, 2013). This report includes soil exploration and testing, structure foundation recommendations, Outlet Channel recommendations, and recommendations concerning the location and geometry of the proposed Conveyance Channel within Pool 3. The conclusions of their recommendations are as follows:

8.5.2.1 Pool 3 Outlet Channel

3.5:1 (H:V) side slopes meet required factors of safety in portions of the Outlet Channel, but not for the entire Outlet Channel length. 4:1 (H:V) side slopes meet the required factor of safety for the entire length of the Outlet Channel. Thus, the proposed Outlet Channel is recommended to have 4:1 (H:V) side slopes. Spoil piles should not be any higher than the depth of the ditch excavation.

8.5.2.2 Conveyance Channel

The proposed scope of the Conveyance Channel has changed since the time that the USACE's Preliminary Geotechnical Report was completed. In the Preliminary Engineer's Report, the Conveyance Channel was proposed to be excavated the entire length of the Pool 3 dike, from its junction with Pool 2 all the way to the new Pool 3 Outlet Structure at the west end of Pool 3. Now, the proposed Conveyance Channel will consist of excavating the existing channel to an extent approximately 2,200 feet upstream of the proposed Pool 3 Outlet Structure, where it will tie in with the channel adjacent to the existing dike. The existing channel adjacent to the Pool 3 dike will convey water to the newly excavated Conveyance Channel, allowing water to discharge through the new Pool 3 Outlet Structure. As discussed in Section 2.6.1.2.2 of the Preliminary Geotechnical Report, the recommended side slope for the Conveyance Channel is 4:1 (H:V). This side slope meets the required factor of safety for all water level cases. It is recommended that excavated material from the Conveyance Channel be placed at the toe of the existing dike to increase the factor of safety against slope stability, provide additional erosive protection against wave action, and lengthen the seepage path through the dike.

8.5.2.3 Pool 2 to 3 and Pool 3 Outlet Structures

The foundation and stability design of the Pool 2 to 3 and Pool 3 structures should be based on a net allowable soil bearing pressure of up to 1,700 pounds per square foot (psf). This includes a factor of safety of at least 3.0 against shear of base failure of the foundation (Appendix C).

The soft clays at the foundation grade of the Pool 2 to Pool 3 structure will compress under the weight of the structure. The estimated total settlement of the Pool 2 to Pool 3 structure is 1.75 inches, and will occur over several years (Appendix C).

The Pool 3 Outlet Structure foundation is beneath the soft glacio-lacustrine clays, and will bear on medium stiff till soils. These soils are a little less compressible than the glacio-lacustrine soils. The estimated total settlement of the Pool 3 Outlet Structure is estimated to be 1 inch or less (Appendix C).

Drainage fill material, designed as a filter, should be placed around the downstream 1/3 of the outlet pipes in order to prevent piping of material along the outside of the conduit. The Preliminary Geotechnical Report by USACE and Geotechnical Memorandum by HDR are included in Appendix C.

8.6 EROSION CONTROL

8.6.1 SEDIMENTATION AT ROSEAU RIVER

Sedimentation at the Roseau River is reduced through a combination of two methods. A properly executed Stormwater Pollution Prevention Plan (SWPPP) is important to prevent soil from eroding during construction. Secondly, the Outlet Channel from Pool 3 is designed to maintain water velocities below 3.5 feet/second. This velocity is low enough to reduce erosion of the fat clay (CH) soils along the alignment of the Outlet Channel, as well as prevent suspended sediment from settling to the bottom of the channel. Sedimentation where the Outlet Channel meets the Roseau River should not occur because channel velocities do not drastically decrease in going from the Outlet Channel to the Roseau River.

8.6.2 PREVENTION OF DIKE EROSION

With the constructed project, spoil material from the new excavated Conveyance Channel will be placed on the side slope of the Pool 3 dike. This provides a greater factor of safety against slope failures and increases protection against wave action and ditch flows. Spoil material placed on the dike side slopes will be vegetated to provide maximum erosion protection.

9.0 OPINION OF PROBABLE COST

Table 30 through Table 35 outline the estimated costs for six separate alternatives in 2014 dollars. Table 36 provides a comparison of the cost between each alternative.

TABLE 30. ALTERNATIVE 1A OPINION OF PROBABLE COST

Roseau River Watershed District	**Alternative 1A**			
Roseau River WMA Project	**Engineer's Opinion of Most Probable Cost**			
Construction Costs				
Item	**Unit**	**Qty**	**Unit Cost**	**Cost**
MOBILIZATION	LS	1	$43,000.00	$43,000.00
FIELD LABORATORY - TYPE D	EACH	1	$8,000.00	$8,000.00
CLEARING AND GRUBBING	ACRE	18.7	$1,500.00	$28,017.00
REMOVE EXISTING POOL 2 TO POOL 3 STRUCTURE	EACH	1	$25,000.00	$25,000.00
COMMON EXCAVATION (P)	CY	119,000	$3.25	$386,750.00
COMPACT RAISED ROAD SUBGRADE (P)	CY	60,000	$1.50	$90,000.00
AGGREGATE SURFACING, CLASS 5	CY	5,320	$15.00	$79,800.00
POOL 2 TO POOL 3 STRUCTURE	EACH	1	$ 112,000.00	$112,000.00
POOL 3 OUTLET STRUCTURE	EACH	1	$ 150,000.00	$150,000.00
STRUCTURE EXCAVATION	CY	3,121	$5.50	$17,163.00
GRANULAR BEDDING (CV)	TON	28	$16.00	$448.00
RANDOM RIPRAP, CLASS 3 TO CLASS 5	CY	1,237	$70.00	$86,590.00
OUTLET DITCH ACCESS CROSSING	EACH	2	$11,900.00	$23,800.00
TRAFFIC CONTROL	LS	1	$2,500.00	$2,500.00
TEMPORARY DITCH CHECK, 12" BIOROLLS	LF	126	$2.50	$315.00
EROSION CONTROL BLANKET	SY	5,466	$1.25	$6,833.00
SEEDING	ACRE	36	$125.00	$4,538.00
SEED MIXTURE, MN/DOT 35-241	POUND	1,325	$4.25	$5,632.00
MULCH MATERIAL TYPE 1	TON	70	$100.00	$7,034.00
DISK ANCHORING	ACRE	36	$25.00	$908.00
FERTILIZER, TYPE 3	TON	5.4	$800.00	$4,356.00
Subtotal				$1,082,684.00
Engineering and Administration	30	%		$324,806.00
Wetland Mitigation	7.6	acres	$5,000/acre	$38,000.00
Materials Testing (Construction)	2	% of Earthwork Cost		$11,131.00
Contingencies	20	%		$216,537.00
Total Construction				**$1,673,200**

TABLE 31. ALTERNATIVE 1B OPINION OF PROBABLE COST

Roseau River Watershed District	**Alternative 1B**			
Roseau River WMA Project	**Engineer's Opinion of Most Probable Cost**			
Construction Costs				
Item	**Unit**	**Qty**	**Unit Cost**	**Cost**
MOBILIZATION	LS	1	$46,000.00	$46,000.00
FIELD LABORATORY - TYPE D	EACH	1	$8,000.00	$8,000.00
CLEARING AND GRUBBING	ACRE	26.2	$1,500.00	$39,303.00
REMOVE EXISTING POOL 2 TO POOL 3 STRUCTURE	EACH	1	$25,000.00	$25,000.00
COMMON EXCAVATION (P)	CY	125,000	$3.25	$406,250.00
COMPACT RAISED ROAD SUBGRADE (P)	CY	60,000	$1.50	$90,000.00
AGGREGATE SURFACING, CLASS 5	CY	5,320	$15.00	$79,800.00
POOL 2 TO POOL 3 STRUCTURE	EACH	1	$ 112,000.00	$112,000.00
POOL 3 OUTLET STRUCTURE	EACH	1	$ 150,000.00	$150,000.00
STRUCTURE EXCAVATION	CY	3,121	$5.50	$17,163.00
GRANULAR BEDDING (CV)	TON	28	$16.00	$448.00
RANDOM RIPRAP, CLASS 5	CY	1,377	$70.00	$96,390.00
OUTLET DITCH ACCESS CROSSING	EACH	3	$11,900.00	$35,700.00
TRAFFIC CONTROL	LS	1	$2,500.00	$2,500.00
TEMPORARY DITCH CHECK, 12" BIOROLLS	LF	230	$2.50	$575.00
EROSION CONTROL BLANKET	SY	5,733	$1.25	$7,167.00
SEEDING	ACRE	38	$125.00	$4,703.00
SEED MIXTURE, MN/DOT 35-241	POUND	1,373	$4.25	$5,836.00
MULCH MATERIAL TYPE 1	TON	73	$100.00	$7,288.00
DISK ANCHORING	ACRE	38	$25.00	$941.00
FERTILIZER, TYPE 3	TON	5.6	$800.00	$4,515.00
Subtotal				$1,139,579.00
Engineering and Administration	30	%		$341,874.00
Land Acquisition	33.3	acres	$1,000/acre	$33,300.00
Wetland Mitigation	7.8	acres	$5,000/acre	$39,000.00
Materials Testing (Construction)	2	% of Earthwork Cost		$11,521.00
Contingencies	20	%		$227,916.00
Total Construction				**$1,793,200**

TABLE 32. ALTERNATIVE 2A OPINION OF PROBABLE COST

Roseau River Watershed District	**Alternative 2A**			
Roseau River WMA Project	**Engineer's Opinion of Most Probable Cost**			
Construction Costs				
Item	**Unit**	**Qty**	**Unit Cost**	**Cost**
MOBILIZATION	LS	1	$50,000.00	$50,000.00
FIELD LABORATORY - TYPE D	EACH	1	$8,000.00	$8,000.00
CLEARING AND GRUBBING	ACRE	22.6	$1,500.00	$33,960.00
REMOVE EXISTING POOL 2 TO POOL 3 STRUCTURE	EACH	1	$25,000.00	$25,000.00
COMMON EXCAVATION (P)	CY	142,000	$3.25	$386,750.00
COMPACT RAISED ROAD SUBGRADE (P)	CY	60,000	$1.50	$90,000.00
AGGREGATE SURFACING, CLASS 5	CY	5,320	$15.00	$79,800.00
POOL 2 TO POOL 3 STRUCTURE	EACH	1	$ 138,000.00	$138,000.00
POOL 3 OUTLET STRUCTURE	EACH	1	$ 240,000.00	$240,000.00
STRUCTURE EXCAVATION	CY	3,442	$5.50	$18,934.00
GRANULAR BEDDING (CV)	TON	28	$16.00	$448.00
RANDOM RIPRAP, CLASS 5	CY	1,347	$70.00	$94,290.00
OUTLET DITCH ACCESS CROSSING	EACH	2	$23,800.00	$47,600.00
TRAFFIC CONTROL	LS	1	$2,500.00	$2,500.00
TEMPORARY DITCH CHECK, 12" BIOROLLS	LF	295	$2.50	$738.00
EROSION CONTROL BLANKET	SY	8,200	$1.25	$10,250.00
SEEDING	ACRE	44	$125.00	$5,500.00
SEED MIXTURE, MN/DOT 35-241	POUND	1,606	$4.25	$6,826.00
MULCH MATERIAL TYPE 1	TON	85	$100.00	$8,462.00
DISK ANCHORING	ACRE	44	$25.00	$1,100.00
FERTILIZER, TYPE 3	TON	6.6	$800.00	$5,280.00
Subtotal				$1,253,438.00
Engineering and Administration	30	%		$376,032.00
Wetland Mitigation	9.4	acres	$5,000/acre	$47,000.00
Materials Testing (Construction)	2	% of Earthwork Cost		$11,131.00
Contingencies	20	%		$250,688.00
Total Construction				**$1,938,300**

TABLE 33. ALTERNATIVE 2B OPINION OF PROBABLE COST

Roseau River Watershed District	**Alternative 2B**			
Roseau River WMA Project	**Engineer's Opinion of Most Probable Cost**			
Construction Costs				
Item	**Unit**	**Qty**	**Unit Cost**	**Cost**
MOBILIZATION	LS	1	$56,000.00	$56,000.00
FIELD LABORATORY - TYPE D	EACH	1	$8,000.00	$8,000.00
CLEARING AND GRUBBING	ACRE	31.8	$1,500.00	$47,640.00
REMOVE EXISTING POOL 2 TO POOL 3 STRUCTURE	EACH	1	$25,000.00	$25,000.00
COMMON EXCAVATION (P)	CY	150,000	$3.25	$487,500.00
COMPACT RAISED ROAD SUBGRADE (P)	CY	60,000	$1.50	$90,000.00
AGGREGATE SURFACING, CLASS 5	CY	5,320	$15.00	$79,800.00
POOL 2 TO POOL 3 STRUCTURE	EACH	1	$ 138,000.00	$138,000.00
POOL 3 OUTLET STRUCTURE	EACH	1	$ 240,000.00	$240,000.00
STRUCTURE EXCAVATION	CY	3,442	$5.50	$18,934.00
GRANULAR BEDDING (CV)	TON	28	$16.00	$448.00
RANDOM RIPRAP, CLASS 5	CY	1,497	$70.00	$104,790.00
OUTLET DITCH ACCESS CROSSING	EACH	3	$23,800.00	$71,400.00
TRAFFIC CONTROL	LS	1	$2,500.00	$2,500.00
TEMPORARY DITCH CHECK, 12" BIOROLLS	LF	295	$2.50	$738.00
EROSION CONTROL BLANKET	SY	8,600	$1.25	$10,750.00
SEEDING	ACRE	46	$125.00	$5,700.00
SEED MIXTURE, MN/DOT 35-241	POUND	1,664	$4.25	$7,074.00
MULCH MATERIAL TYPE 1	TON	88	$100.00	$8,764.00
DISK ANCHORING	ACRE	46	$25.00	$1,140.00
FERTILIZER, TYPE 3	TON	6.8	$800.00	$5,472.00
Subtotal				$1,409,650.00
Engineering and Administration	30	%		$422,895.00
Land Acquisition	40.2	acres	$1,000/acre	$40,200.00
Wetland Mitigation	9.0	acres	$5,000/acre	$45,000.00
Materials Testing (Construction)	2	% of Earthwork Cost		$13,146.00
Contingencies	20	%		$281,930.00
Total Construction				**$2,212,900**

TABLE 34. ALTERNATIVE 3A OPINION OF PROBABLE COST

Roseau River Watershed District	Alternative 3A			
Roseau River WMA Project	**Engineer's Opinion of Most Probable Cost**			
Construction Costs				
Item	**Unit**	**Qty**	**Unit Cost**	**Cost**
MOBILIZATION	LS	1	$65,000.00	$65,000.00
FIELD LABORATORY - TYPE D	EACH	1	$8,000.00	$8,000.00
CLEARING AND GRUBBING	ACRE	28.3	$1,500.00	$42,450.00
REMOVE EXISTING POOL 2 TO POOL 3 STRUCTURE	EACH	1	$25,000.00	$25,000.00
COMMON EXCAVATION (P)	CY	194,000	$3.25	$630,500.00
COMPACT RAISED ROAD SUBGRADE (P)	CY	60,000	$1.50	$90,000.00
AGGREGATE SURFACING, CLASS 5	TON	5,320	$15.00	$79,800.00
POOL 2 TO POOL 3 STRUCTURE	EACH	1	$ 167,000.00	$167,000.00
POOL 3 OUTLET STRUCTURE	EACH	1	$ 277,000.00	$277,000.00
STRUCTURE EXCAVATION	CY	3,764	$5.50	$20,705.00
GRANULAR BEDDING (CV)	TON	28	$16.00	$448.00
RANDOM RIPRAP, CLASS 5	CY	1,418	$70.00	$99,260.00
OUTLET DITCH ACCESS CROSSING	EACH	2	$35,700.00	$71,400.00
TRAFFIC CONTROL	LS	1	$2,500.00	$2,500.00
TEMPORARY DITCH CHECK, 12" BIOROLLS	LF	360	$2.50	$900.00
EROSION CONTROL BLANKET	SY	13,667	$1.25	$17,084.00
SEEDING	ACRE	55	$125.00	$6,875.00
SEED MIXTURE, MN/DOT 35-241	POUND	2,008	$4.25	$8,532.00
MULCH MATERIAL TYPE 1	TON	104	$100.00	$10,436.00
DISK ANCHORING	ACRE	55	$25.00	$1,375.00
FERTILIZER, TYPE 3	TON	8.3	$800.00	$6,600.00
Subtotal				$1,630,865.00
Engineering and Administration	30	%		$489,260.00
Wetland Mitigation	12.3	acres	$5,000/acre	$61,500.00
Materials Testing (Construction)	2	% of Earthwork Cost		$16,006.00
Contingencies	20	%		$326,173.00
Total Construction				**$2,523,900**

TABLE 35. ALTERNATIVE 3B OPINION OF PROBABLE COST

Roseau River Watershed District	**Alternative 3B**			
Roseau River WMA Project	**Engineer's Opinion of Most Probable Cost**			
Construction Costs				
Item	**Unit**	**Qty**	**Unit Cost**	**Cost**
MOBILIZATION	LS	1	$69,000.00	$69,000.00
FIELD LABORATORY - TYPE D	EACH	1	$8,000.00	$8,000.00
CLEARING AND GRUBBING	ACRE	39.7	$1,500.00	$59,550.00
REMOVE EXISTING POOL 2 TO POOL 3 STRUCTURE	EACH	1	$25,000.00	$25,000.00
COMMON EXCAVATION (P)	CY	205,000	$3.25	$666,250.00
COMPACT RAISED ROAD SUBGRADE (P)	CY	60,000	$1.50	$90,000.00
AGGREGATE SURFACING, CLASS 5	CY	5,320	$15.00	$79,800.00
POOL 2 TO POOL 3 STRUCTURE	EACH	1	$ 167,000.00	$167,000.00
POOL 3 OUTLET STRUCTURE	EACH	1	$277,000.00	$277,000.00
STRUCTURE EXCAVATION	CY	3,764	$5.50	$20,705.00
GRANULAR BEDDING (CV)	TON	28	$16.00	$448.00
RANDOM RIPRAP, CLASS 5	CY	1,575	$70.00	$110,250.00
OUTLET DITCH ACCESS CROSSING	EACH	3	$35,700.00	$107,100.00
TRAFFIC CONTROL	LS	1	$2,500.00	$2,500.00
TEMPORARY DITCH CHECK, 12" BIOROLLS	LF	360	$2.50	$900.00
EROSION CONTROL BLANKET	SY	14,333	$1.25	$17,917.00
SEEDING	ACRE	57	$125.00	$7,125.00
SEED MIXTURE, MN/DOT 35-241	POUND	2,081	$4.25	$8,843.00
MULCH MATERIAL TYPE 1	TON	108	$100.00	$10,808.00
DISK ANCHORING	ACRE	57	$25.00	$1,425.00
FERTILIZER, TYPE 3	TON	8.6	$800.00	$6,840.00
Subtotal				$1,736,461.00
Engineering and Administration	30	%		$520,939.00
Land Acquisition	50.5	acres	$1,000/acre	$50,500.00
Wetland Mitigation	10.6	acres	$5,000/acre	$53,000.00
Materials Testing (Construction)	2	% of Earthwork Cost		$16,721.00
Contingencies	20	%		$347,293.00
Total Construction				**$2,725,000**

TABLE 36. OPINION OF PROBABLE COST SUMMARY

Alternative	Opinion of Probable Costs
1A	$1,673,200
1B	$1,793,200
2A	$1,938,300
2B	$2,212,900
3A	$2,523,900
3B	$2,725,000

10.0 COMPATIBILITY WITH EXISTING PLANS, STATUTES, RULES, AND PERMITS

10.1 ROSEAU RIVER WATERSHED DISTRICT PLAN

It is the intention of the Board to manage the waters and related resources within the Watershed District in a reasonable and orderly manner to improve the general welfare and public health of the residents of the Watershed District. The overall goals for the RRWD include:

Flood Damage Reduction (FDR) Goals

- Provide 100-year flood protection for the City of Roseau and rural homesteads in the district.
- Provide 10-year flood protection for agricultural lands.
- Reduce flood damage to roads and crossings.
- Reduce drought damages.
- Preserve ground water supply and recharge areas.

Natural Resource Enhancement (NRE) Goals

- Protect, restore, enhance, and manage lakes and streams in the RRWD to support sustainable aquatic communities.
- Manage wetland and upland habitats to support sustainable wildlife communities.
- Preserve, protect, and restore unique natural resource communities and other features in the watershed.
- Increase and promote outdoor recreational activities related to fish, wildlife, and other natural resources in the watershed.
- Improve water quality in the RRWD.

The Project will contribute to many of these RRWD goals.

10.2 LOCAL MUNICIPAL PLANS

In response to the June 2002 flood, the City of Roseau and the USACE began planning for various flood mitigation projects for the City. Based on a draft feasibility report, the desired mitigation project is the construction of a high flow channel that would divert the Roseau River through the east side of Roseau. The channel would be utilized during major flood events. The proposed RRWMA project will not increase water surface elevations on the Roseau River through the City.

Roseau County staff and commissioners have participated in project planning throughout the PWT process. The proposed Project's flood control and natural resource benefits are supported by the County Water Plan goals and objectives.

10.3 MINNESOTA STATUTES AND RULES

Section 103D of Minnesota Statutes pertains to Watershed Districts. Section 103D.335, Subd. 5 enables watershed districts to exercise the power to "…make necessary surveys or utilize other reliable surveys and data and develop projects to accomplish the purposes for which the district is organized." Section 103D.335, Subd. 8 gives the watershed district the power to "…construct, clean, repair, alter, abandon, consolidate, reclaim, or change the course or terminus of any public ditch, drain, sewer, river, watercourse, natural or artificial, within the district." In addition, Section 103D.335, Subd. 9 give the power to "…acquire, operate, construct, and maintain dams, levees, reservoirs, and appurtenant works."

Also required by Section 103D.711 is the preparation of an "Engineer's Report". Requirements relative to the content of the report include:

- A scaled map of the area to be improved.
- Location of the proposed improvements; location of respective outlets.
- The watershed of the Project Area; the location of existing highways, bridges and culverts
- All lands, highways, and utilities affected, the outlines of any public lands and public bodies of water affected; potential benefiting lands; easement maps; and principal Project features.

This report is intended to satisfy the requirements of 103D.605, 103D.701, and 103D.711.

Additional Statutory requirements include interaction with Statute 103E (Roseau County Ditch Authority). Roseau County Ditch 17 runs along the outside toe of the pool dikes. This ditch is the current outlet for Pool 2 and Pool 3. The RRWD will need the approval of the County Ditch Authority to proceed with the work as described. The process will likely involve a petition from the

RRWD to the Roseau County Board, after which a public hearing will be held to review and evaluate the proposal.

10.4 STATE ENVIRONMENTAL REVIEW

Minnesota Rules Chapter 4410 requires the preparation of an Environmental Assessment Worksheet (EAW). The mandatory preparation of an EAW (Minnesota Rules 4410.4300, subpart 27) is necessary "for projects that will change or diminish the course, current, or cross-section of one acre or more of any public water or public waters wetland except for those to be drained without a permit pursuant to Minnesota Statutes, chapter 103G." With the construction of the new Conveyance Channel and Pool 3 Outlet Channel, the project will disturb more than one acre of public water and requires the preparation of an EAW. An EAW was completed through a cooperative effort between the MN DNR, Roseau River WD, and HDR in June 2014.

10.5 U.S. ARMY CORPS OF ENGINEERS SECTION 10 OR SECTION 404

A Section 404 permit will be required by the USACE due to the fact that excavation will take place through a wetland that is connected to the Roseau River. Meetings will be held with USACE permitting authorities regarding the proposed Project. The permit may require a review of operational parameters, such as wetland inundation, bounce, flood frequency, and water depth, in addition to wetland impacts from the construction footprint. Construction will not begin until all permits are received.

10.6 MINNESOTA DEPARTMENT OF NATURAL RESOURCES

The proposed project will likely require a dam safety permit from the MnDNR in accordance with Minnesota Rules 6115.0300. The purpose of these rules is to regulate the construction and enlargement of dams, as well as the repair, alteration, maintenance, operation, and abandonment, in such a manner as to best provide for public health, safety, and welfare. Pool 2 and Pool 3 dikes are likely to be classified as Class III low hazard dams. The MnDNR may determine that the Pool 2 and 3 dikes are classified to be non-hazardous dams. If the Pool 2 and 3 dikes are classified to be Class III low hazard dams, then the construction of this Project and the alteration of the dams will require a dam safety permit and will be issued through a review of the proposed design, by the MnDNR.

A MnDNR Public Waters Work Permit is required for changes in the course, current, or cross-section of Pool 3, the Roseau River, and channels outletting to the Roseau River.

10.7 WETLAND CONSERVATION ACT (WCA)

Meetings have been held with Wetland Conservation Act (WCA) permitting authorities regarding the proposed Project. It is understood that an individual wetland permit will be required from the local government unit (LGU), which will include a review of operational parameters, such as wetland inundation, bounce, flood frequency, and water depth, in addition to wetland impacts from the construction footprint. Construction will not begin until all permits are received.

10.8 NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM REQUIREMENTS

Because the construction of this project will result in more than one acre of land disturbance, a National Pollutant Discharge Elimination System (NPDES)/State Disposal System (SDS) Construction Stormwater (CSW) permit is required for the construction of this Project. The permittee must develop a SWPPP to address their stormwater discharges from the site. Each regulated party determines the appropriate pollution prevention practices, or best management practices (BMPs), to minimize pollution from the construction site.

11.0 RECOMMENDATIONS

Given the location of the project, it is emphasized herein that the MnDNR will ultimately review all alternatives and approve the most effective approach as it relates to the State's RRWMA objectives. On behalf of the RRWD, HDR provides the following recommendations.

Based on an assessment of the project features and their effectiveness in providing the stated project objectives HDR recommends Alternative 3A as the best option for flood damage reduction and natural resource enhancements. The probable overall construction, permitting, and engineering cost for Alternative 3A is $2,523,900. This is lower than the cost for Alternative 3B, as Alternative 3B has higher earthwork, land acquisition, and clearing and grubbing costs. Alternative 3A will provide the maximum cumulative benefit of the alternatives considered. These benefits are:

- Greatest reduction in peak flows on the Roseau River near Caribou (77 cfs or 2% during the 100-year 10-day event and 143 cfs or 5% during the 100-year 24-hour event)
- Largest reduction in overflows to the Two Rivers watershed (9,490 ac-ft and 110 cfs during the 100-year 10-day event and 4,852 ac-ft and 71 cfs during the 100-year 24-hour event)
- Smallest pool bounce compared to existing (Pool 3 bounce of 1.0 ft compared with 1.7 ft under existing conditions during the 100-year 24-hour event)
- Improved timing of storage in the Big Swamp (21,721 ac-ft during the 100-year 10-day event and 28,386 ac-ft during the 100-year 24-hour event)

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APPENDIX A.
STAR VALUE

TABLE A-1. PRE-PROJECT STAR VALUE TO ROSEAU RIVER

Star Value Computation Worksheet
Red River Watershed Management Board

Enter values only in the cells that have been shaded. All other values are computed from these values.

Project Name:	Pre-Project to Roseau River		Step 2	Enter Project Name. (Status eg Step)
Watershed District:	RRWD - RRWMA Pool 3 Outlet Project			Enter Name of Watershed District.
Project Location:	Northwest Roseau County			Enter Project Location.
Estimated Total Cost:	$ 2,500,000			Enter the estimated project costs. These are used to compute the cost per star value.
RRWMB Cost:	$ 418,750	CPI (1984=100)	CPI (2013=100)	
Year of Estimate:	2013	232.96	100.00	Ratios of the Consumer price index read from the CPI worksheet.
Adj. to SummaryAll Base Yr:	2000	172.20	73.92	
Drainage Area (square miles)	202.0	Enter the drainage area in square miles used to compute the runoff volume.		

Storage Volume(s):	Acre-feet	Inches	Adj. Storage (ac-ft)	
Drawdown	0	0.00	0	The adjusted storage is total storage is multiplied by the Volume Adjustment Factor which can reduce the storage. Storage is removed 1st from the ungated storage, 2nd from the gated (2) storage, 3rd from the gated (1) storage and last from the drawdown st
Gated (1)	0	0.00	0	
Gated (2)	0	0.00	0	
Ungated (to emergency spillway)	7,988	0.74	7,988	
Total Storage (8.1 inches Max.)	7,988	0.74	7,988	
Volume Adjustment Factor	1.00	0		

Est. of Ungated Detention Time	Volume (ac-ft)	Elevation (ft)	Discharge (cfs)	
Emergency Spillway		0		Note: this section is provided for reference only. The values are not used in the calculations.
10% of Ungated	0	0		
90% of Ungated Volume	0			
	Average Discharge (cfs)		0	
	Discharge in AF per day		0	
	Average Detention Time (days)		not applicable	

Detention Time:		
Gated (1) from Operation plan	0.0	Enter gated detention time for the 1st category of gated storage.
Gated (2) from Operation plan	0.0	Enter gated detention time for the 2nd category of gated storage.
UnGated (from Operation Plan or above)	0.0	Enter ungated detention time. (Center of Mass to Center of mass)
Ungated Storage Offset	0.0	Offset of center of mass of inflow hydrogragh to center of mass of storage.

Average Time Interval between Routed Site Peak and Red River Peak (days). (Negative is ahead of peak, positive is after peak)	5.0	Existing Relative T	3.34	Existing Relative T is based on the average time interval between the routed site peak flows and the RRN.

Calculation of Star Value	Routed Relative T	Adj. Storage (Ac-ft)	Star Value	
Drawdown Storage (30 - 3.40)	26.60	0	0	Routed relative T is the value of the detention times computed using the regression equations given in figure 3. The Existing Relative T is subtracted from the project Relative T.
Gated (1) Storage (3.40 - 3.40)	0.00	0	0	
Gated (2) Storage (3.40 - 3.40)	0.00	0	0	
Ungated) Storage (3.40 - 3.40)	0.00	7,988	0	
Star Value		7,988	0	STAR VALUE

	2013 dollars	2000 dollars	
Total Cost per Star Value	Not Available	Not available	Total Cost divided by STAR Value
RRWMB Cost per Star Value	Not Available	Not Available	RRWMB Cost divided by STAR Value

Prepared By:	Nate Dalager		Enter name of preparer
Source of Data:	Final Engineer's Report		Enter source data.
Frequency/Date of Preparation:	100yr 10day	27-Jun-14	Enter frequency and date.

TABLE A-2. PRE-PROJECT STAR VALUE TO TWO RIVERS WATERSHED

Star Value Computation Worksheet
Red River Watershed Management Board

Enter values only in the cells that have been shaded. All other values are computed from these values.

Project Name:	Pre-Project to Two Rivers		Step 2	Enter Project Name. (Status eg Step)
Watershed District:	RRWD - RRWMA Pool 3 Outlet Project			Enter Name of Watershed District.
Project Location:	Northwest Roseau County			Enter Project Location.

Estimated Total Cost:	$ 2,500,000			Enter the estimated project costs. These are used to compute the cost per star value.
RRWMB Cost:	$ 418,750	CPI (1984=100)	CPI (2013=100)	
Year of Estimate:	2013	232.96	100.00	Ratios of the Consumer price index read from the CPI worksheet.
Adj. to SummaryAll Base Yr:	2000	172.20	73.92	

Drainage Area (square miles)	202.0	Enter the drainage area in square miles used to compute the runoff volume.

Storage Volume(s):	Acre-feet	Inches	Adj. Storage (ac-ft)	
Drawdown	0	0.00	0	The adjusted storage is total storage is multiplied by the Volume Adjustment Factor which can reduce the storage. Storage is removed 1st from the ungated storage, 2nd from the gated (2) storage, 3rd from the gated (1) storage and last from the drawdown st
Gated (1)	0	0.00	0	
Gated (2)	0	0.00	0	
Ungated (to emergency spillway)	9,490	0.88	9,490	
Total Storage (8.1 inches Max.)	9,490	0.88	9,490	
Volume Adjustment Factor	1.00	0		

Est. of Ungated Detention Time	Volume (ac-ft)	Elevation (ft)	Discharge (cfs)	
Emergency Spillway		0		Note: this section is provided for reference only. The values are not used in the calculations.
10% of Ungated	0	0		
90% of Ungated Volume	0			
	Average Discharge (cfs)		0	
	Discharge in AF per day		0	
	Average Detention Time (days)		not applicable	

Detention Time:

Gated (1) from Operation plan	0.0	Enter gated detention time for the 1st category of gated storage.
Gated (2) from Operation plan	0.0	Enter gated detention time for the 2nd category of gated storage.
UnGated (from Operation Plan or above)	0.0	Enter ungated detention time. (Center of Mass to Center of mass)
Ungated Storage Offset	0.0	Offset of center of mass of inflow hydrograph to center of mass of storage.

Average Time Interval between Routed Site Peak and Red River Peak (days). (Negative is ahead of peak, positive is after peak)	9.0	**Existing Relative T**	7.79	Existing Relative T is based on the average time interval between the routed site peak flows and the RRN.

Calculation of Star Value	Routed Relative T	Adj. Storage (Ac-ft)	Star Value	
Drawdown Storage (30 - 7.86)	22.14	0	0	Routed relative T is the value of the detention times computed using the regression equations given in figure 3. The Existing Relative T is subtracted from the project Relative T.
Gated (1) Storage (7.86 - 7.86)	0.00	0	0	
Gated (2) Storage (7.86 - 7.86)	0.00	0	0	
Ungated) Storage (7.86 - 7.86)	0.00	9,490	0	
Star Value		9,490	0	STAR VALUE

	2013 dollars	2000 dollars	
Total Cost per Star Value	Not Available	Not available	Total Cost divided by STAR Value
RRWMB Cost per Star Value	Not Available	Not Available	RRWMB Cost divided by STAR Value

Prepared By:	Nate Dalager		Enter name of preparer
Source of Data:	Final Engineer's Report		Enter source data.
Frequency/Date of Preparation:	100yr 10day	27-Jun-14	Enter frequency and date.

TABLE A-3. POST-PROJECT STAR VALUE TO ROSEAU RIVER

Star Value Computation Worksheet
Red River Watershed Management Board

Enter values only in the cells that have been shaded. All other values are computed from these values.

Project Name:	Post-Project to Roseau River	Step 2	Enter Project Name. (Status eg Step)
Watershed District:	RRWD - RRWMA Pool 3 Outlet Project		Enter Name of Watershed District.
Project Location:	Northwest Roseau County		Enter Project Location.

Estimated Total Cost:	$ 2,500,000			Enter the estimated project costs. These are used to compute the cost per star value.
RRWMB Cost:	$ 418,750	CPI (1984=100)	CPI (2013=100)	
Year of Estimate:	2013	232.96	100.00	Ratios of the Consumer price index read from the CPI worksheet.
Adj. to SummaryAll Base Yr:	2000	172.20	73.92	

Drainage Area (square miles)	202.0	Enter the drainage area in square miles used to compute the runoff volume.

Storage Volume(s):	**Acre-feet**	**Inches**	**Adj. Storage (ac-ft)**
Drawdown	0	0.00	0
Gated (1)	0	0.00	0
Gated (2)	0	0.00	0
Ungated (to emergency spillway)	7,988	0.74	7,988
Total Storage (8.1 inches Max.)	7,988	0.74	7,988
Volume Adjustment Factor	1.00	0	

The adjusted storage is total storage is multiplied by the Volume Adjustment Factor which can reduce the storage. Storage is removed 1st from the ungated storage, 2nd from the gated (2) storage, 3rd from the gated (1) storage and last from the drawdown st

Est. of Ungated Detention Time	**Volume (ac-ft)**	**Elevation (ft)**	**Discharge (cfs)**
Emergency Spillway		0	
10% of Ungated	0	0	
90% of Ungated Volume	0		
	Average Discharge (cfs)		0
	Discharge in AF per day		0
	Average Detention Time (days)		not applicable

Note: this section is provided for reference only. The values are not used in the calculations.

Detention Time:		
Gated (1) from Operation plan	0.0	Enter gated detention time for the 1st category of gated storage.
Gated (2) from Operation plan	0.0	Enter gated detention time for the 2nd category of gated storage.
UnGated (from Operation Plan or above)	-17.2	Enter ungated detention time. (Center of Mass to Center of mass)
Ungated Storage Offset	0.0	Offset of center of mass of inflow hydrograph to center of mass of storage.

Average Time Interval between Routed Site Peak and Red River Peak (days). (Negative is ahead of peak, positive is after peak)	5.0	**Existing Relative T**	3.34	Existing Relative T is based on the average time interval between the routed site peak flows and the RRN.

Calculation of Star Value	**Routed Relative T**	**Adj. Storage (Ac-ft)**	**Star Value**
Drawdown Storage (30 - 3.40)	26.60	0	0
Gated (1) Storage (3.40 - 3.40)	0.00	0	0
Gated (2) Storage (3.40 - 3.40)	0.00	0	0
Ungated) Storage (14.97 - 3.40)	11.57	7,988	92,420
Star Value		**7,988**	**92,420**

Routed relative T is the value of the detention times computed using the regression equations given in figure 3. The Existing Relative T is subtracted from the project Relative T.

STAR VALUE

	2013 dollars	**2000 dollars**	
Total Cost per Star Value	$ 27.05	$ 20.00	Total Cost divided by STAR Value
RRWMB Cost per Star Value	$ 4.53	$ 3.35	RRWMB Cost divided by STAR Value

Prepared By:	Nate Dalager		Enter name of preparer
Source of Data:	Final Engineer's Report		Enter source data.
Frequency/Date of Preparation:	100yr 10day	27-Jun-14	Enter frequency and date.

TABLE A-4. POST-PROJECT STAR VALUE TO TWO RIVERS WATERSHED EARLY

Star Value Computation Worksheet
Red River Watershed Management Board

Enter values only in the cells that have been shaded. All other values are computed from these values.

Project Name:	Post-Project to Two Rivers (2)	Step 2		Enter Project Name. (Status eg Step)
Watershed District:	RRWD - RRWMA Pool 3 Outlet Project			Enter Name of Watershed District.
Project Location:	Northwest Roseau County			Enter Project Location.
Estimated Total Cost:	$ 2,500,000			Enter the estimated project costs. These are used to compute the cost per star value.
RRWMB Cost:	$ 418,750	CPI (1984=100)	CPI (2013=100)	
Year of Estimate:	2013	232.96	100.00	Ratios of the Consumer price index read from the CPI worksheet.
Adj. to SummaryAll Base Yr:	2000	172.20	73.92	
Drainage Area (square miles)	202.0	Enter the drainage area in square miles used to compute the runoff volume.		

Storage Volume(s):	Acre-feet	Inches	Adj. Storage (ac-ft)	The adjusted storage is total storage is multiplied by the Volume Adjustment Factor which can reduce the storage. Storage is removed 1st from the ungated storage, 2nd from the gated (2) storage, 3rd from the gated (1) storage and last from the drawdown st
Drawdown	0	0.00	0	
Gated (1)	0	0.00	0	
Gated (2)	0	0.00	0	
Ungated (to emergency spillway)	1,323	0.12	1,323	
Total Storage (8.1 inches Max.)	1,323	0.12	1,323	
Volume Adjustment Factor	1.00	0		

Est. of Ungated Detention Time	Volume (ac-ft)	Elevation (ft)	Discharge (cfs)	Note: this section is provided for reference only. The values are not used in the calculations.
Emergency Spillway		0		
10% of Ungated	0	0		
90% of Ungated Volume	0			
	Average Discharge (cfs)		0	
	Discharge in AF per day		0	
	Average Detention Time (days)		not applicable	

Detention Time:		
Gated (1) from Operation plan	0.0	Enter gated detention time for the 1st category of gated storage.
Gated (2) from Operation plan	0.0	Enter gated detention time for the 2nd category of gated storage.
UnGated (from Operation Plan or above)	-18.7	Enter ungated detention time. (Center of Mass to Center of mass)
Ungated Storage Offset	0.0	Offset of center of mass of inflow hydrogragh to center of mass of storage.

Average Time Interval between Routed Site Peak and Red River Peak (days). (Negative is ahead of peak, positive is after peak)	9.0	Existing Relative T	7.79	Existing Relative T is based on the average time interval between the routed site peak flows and the RRN.

Calculation of Star Value	Routed Relative T	Adj. Storage (Ac-ft)	Star Value	
Drawdown Storage (30 - 7.86)	22.14	0	0	Routed relative T is the value of the detention times computed using the regression equations given in figure 3. The Existing Relative T is subtracted from the project Relative T.
Gated (1) Storage (7.86 - 7.86)	0.00	0	0	
Gated (2) Storage (7.86 - 7.86)	0.00	0	0	
Ungated) Storage (12.69 - 7.86)	4.84	1,323	6,397	
Star Value		1,323	6,397	STAR VALUE

	2013 dollars	2000 dollars	
Total Cost per Star Value	$ 390.81	$ 288.88	Total Cost divided by STAR Value
RRWMB Cost per Star Value	$ 65.46	$ 48.39	RRWMB Cost divided by STAR Value

Prepared By:	Nate Dalager		Enter name of preparer
Source of Data:	Final Engineer's Report		Enter source data.
Frequency/Date of Preparation:	100yr 10day	27-Jun-14	Enter frequency and date.

TABLE A-5. POST-PROJECT STAR VALUE TO TWO RIVERS WATERSHED LATE

Star Value Computation Worksheet
Red River Watershed Management Board

Enter values only in the cells that have been shaded. All other values are computed from these values.

Project Name:	Post-Project to Two Rivers (1)	Step 2	Enter Project Name. (Status eg Step)
Watershed District:	RRWD - RRWMA Pool 3 Outlet Project		Enter Name of Watershed District.
Project Location:	Northwest Roseau County		Enter Project Location.

		CPI (1984=100)	CPI (2013=100)	
Estimated Total Cost:	$ 2,500,000			Enter the estimated project costs. These are used to compute the cost per star value.
RRWMB Cost:	$ 418,750			
Year of Estimate:	2013	232.96	100.00	Ratios of the Consumer price index read from the CPI worksheet.
Adj. to SummaryAll Base Yr:	2000	172.20	73.92	

Drainage Area (square miles)	202.0	Enter the drainage area in square miles used to compute the runoff volume.

Storage Volume(s):	Acre-feet	Inches	Adj. Storage (ac-ft)
Drawdown	0	0.00	0
Gated (1)	0	0.00	0
Gated (2)	0	0.00	0
Ungated (to emergency spillway)	8,167	0.76	8,167
Total Storage (8.1 inches Max.)	8,167	0.76	8,167
Volume Adjustment Factor	1.00	0	

The adjusted storage is total storage is multiplied by the Volume Adjustment Factor which can reduce the storage. Storage is removed 1st from the ungated storage, 2nd from the gated (2) storage, 3rd from the gated (1) storage and last from the drawdown st

Est. of Ungated Detention Time	Volume (ac-ft)	Elevation (ft)	Discharge (cfs)
Emergency Spillway		0	
10% of Ungated	0	0	
90% of Ungated Volume	0		
	Average Discharge (cfs)		0
	Discharge in AF per day		0
	Average Detention Time (days)		not applicable

Note: this section is provided for reference only. The values are not used in the calculations.

Detention Time:		
Gated (1) from Operation plan	0.0	Enter gated detention time for the 1st category of gated storage.
Gated (2) from Operation plan	0.0	Enter gated detention time for the 2nd category of gated storage.
UnGated (from Operation Plan or above)	30.0	Enter ungated detention time. (Center of Mass to Center of mass)
Ungated Storage Offset	0.0	Offset of center of mass of inflow hydrogragh to center of mass of storage.

Average Time Interval between Routed Site Peak and Red River Peak (days). (Negative is ahead of peak, positive is after peak)	9.0	Existing Relative T	7.79	Existing Relative T is based on the average time interval between the routed site peak flows and the RRN.

Calculation of Star Value	Routed Relative T	Adj. Storage (Ac-ft)	Star Value
Drawdown Storage (30 - 7.86)	22.14	0	0
Gated (1) Storage (7.86 - 7.86)	0.00	0	0
Gated (2) Storage (7.86 - 7.86)	0.00	0	0
Ungated) Storage (28.00 - 7.86)	20.14	8,167	164,507
Star Value		8,167	164,507

Routed relative T is the value of the detention times computed using the regression equations given in figure 3. The Existing Relative T is subtracted from the project Relative T.

STAR VALUE

	2013 dollars	2000 dollars	
Total Cost per Star Value	$ 15.20	$ 11.23	Total Cost divided by STAR Value
RRWMB Cost per Star Value	$ 2.55	$ 1.88	RRWMB Cost divided by STAR Value

Prepared By:	Nate Dalager		Enter name of preparer
Source of Data:	Final Engineer's Report		Enter source data.
Frequency/Date of Preparation:	100yr 10day	27-Jun-14	Enter frequency and date.

TABLE A-6. STAR VALUE SUMMARY

	Value or Cost ($)
POST-PROJECT STAR VALUE (TO ROSEAU RIVER)	92,420
POST-PROJECT STAR VALUE (TO TWO RIVERS EARLY)	6,397
POST-PROJECT STAR VALUE (TO TWO RIVERS LATE)	164,507
NET STAR VALUE INCREASE	263,324
*RRWMB COST PER STAR	$1.59

* Based upon a RRWMB contribution of $418,750, which is 2/3 of the 25% RRWD/RRWMB local share – assuming a $2.5M project.

FIGURE A-1. STAR VALUE HYDROGRAPHS AT CARIBOU

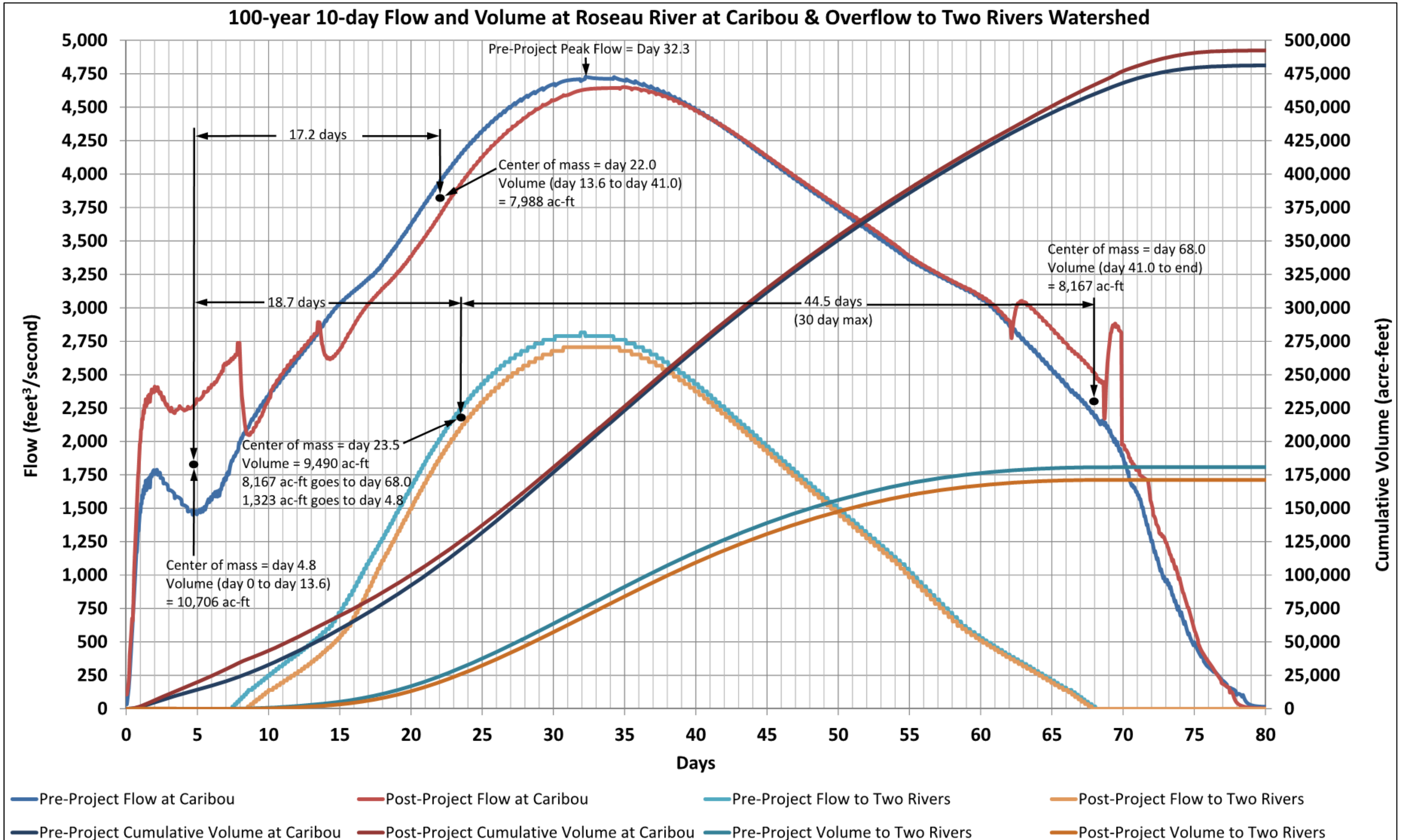

FIGURE A-2. INTERVAL BETWEEN SITE PEAK AND RED RIVER OF THE NORTH