APPENDIX O

Manitoba - United States Transmission Development Wind Injection Study

Maximizing Wind and Water

Prepared for:

Minnesota Power

Excel Engineering, Inc.

Revision Date
March 1, 2013

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Disclaimer

The information contained in this report is subject to change. The best available information has been used to model the future transmission and generation facilities in this study. Should any of these assumptions change, the results and conclusions from the study are subject to reevaluation.

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Table and figures

0 Certification

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.

Michael Cronier
Registration Number 46591
March 1, 2013

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1 Executive Summary

Excel Engineering performed a wind injection study to identify and evaluate incremental Western Minnesota wind injection capability in conjunction with 1100 MW of new Manitoba to United State transmission service requests and their associated facilities. The two main Manitoba to US transmission configurations evaluated include a Fargo (western) configuration with a Winnipeg, MB (Dorsey substation) to Fargo, ND (Bison substation) 500 kV then connecting to the CapX (Fargo to Twin Cities) transmission and an Iron Range (eastern) configuration with a Winnipeg, MB (Dorsey substation) to Iron Range, MN (Blackberry substation) 500 kV line then continuing with a double circuit 345 kV to Duluth, MN (Arrowhead substation).

In general, the study found that Dorsey- Iron Range plan allowed for significantly higher levels of wind injection simultaneous with 1100 MW of new Manitoba to US transfers. The Iron Range plan can support 500 MW of wind injection directly without any additional transmission upgrades, whereas, the Fargo plan would require a significant transmission upgrade investment ($ 273 M). While the Iron Range plan will support higher levels of wind injection (1000 – 1500 MW) with modest transmission upgrade costs, the Fargo plan may not be able to achieve these levels due to limitations on the existing Dorsey – Forbes 500 kV transmission line.

1.0 Study Overview

Multiple options for both of the Manitoba outlet configurations were reviewed using incremental injection analysis under two injection scenarios. These two scenarios include a Fargo, ND only injection and a split (50/50) between Fargo, ND and Brookings, SD injection.

Thirty five different evaluations were performed to review the different configurations along with the two scenarios of injection points. This was used to judge the amount of wind injection is available in the Dakotas as well as the potential benefit of a North-South transmission corridor through the Red River Valley area into Buffalo Ridge area.

For each constraint found during the incremental injection analysis, transmission mitigation options and costs were determined. The cumulative mitigation costs were then used to compare the various transmission configurations and injection scenarios. The costs used in this report are in 2012 dollars. Appendix D contains additional cost basis information.

Due to the limitations of the existing Roseau series capacitors and DC runback schemes, the Fargo Option was limited by the existing 2000 Amp overload for the series caps used in the DC runback scheme. Table 1.0-1 compares the constraint mitigation costs to accommodate 500, 1000, and 1500 MW of wind injection at Fargo only and at Fargo/Brookings for the study base case assumptions between the two 500 kV configurations. The Iron Range Option is able to continue over 2000 MW. Refer to Section 4.1 for additional information on the impact of the Roseau series capacitors.

Table 1.0-1 Incremental Constraint Mitigation Cost Summary

	Fargo 500 kV Line	Iron Range 500 kV Line
Fargo Wind Injection		
500 MW	$ 273 M (at 490 MW)	$ 0 M
1000 MW	N/A	$ 43 M
1500 MW	N/A	$ 176 M
Fargo/Brookings Wind Injection		
500 MW	$ 3 M	$ 0 M
1000 MW	$ 273 M (at 740 MW)	$ 0 M
1500 MW	N/A	$ 12 M

1.1 Fargo Injection

When evaluating the Fargo injection scenario, it was quickly observed that the CapX transmission (either single or double circuit) from Fargo, ND to St. Cloud was the most limiting contingency, with or without runback on the 345kV lines. If injecting additional wind at Fargo, the need for additional transmission on a separate right-of-way was shown. Fargo has some loading concerns, particularly between the Maple River and Bison substations for this scenario. The most limiting first contingency incremental transfer for the Fargo wind injection is shown in Table 1.1-1. This was done with 50% series compensation on the new 500 kV line.

Table 1.1-1 Worst Case Limiters Fargo Wind Injection

Option	MW	Limiting Facility	Outage	Case
Fargo	-240	Bison-Maple River 230 kV line	Bison-Maple River 345 kV line	W1B1
Iron Range	670	Bison-Maple River 230 kV line	Bison-Maple River 345 kV line Maple River 345/230 kV tx 2 Maple River 345/230 kV tx 1	Y1B1

1.1.1 Fargo 500 kV Line

The Fargo 500 kV line provided an additional Fargo area outlet transmission line, but does not lessen the impact of the CapX transmission contingencies because the flow is toward the southeast. The sharing of the total transfer of power from Manitoba to US was unbalanced between the new and existing 500 kV line under system intact conditions requiring the need for upgrades on the existing 500 kV line. In addition, the Fargo 500 kV line pushes additional power into Fargo from Manitoba and requires additional transmission sooner than that of the Iron Range 500 kV line. Additional transmission, particularly 500 kV, going south from Fargo to the Buffalo Ridge area allows the Manitoba power and the additional wind injection to get out of Fargo area during contingency events. The largest concern for the new 500 kV line is the overloading of the Roseau series capacitors on the existing 500 kV line for system intact conditions.

1.1.2 Iron Range 500 kV Line

The Iron Range 500 kV provides a path for the Manitoba to US power transfers which does not directly conflict with Fargo wind injections thus reducing the need for additional transmission out of the Fargo area. At higher levels of Fargo power injection, a new transmission line, particularly 345 kV, would be required to mitigate the local area overloads for the CapX transmission contingencies. The Iron Range line also balances better between the existing and new 500 kV lines and does not, therefore, require any additional improvement to the existing 500 kV line. The Iron Range line helps extend the time when new or upgraded lines are required.

1.2 Fargo/Brookings County Injection

The Fargo/Brookings injection results are very similar to the Fargo inject result, but only half the power is being injected at Fargo. Some South Dakota issues show due to the injection at Brookings Co. The concern for additional transmission from Fargo is still valid, while Brookings Co has a smaller concern for additional transmission. The most limiting first contingency incremental transfer for the Fargo/Brookings wind injection is shown in Table 1.2-1. This was done with 50% series compensation on the new 500 kV line.

Table 1.2-1 Worst Case Limiters Fargo/Brookings Wind Injection

Option	MW	Limiting Facility	Outage	Case
Fargo	-530	Bison-Maple River 230 kV line	Bison-Maple River 345 kV line	W1B2
Iron Range	1130	Split Rock-White 345 kV line	Brookings Co-Lyon Co 345 kV line	Y1B2

1.2.1 Fargo 500 kV Line

The same concern about the balance between the existing and new 500 kV line are still present as in the Fargo injection. As before, the Fargo line reduces the overall wind injection by pushing more power into the Fargo area from Manitoba.

1.2.2 Iron Range 500 kV Line

The sharing between the existing and new 500 kV lines is still more balanced. As before, the Iron Range line helps with CapX contingency because the Manitoba power and the wind injection are not at the same point. The need for additional transmission out of the Fargo is still required and it would be beneficial to connect Fargo and Brookings County substations.

1.3 60% Series Compensation Sensitivity

An addition evaluation was done using 60% series compensation on the new 500 kV line instead of the 50% for only the Fargo wind injection with the Fargo 500 kV line with second Bison-Quarry 345 kV and Iron Range 500 kV line. With the 60% series compensation, the two new 500 kV lines from Manitoba are better balanced with the existing 500 kV line. The Roseau series capacitors still overload for the Fargo 500 kV line option, while the Iron Range 500 kV line overloads the Roseau series capacitors beyond the 2000 MW wind injection level.

1.4 Additional Sensitivities

Sensitivities were performed on a scenario with addition of all MVP projects (Section 4.2.5), Roseau Series Capacitors upgraded to 2500 Amps (Section 4.2.6), and using North Dakota Export area as the source (Section 4.4).

2 Study Development and Assumptions

2.1 Study Procedure

The Siemens Power Technologies, Inc. "PSS/E MUST" digital computer powerflow simulation program was used to identify the MW levels at which the limiting facilities (lines and/or transformers) are sequentially encountered as the power injection (generation output) is incrementally increased at the sites of interest (Fargo or Fargo/Brookings)

The analysis described in this report is based on the "generation to generation" method of modeling new generation resources; consistent with MISO evaluation practice; no load scale-up was used in this modeling excluding the sensitivity. In all the analyses performed, the injected power was sunk to Eastern MISO by scaling generation in the following areas and zone listed in Table 2.1-1:

Table 2.1-1 Generation Sink

Area Name	Area #	Area Name	Area #
FE	202	METC	218
HE	207	ITCT	219
DEM	208	AMMO	356
SIGE	210	AMIL	357
IPL	216	CWLP	360
NIPS	217	SIPC	361

2.2 Steady-State Thermal Analysis

"Injection Constraints" were identified using 5% DF as the criteria for both the system intact and contingencies.

Loadings were monitored for facilities in the following control areas listed in Table 2.2-1.

Table 2.2-1 Monitored Areas

Area Name	Voltage	Area #	Area Name	Voltage	Area #
CE	100 kV & above	222	MEC	100 kV & above	635
AECI	100 kV & above	330	NPPD	100 kV & above	640
AMMO	100 kV & above	356	OPPD	100 kV & above	645
AMIL	100 kV & above	357	LES	100 kV & above	650
MIPU	100 kV & above	540	WAPA	100 kV & above	652
XEL	100 kV & above	600	MH	100 kV & above	667
MP	100 kV & above	608	SPC	100 kV & above	672
SMMPA	100 kV & above	613	DPC	100 kV & above	680
GRE	100 kV & above	615	ALTE	100 kV & above	694
OTP	100 kV & above	620	WPS	100 kV & above	696
ALTW	100 kV & above	627	MGE	100 kV & above	697
OPPD	100 kV & above	645	UPPC	100 kV & above	698
MPW	100 kV & above	633			

Single and multi-element contingencies were analyzed for the study. Single contingencies were taken in the areas and voltages listed in Table 2.2-2. Multi-element contingency information was supplied by Client and included in the following contingency files:

- MH-DCrunback.con
- Out_Year_con.com
- GRE_OTP_MP_DPC_WAPA_out_year-Converted.con
- XEL_CatB_updated.con

The study procedure used to model the existing Manitoba Hydro Special Projection System (SPS) for the Manitoba – US interconnection tie lines was modified to include either of the new 500 kV lines from Manitoba. The MH-DC runback contingency file was modified to include these additional runbacks for the new 500 kV lines. For the Fargo line, 100% runback was used for the loss of the new Winnipeg-Fargo 500 kV line and 50% runback for the loss of the Winnipeg-Fargo series capacitors, one of the Bison 500/345 kV transformers, and loss of any of the double circuit lines from Fargo-Monticello. For the scenarios with the 500 kV line continuing from Fargo to Brookings there also was a 50% runback for the loss of either the 500 kV line or the series capacitors on that line. While for the new Iron Range 500 kV line, there was 100% runback for the loss of the Winnipeg-Iron Range 500 kV line and also 50% runback for the loss of Winnipeg-Iron Range series capacitors, one of the 500/345 kV transformers at Winnipeg-Iron Range, the double circuit line from Blackberry-Arrowhead, and the Arrowhead-Stone Lake 345 kV line.

Table 2.2-2 Branch Contingencies Applied

Area Name	Voltage	Area #		Area Name	Voltage	Area #
XEL	69 kV & above	600		LES	100 kV & above	650
MP	69 kV & above	608		WAPA	69 kV & above	652
SMMPA	69 kV & above	613		MH	100 kV & above	667
GRE	69 kV & above	615		DPC	69 kV & above	680
OTP	69 kV & above	620		ALTE	100 kV & above	694
ALTW	69 kV & above	627		WPS	100 kV & above	696
MEC	69 kV & above	635		MGE	100 kV & above	697
NPPD	100 kV & above	640		UPPC	100 kV & above	698
OPPD	100 kV & above	645		WPS	100 kV & above	696

The analysis was performed using PTI's MUST AC contingency analysis program and activity FCITC. Non-convergent cases were solved manually using PTI's PSS/E and results added to the MUST contingency tabulation.

The FCITC activity processes a list of contingencies defined by the user; monitors a defined set of model elements, and reports on excursions outside of operating criteria defined by an input monitor file. Facility loading violations were reported for conditions that exceeded the criteria as defined above. These violations were scrutinized to determine their validity.

The generator output distribution factors (DF) were calculated using PSS MUST operation "Monitored Element Sensitivity". A subsystem containing the project and its respective MW participation factor was defined as the exporting system for the sensitivity analysis. Generation in the Areas and Zone listed in

Table 2.1-1 defined as the importing system. The exporting and importing subsystems reproduce the methodology used to dispatch generation to create the post-generation case. To expedite reporting, the sensitivity analysis operation was initiated from a DC Contingency Analysis Report. The distribution factors below the cutoff for the project were removed from the report. Branch violations with no distribution factors above the cutoff level were removed from the report.

3 Model Development

3.1 Starting Model

The model received from Minnesota Power was based on the MISO 2017 summer peak MTEP08 used in the 2009 MHEB Group TSR System Impact Study: MH_SUPK_2175-Base-Case-latest.sav.

3.2 Model Development

The following changes were made to get the Base Case for this study:

- Added Center-Prairie 345 kV line
- Added 2nd Center-Square Butte transformer
- Added Prairie 345/230 kV transformer
- Removed 2nd Dorsey-Riel 500 kV line
- Removed Excelsior generation of 600 MW
- Reduced load at Mesaba to 140 MW
- Changed Forbes-Roseau 500 kV line resistance to 0.0018
- Changed Roseau-Chisago County 500 kV line resistance to 0.0017
- Changed Cass County-Red River 115 kV line properties
- Changed Maple River-Sheyenne 230 kV line resistance and ratings
- Changed Chisago County-Kohlman Lake 345 kV line ratings
- Changed Frontier-Maple River 230 kV line ratings
- Changed Frontier-Wahpeton 230 kV line ratings
- Changed Riel-Roseau-Forbes 500 kV line ratings to 3011 MVA
    - Roseau series capacitor ratings 1732 MVA (2000 Amps)

From the Base case, 1100 MW of generation (negative load) was added to Riel 500 kV bus and generation was dispatched as shown Table 3.2-1 MH to US Dispatch:

Table 3.2-1 MH to US Dispatch

Bus #	Unit #	Name	MW
GRE			
615031	1	Pleasant Valley	29
615041	1	Lakefield	84.9
615045	5	Lakefield	86.1
WPA			
699993	1	Skygen	171.4
699661	3	West Marinette	74.8
699597	1	Pulliam	74
698925	GT	AP_PPRGT	42.2
699591	5	Pulliam	50.8
699679	1	Weston	61.8
699595	6	Pulliam	25
MP			
608667	4	Potlatch	24
608676	3	Hibbard	20
608676	4	Hibbard	15
608776	1	Boswell	54
608777	2	Boswell	54
608665	6	Thomson	36
608702	1	Laskin	25
608702	2	Laskin	22
Xcel			
600073	1	River Falls	20
605308	1	Hatfield	6
600035	4	Wheaton	24
WEC			
699322	5	Germantown	83
699507	2	Valley	17
		Total	**1100**

3.3 Study Options

For the purpose of this study, there were two main transmission options: the Fargo (Bison) or Iron Range (Blackberry) 500 kV lines coming out of Dorsey. The cases studied are listed in Table 3.3-1 Study Options. With the wind injection at the Bison 345 kV bus or at the Bison and Brooking County 345 kV buses.

Table 3.3-1 Study Options

Fargo Option	Iron Range Option
W1A	**Y1A**
Dorsey-Bison 500 kV line 50% series compensated	Dorsey-Blackberry 500 kV line 50% series compensated
Bison 500/345 kV Tx #1 & #2	Blackberry 500/345 kV Tx #1 & #2
	Blackberry-Arrowhead 345 kV lines #1 & #2
	Blackberry 345/230 kV TX
Bison-Alexandria-Quarry-Monticello 345 kV line #2	Bison-Alexandria-Quarry-Monticello 345 kV line #2
W1AP	**Y1AP**
W1 with phase shirt transformer (PST) on Glenboro-Harvey 230 kV line at Glenboro	Y1 with phase shirt transformer (PST) on Glenboro-Harvey 230 kV line at Glenboro
Dorsey-Bison 500 kV line 50% series compensated	Dorsey-Blackberry 500 kV line 50% series compensated
Bison 500/345 kV Tx #1 & #2	Blackberry 500/345 kV Tx #1 & #2
	Blackberry-Arrowhead 345 kV lines #1 & #2
	Blackberry 345/230 kV TX
Bison-Alexandria-Quarry-Monticello 345 kV line #2	Bison-Alexandria-Quarry-Monticello 345 kV line #2
W1B	**Y1B**
W1 without Bison-Alexandria-Quarry-Monticello 345 kV line #2	Y1 without Bison-Alexandria-Quarry-Monticello 345 kV line #2
Dorsey-Bison 500 kV line 50% series compensated	Dorsey-Blackberry 500 kV line 50% series compensated
Bison 500/345 kV Tx #1 & #2	Blackberry 500/345 kV Tx #1 & #2
	Blackberry-Arrowhead 345 kV lines #1 & #2
	Blackberry 345/230 kV TX
W1C	**Y1C**
W1 with MVP not already in case added	Y1 with MVP not already in case added
Dorsey-Bison 500 kV line 50% series compensated	Dorsey-Blackberry 500 kV line 50% series compensated
Bison 500/345 kV Tx #1 & #2	Blackberry 500/345 kV Tx #1 & #2
	Blackberry-Arrowhead 345 kV lines #1 & #2
	Blackberry 345/230 kV TX
Bison-Alexandria-Quarry-Monticello 345 kV line #2	Bison-Alexandria-Quarry-Monticello 345 kV line #2
W2A	**Y2A**
Dorsey-Bison 500 kV line 50% series compensated	Dorsey-Blackberry 500 kV line 50% series compensated
Bison 500/345 kV Tx #1	Blackberry 500/345 kV Tx #1 & #2
	Blackberry-Arrowhead 345 kV lines #1 & #2
	Blackberry 345/230 kV TX
Bison-Brookings County 500 kV line 50% series compensated	Bison-Brookings County 500 kV line 50% series compensated
Brooking County 500/345 kV Tx #1 & #2	Brooking County 500/345 kV Tx #1 & #2

W2B	Y2B
Dorsey-Bison 500 kV line 50% series compensated	Dorsey-Blackberry 500 kV line 50% series compensated
Bison 500/345 kV Tx #1	Blackberry 500/345 kV Tx #1 & #2
	Blackberry-Arrowhead 345 kV lines #1 & #2
	Blackberry 345/230 kV TX
Bison-Brookings County345 kV line	Bison-Brookings County 345 kV line
W6A	**Y6A**
Dorsey-Bison 500 kV line 50% series compensated	Dorsey-Blackberry 500 kV line 50% series compensated
Bison 500/345 kV Tx #1	Blackberry 500/345 kV Tx #1 & #2
	Blackberry-Arrowhead 345 kV lines #1 & #2
	Blackberry 345/230 kV TX
Bison-Brookings County 500 kV line 50% series compensated	Bison-Brookings County 500 kV line 50% series compensated
Brooking County 500/345 kV Tx #1 & #2	Brooking County 500/345 kV Tx #1 & #2
Brooking County-Split Rock 500 kV line	Brooking County-Split Rock 500 kV line
Split Rock 500/345 kV TX #1 & #2	Split Rock 500/345 kV TX #1 & #2
Bison-Alexandria-Quarry-Monticello 345 kV line #2	Bison-Alexandria-Quarry-Monticello 345 kV line #2
Hazel Creek-Panther-McLeod-Blue Lake 345 kV line #1 & #2	Hazel Creek-Panther-McLeod-Blue Lake 345 kV line #1 & #2
Corridor Txs	Corridor Txs
Brookings County-Lyon County 345 kV line #2	Brookings County-Lyon County 345 kV line #2
Helena-Lake Marion-Hampton Corner 345 kV line #2	Helena-Lake Marion-Hampton Corner 345 kV line #2
W6B	**Y6B**
Dorsey-Bison 500 kV line 50% series compensated	Dorsey-Blackberry 500 kV line 50% series compensated
Bison 500/345 kV Tx #1	Blackberry 500/345 kV Tx #1 & #2
	Blackberry-Arrowhead 345 kV lines #1 & #2
	Blackberry 345/230 kV TX
Bison-Alexandria-Quarry-Monticello 345 kV line #2	Bison-Alexandria-Quarry-Monticello 345 kV line #2
Hazel Creek-Panther-McLeod-Blue Lake 345 kV line #1 & #2	Hazel Creek-Panther-McLeod-Blue Lake 345 kV line #1 & #2
Corridor Txs	Corridor Txs
Brookings County-Lyon County 345 kV line #2	Brookings County-Lyon County 345 kV line #2
Helena-Lake Marion-Hampton Corner 345 kV line #2	Helena-Lake Marion-Hampton Corner 345 kV line #2

Maps showing the options studied are included in Figure 3.3-2 to Figure 3.3-7.

Figure 3.3-2 W1A and W1B Map

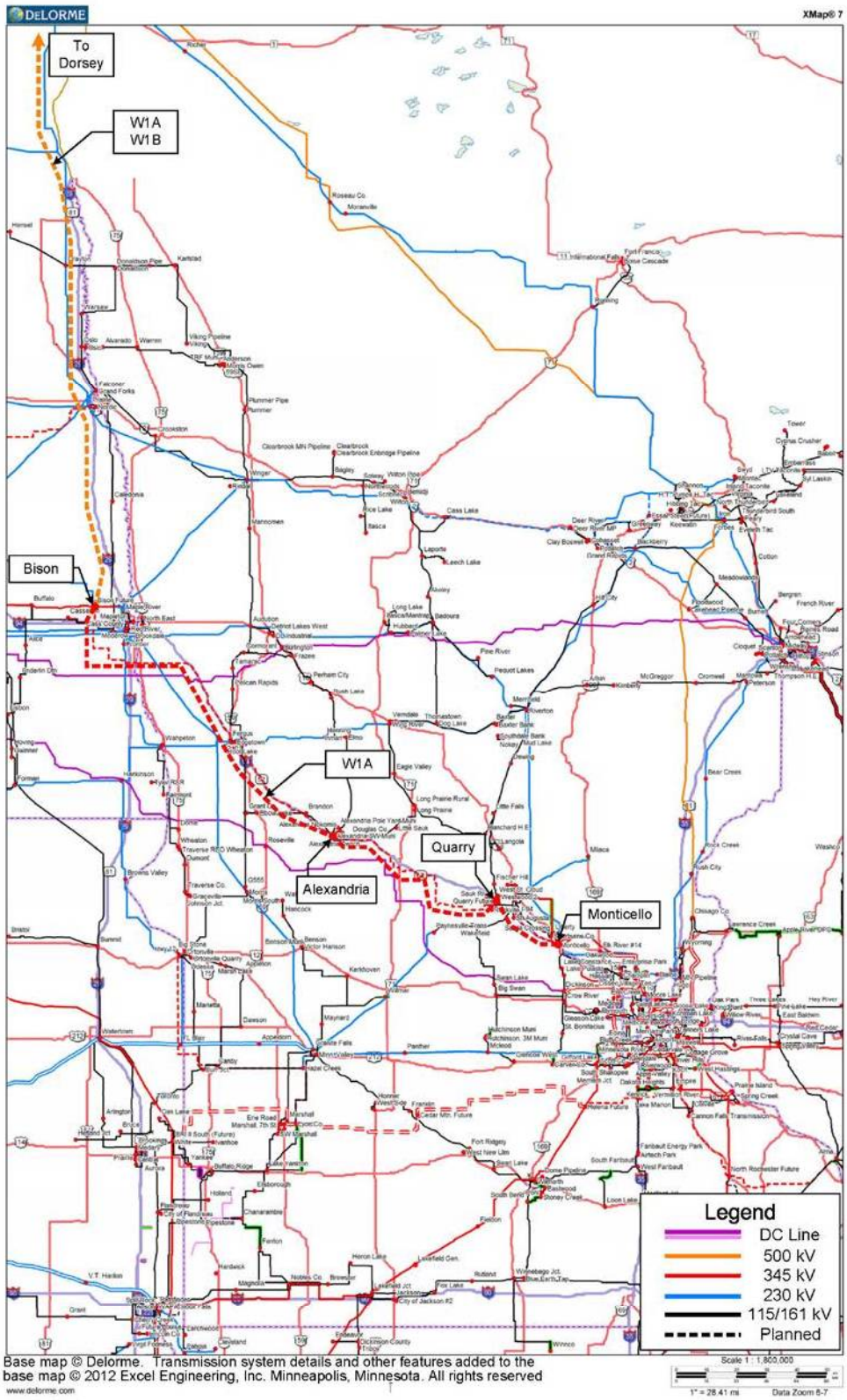


Figure 3.3-3 W2A and W2B Map

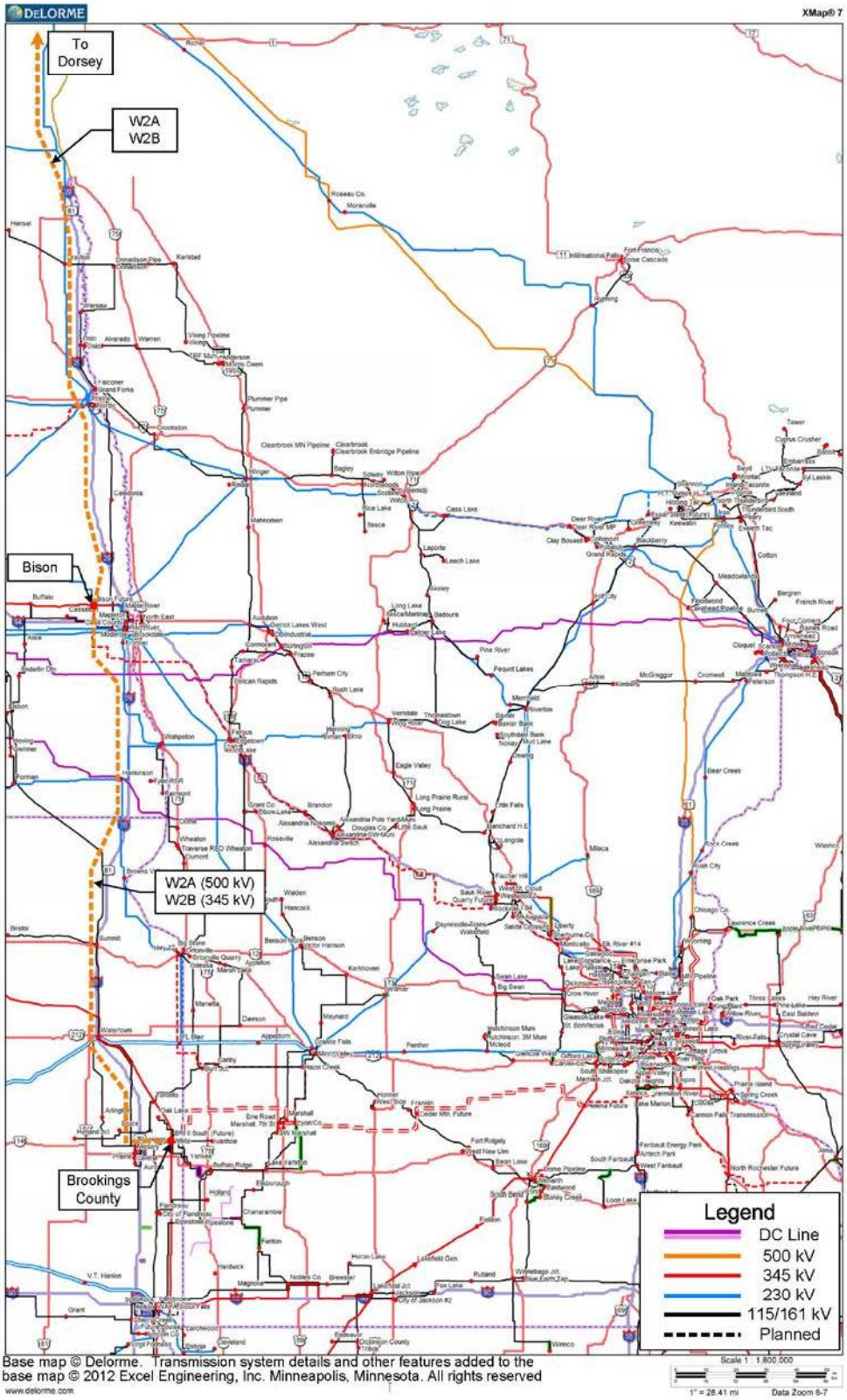


Figure 3.3-4 W6A and W6B Map

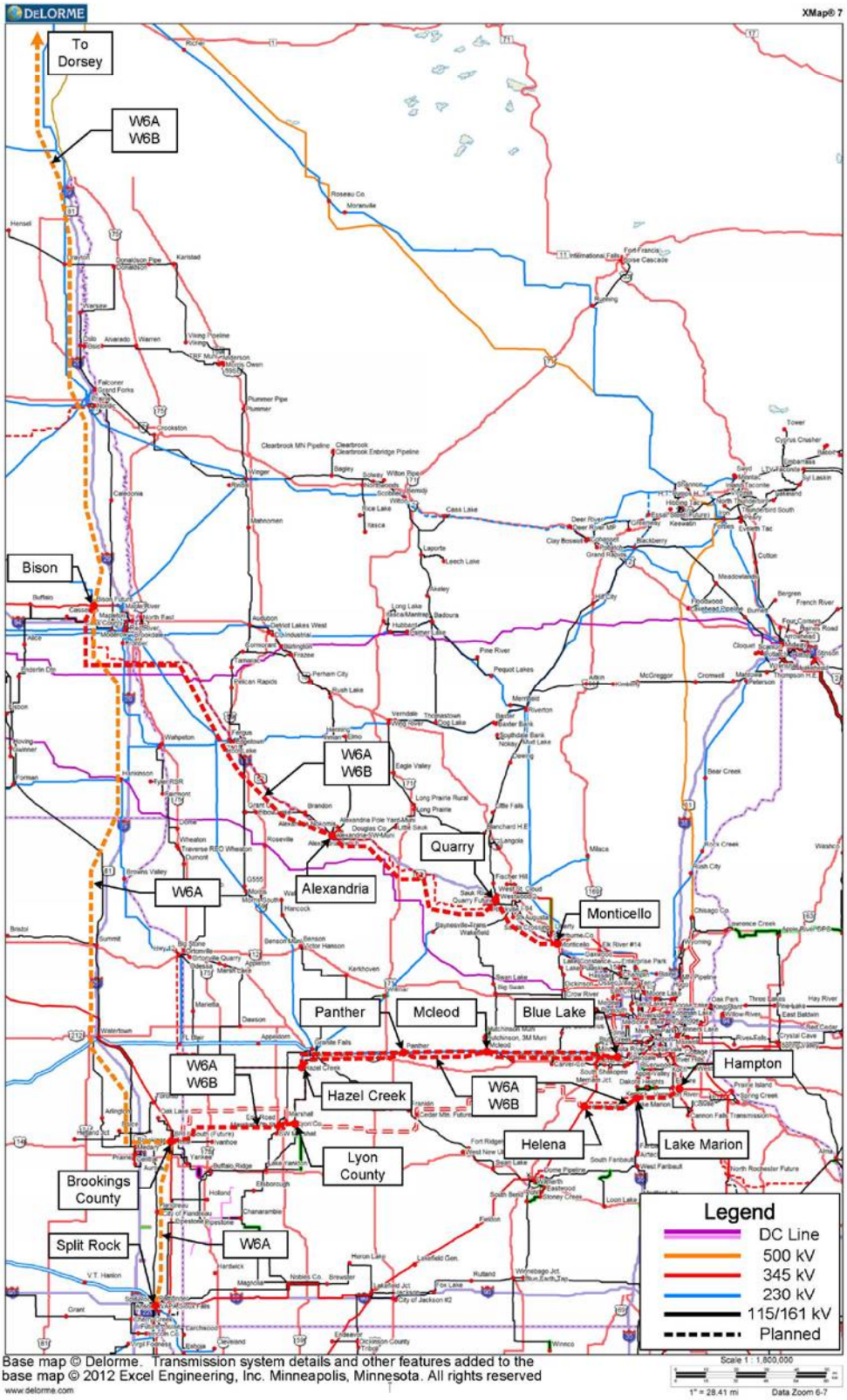


Figure 3.3-5 Y1A and Y1B Map

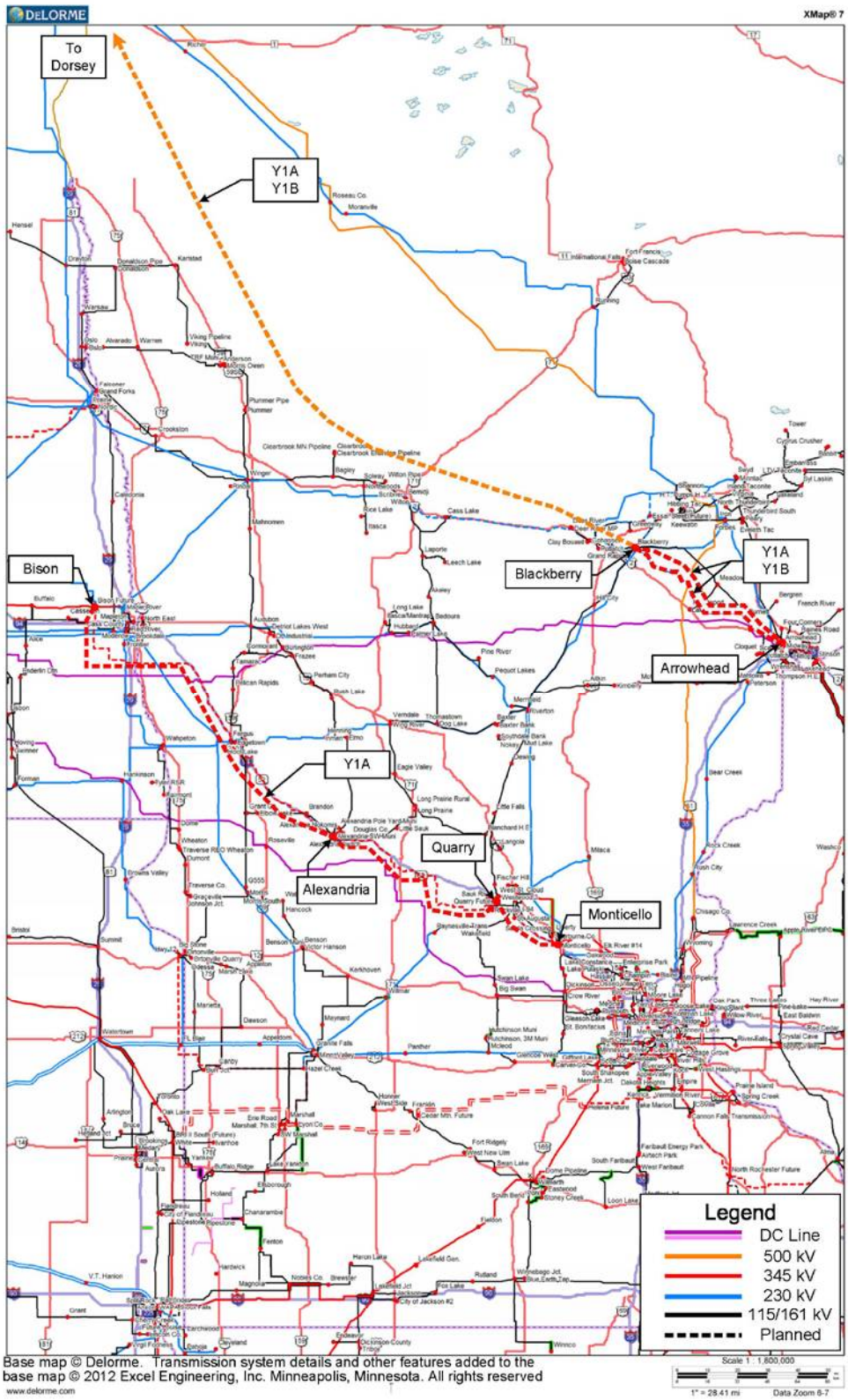


Figure 3.3-6 Y2A and Y2B Map

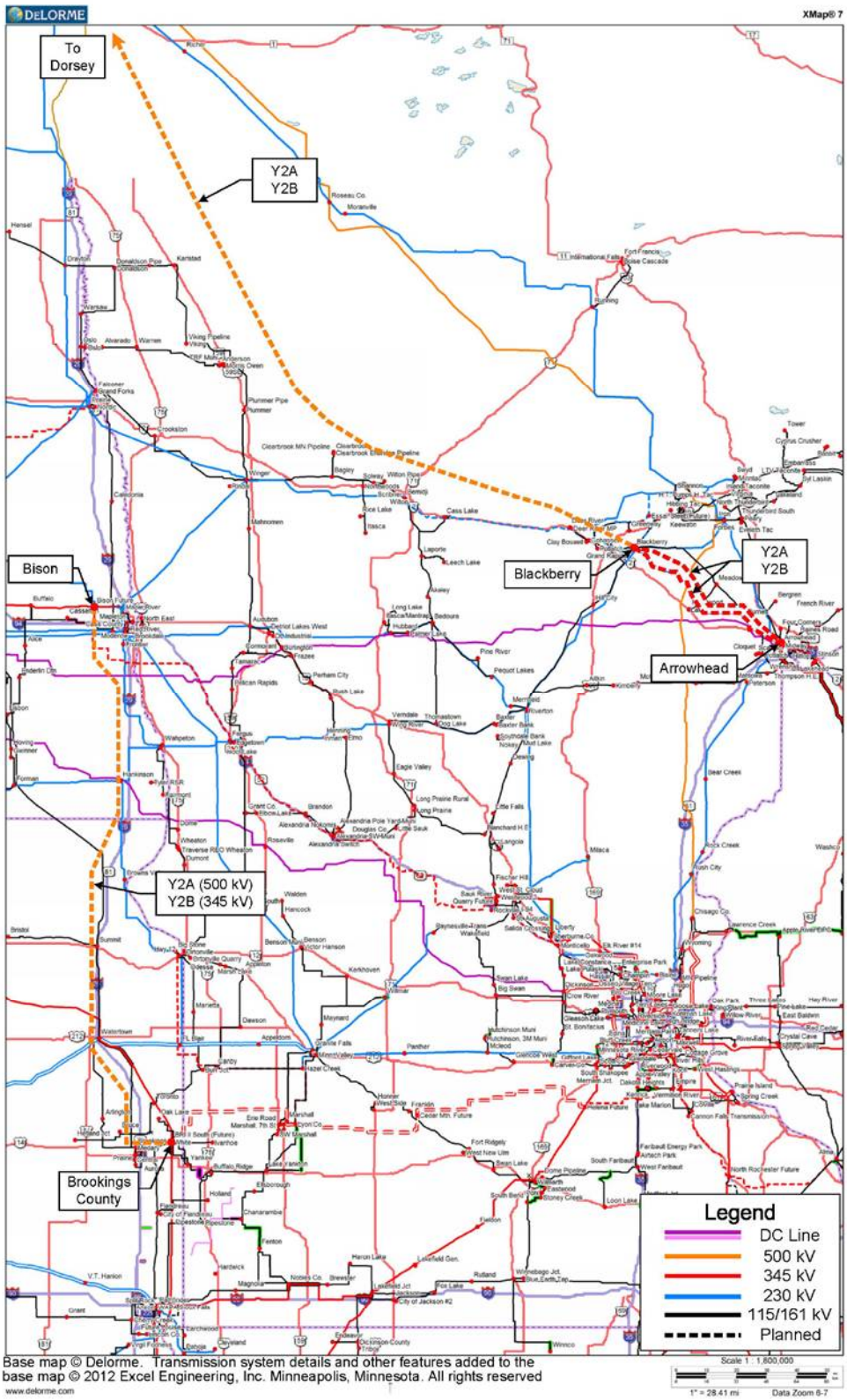
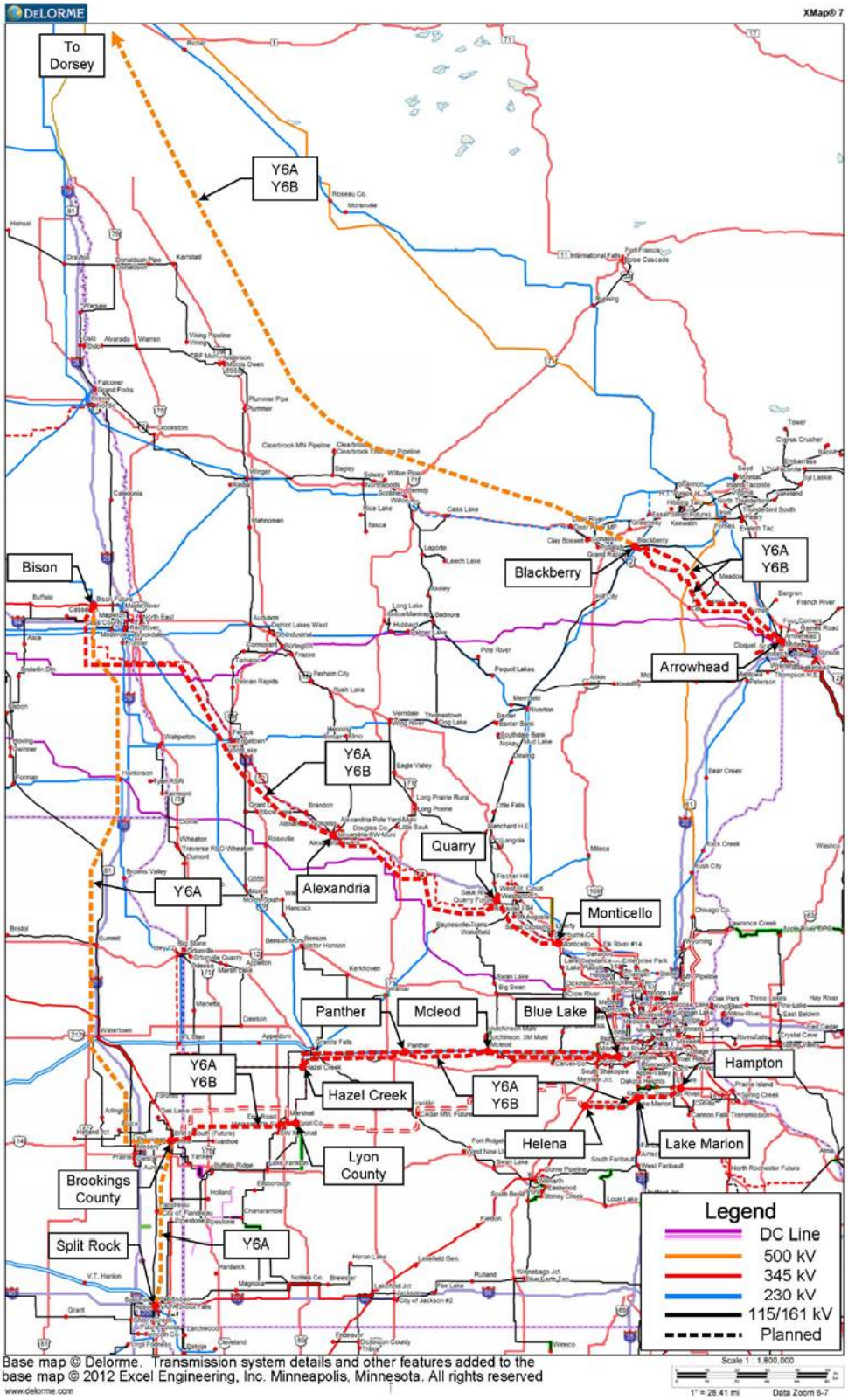


Figure 3.3-7 Y6A and Y6B Map



4 Results

4.1 Impact of the Roseau Series Capacitors

Regional power system analysis has consistently shown that there is an existing North Dakota – Manitoba loop flow issue where higher levels of North Dakota export will flow into Manitoba on the Glenboro-Rugby (G82R) and Letellier-Drayton (L20D) 230 kV lines and cause an overload on the existing Dorsey-Riel-Forbes (D602F) 500 kV line. Recent studies performed for a new Manitoba to U.S. 500 kV tie line have also shown that a new 500 kV line between Dorsey and Bison will dramatically aggravate this problem by introducing a very low impedance path between North Dakota and Manitoba.

The flow limit on the Dorsey (Riel)-Forbes 500 kV line is based on the 2000 Amp (1732 MW) rating of the Roseau series capacitors and line terminal equipment while having a conductor limit of 3011 MVA. It is possible to increase the rating of the Roseau series capacitors to 2500 Amps through equipment upgrades, however, the flow limit on the line may need to remain at 1732 MW for several reasons.

1. The existing Manitoba Hydro DC Reduction Scheme SPS initiates an MH HVDC power order reduction equal to 100% of the flow on the 500 or 230 kV tie lines that are being tripped. If a 100% DC reduction level is maintained on the MH-US interface, the Dorsey (Riel)-Forbes 500 kV line flow limit may need to remain at 1732 MW.
    a. The loss of the Dorsey (Riel)-Forbes 500 kV line and associated DC reduction is currently the largest single contingency in the MRO region and MISO footprint in terms of generation loss. Allowing the Riel-Forbes 500 kV line flows and consequential DC reduction to exceed today's level of 1732 MW would also increase size of the largest contingency in the MISO footprint, which may not be permissible as it would increase operating reserve requirements.
    b. Manitoba Hydro may determine that increased DC reduction levels are undesirable since large power order reductions may negatively impact operation of Northern Manitoba hydro generation.
    c. MISO has historically enforced a policy that prohibits the introduction of any new Special Protection Systems (SPS) that will reduce firm transfers in response to a single contingency, such as the loss of existing 500 kV line. Furthermore, they will not allow an increase in the amount of HVDC or generation runback on an existing SPS beyond its current maximum level. This policy would limit the maximum DC reduction and potentially the Riel – Forbes 500 kV loading limit to 1732 MW.
2. In addition to the Roseau series capacitors, the 500 kV line terminal equipment may also need to be upgraded or replaced to operate at the 2500 Amp level. For example, the transient recovery voltages seen by circuit breakers as they interrupt current may exceed their interrupting and voltage withstand capability.

3. A detailed transient stability study would need to be performed to determine if the static and dynamic reactive power capability of the Forbes Static VAr System (SVS) is adequate to support higher transfers. Costly upgrades of the SVS may be necessary.

Based on these limitations, this study assumes a 2000 Amp Roseau Series capacitor rating. The impact of raising the Roseau Series capacitor limit to 2500 Amps is beyond the scope of this report. The results in the Appendices include additional limitations beyond the 2000 Amp limitations to achieve the full 2000 MW of wind injection.

For this study, the Fargo 500 kV line does not provide enough balance with the existing 500 kV line from Dorsey (Riel)-Forbes, resulting in a system intact overload of the Roseau series compensation capacitors. Even with the double circuit Bison-Quarry 345 kV line and a 500 kV line from Bison-Brookings County, W2A, the Roseau series capacitors overload before 500 MW. If the Fargo 500 kV line has 60% series compensation the wind injection is still capped at 670 MW with the Bison-Brookings 345 kV line added as mitigation at 440 MW, the first Roseau Series Capacitor 2000 Amp limit. While the Iron Range 500 kV line provided a better balance with the existing 500 kV line in this study.

The system intact limits due to the Roseau series capacitors are shown in Table 4.1-1 and Table 4.1-2.

Table 4.1-1 Roseau Series Capacitor System Intact for Fargo Wind Injection

	Fargo Option	**Iron Range Option**
	Dorsey-Bison 500 kV line 50% series compensated Bison 500/345 kV Tx #1 & #2 (only Tx #1 for 2A, 2B, 6A, and 6B)	Dorsey-Blackberry 500 kV line 50% series compensated Blackberry 500/345 kV Tx #1 & #2 Blackberry-Arrowhead 345 kV lines #1 & #2 Blackberry 345/230 kV Tx
Case	**Transfer MW**	**Transfer MW**
*1A	W1A1	Y1A1
Bison-Alexandria-Quarry-Monticello 345 kV line #2	300 *(490 MW with Bison-Brookings Co. 345 kV)*	Beyond 2000 MW
*1A60	W1A160	
Bison-Alexandria-Quarry-Monticello 345 kV line #2 New 500 kV line 60% Series Comp	440 *(670 MW with Bison-Brookings Co. 345 kV)*	NA
*1AP	W1AP1	Y1AP1
Bison-Alexandria-Quarry-Monticello 345 kV line #2 with phase shirt transformer (PST) on Glenboro-Harvey 230 kV line at Glenboro	460 *(680 MW with Bison-Brookings Co. 345 kV)*	Beyond 2000 MW
*1B	W1B1	Y1B1
without Bison-Alexandria-Quarry-Monticello 345 kV line #2	-135 *(50 MW with Bison-Brookings Co. 345 kV)*	Beyond 2000 MW
*1B60		Y1B160
without Bison-Alexandria-Quarry-Monticello 345 kV line #2 New 500 kV line 60% Series Comp	N/A	Beyond 2000 MW

	Fargo Option	Iron Range Option
	Dorsey-Bison 500 kV line 50% series compensated Bison 500/345 kV Tx #1 & #2 (only Tx #1 for 2A, 2B, 6A, and 6B)	Dorsey-Blackberry 500 kV line 50% series compensated Blackberry 500/345 kV Tx #1 & #2 Blackberry-Arrowhead 345 kV lines #1 & #2 Blackberry 345/230 kV Tx
Case	**Transfer MW**	**Transfer MW**
*1C	W1C1	Y1C1
with MVP not already in case added	300 *(490 MW with Bison-Brookings Co. 345 kV)*	Beyond 2000 MW
*2A	W2A1	Y2A1
Bison-Brookings County 500 kV line 50% series compensated	375	Beyond 2000 MW
*2B	W2B1	Y2B1
Bison-Brookings County 345 kV line Brooking County 500/345 kV Tx #1 & #2	-20	Beyond 2000 MW
*6A	W6A1	Y6A1
Bison-Brookings County 500 kV line 50% series compensated Brooking County 500/345 kV Tx #1 & #2 Brooking County-Split Rock 500 kV line Split Rock 500/345 kV TX #1 & #2 Bison-Alexandria-Quarry-Monticello 345 kV line #2 Hazel Creek-Panther-McLeod-Blue Lake 345 kV line #1 & #2 Corridor Txs Brookings County-Lyon County 345 kV line #2 Helena-Lake Marion-Hampton Corner 345 kV line #2	1355	Beyond 2000 MW
*6B	W6B1	Y6B1
Bison-Alexandria-Quarry-Monticello 345 kV line #2 Hazel Creek-Panther-McLeod-Blue Lake 345 kV line #1 & #2 Corridor Txs Brookings County-Lyon County 345 kV line #2 Helena-Lake Marion-Hampton Corner 345 kV line #2	315 *(580 MW with Bison-Brookings Co. 345 kV)*	Beyond 2000 MW

Table 4.1-2 Roseau Series Capacitor System Intact for Fargo/Brookings Wind Injection

	Fargo Option	Iron Range Option
	Dorsey-Bison 500 kV line 50% series compensated Bison 500/345 kV Tx #1 & #2 (only Tx #1 for 2A, 2B, 6A, and 6B)	Dorsey-Blackberry 500 kV line 50% series compensated Blackberry 500/345 kV Tx #1 & #2 Blackberry-Arrowhead 345 kV lines #1 & #2 Blackberry 345/230 kV TX
Case	**Transfer MW**	**Transfer MW**
*1A	W1A2	Y1A2
Bison-Alexandria-Quarry-Monticello 345 kV line #2	510 (740 MW with Bison-Brookings Co. 345 kV)	Beyond 2000 MW
*1AP	W1AP2	Y1AP2
Bison-Alexandria-Quarry-Monticello 345 kV line #2 with phase shirt transformer (PST) on Glenboro-Harvey 230 kV line at Glenboro	785 (1030 MW with Bison-Brookings Co. 345 kV)	Beyond 2000 MW
*1B	W1B2	Y1B2
without Bison-Alexandria-Quarry-Monticello 345 kV line #2	-235 (75 MW with Bison-Brookings Co. 345 kV)	Beyond 2000 MW
*2A	W2A2	Y2A2
Bison-Brookings County 500 kV line 50% series compensated	465	Beyond 2000 MW
*2B	W2B2	Y2B2
Bison-Brookings County 345 kV line Brooking County 500/345 kV Tx #1 & #2	-30	Beyond 2000 MW

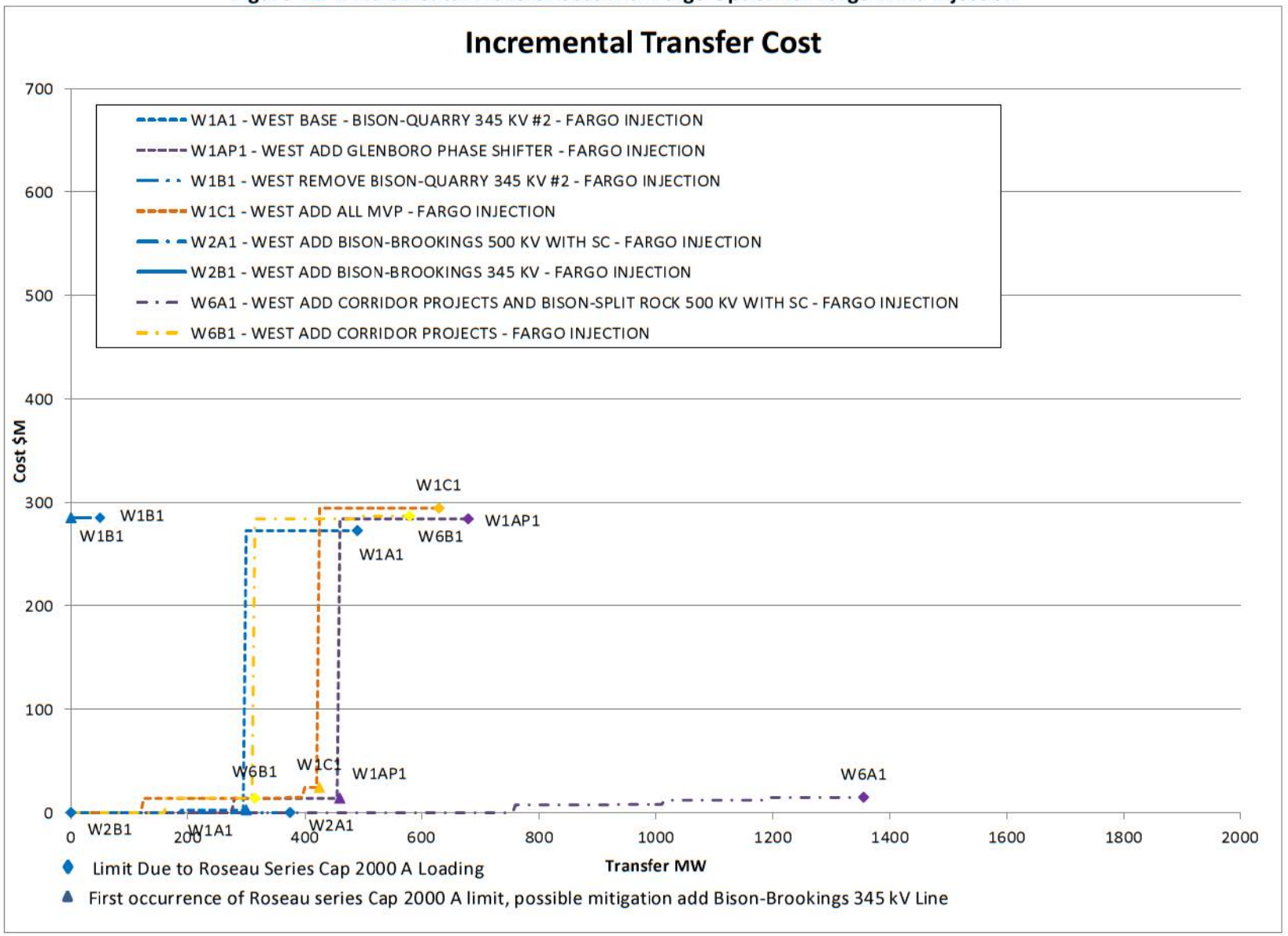
4.2 Fargo Wind Injection Results

4.2.1 Fargo Option Fargo Wind Injection

The Fargo options all have a 500 kV line from Dorsey to Bison at 50% series compensation and at least one 500/345 kV transformer at Bison. With these scenarios, the Manitoba power and the wind injection are both entering the 345 kV system at about the same point (Bison 345 kV bus). The scenarios with the strongest outlets from the Red River Valley had the lowest incremental cost. With the MH runback, the Roseau Series Capacitors overloading during system intact conditions is the most limiting element, even with the addition of the Bison-Brookings 345 kV line for the first Roseau Series Capacitor 2000 Amps overload. The loss of the CapX 345 kV line from Fargo-Twin Cities produced overloads on the lower voltage system but this occurs after the Roseau Series Capacitor system intact overload. The overload output for all scenarios ran is in Appendix A1.

The Fargo 500 kV line options are not able to complete the 2000 MW transfer. The scenario with the lowest incremental cost is W6A (Bison-Split Rock 500 kV, Hazel Creek-Blue Lake Corridor 345 kV double circuit and complete second circuit on the Brookings Co.-Hampton Corner 345 kV lines). A chart showing the incremental cost is in Figure 4.2-1 .

Figure 4.2-1 Incremental Transfer Cost with Fargo Option for Fargo Wind Injection



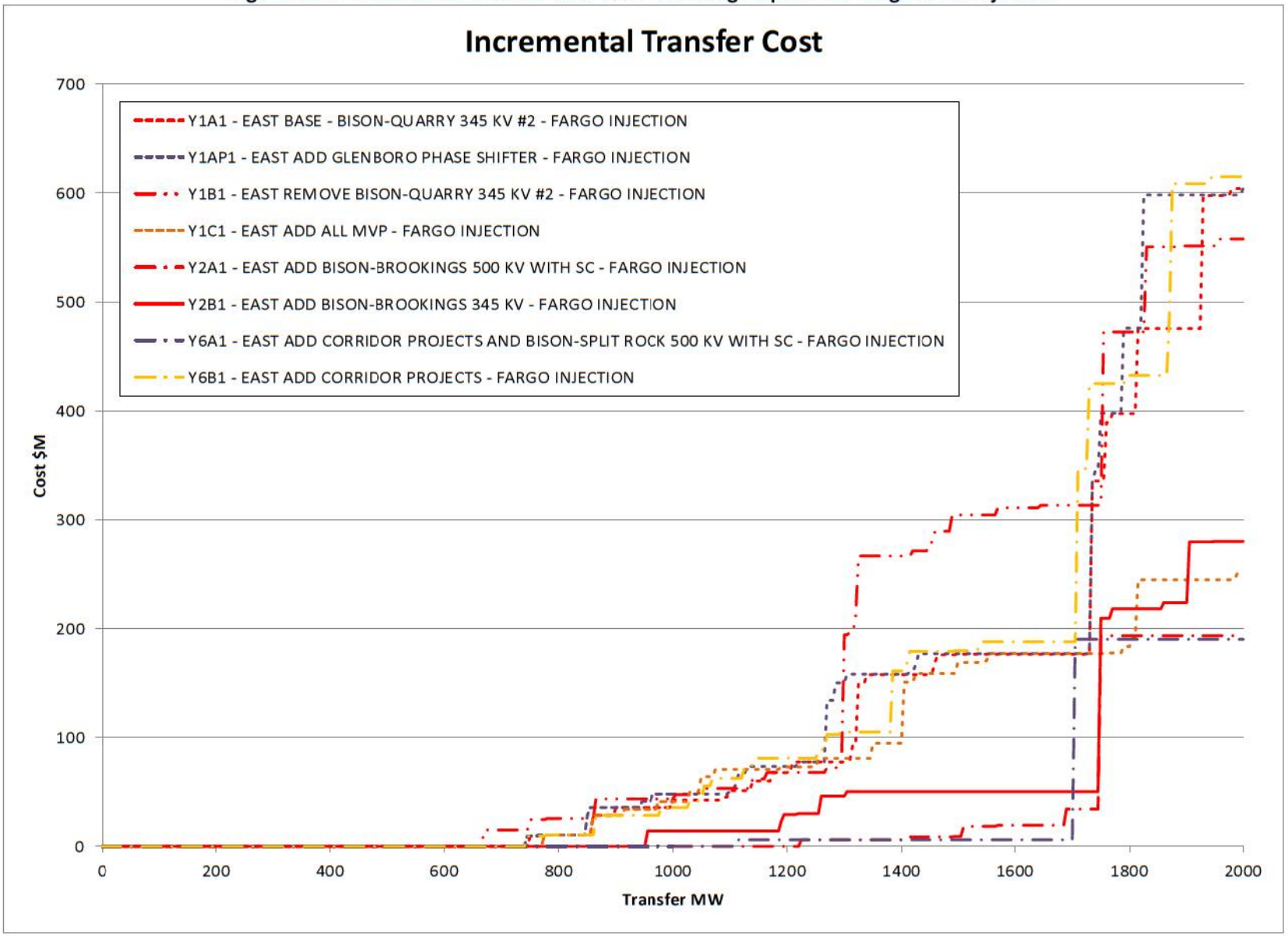
4.2.2 Iron Range Option Fargo Wind Injection

The Iron Range scenarios all have a 500 kV line from Dorsey to Blackberry with 50% series compensation, a double circuit 345 kV line from the Blackberry to Arrowhead, two 500/345 kV transformers at Blackberry, and one 345/230 kV transformer at Blackberry. With these scenarios the Manitoba power and the wind injection are entering the 345 kV system at totally different points, most of the same upgrades due to CapX line outages are still required but at higher wind injection levels, some occur after the 2000 MW cutoff. The Roseau capacitors do not overload for this option. For the Iron Range line scenarios, there is no runback for the loss of the double circuit 345 kV line from Fargo-Monticello. These overloads also show up in the Fargo 500 kV line but, they are beyond the Roseau Series Capacitor 2000 Amp limit.

The Bison-Maple River 345 kV, Bison-Maple River 230 kV, Maple River-Sheyenne 230 kV, Fargo-Moorhead 230 kV, Maple River-Frontier 230 kV, and Sheyenne-Audubon 230 kV lines and the Maple River 345/230 kV transformers overload for the loss of Bison-Alexandria 345 kV line at about 670 MW wind injections when there is not an additional outlet for the wind injection out of the Fargo area. The lines still overloads for some of the other disturbances but at higher wind injection levels. When the loss is the Alexandria-Quarry 345 kV, line the 115 kV system in the Alexandria area in addition to the Fargo area 230 kV system overloads. For a loss of the Quarry-Monticello 345 kV line, the 115 kV system in the St. Cloud area, Alexandria, and Fargo 230 and 115 kV system overloads. The single most costly upgrade is the Electric Junction-Nelson 345 kV line in Illinois. It occurs between 1700 MW and 1800 MW. The stronger the outlet to Brookings County, the lower the wind injection that Electric Junction-Nelson overload occurs. The overload output for all scenarios ran is in Appendix A2.

The scenario with the lowest incremental cost is Y6A (Bison-Split Rock 500 kV, Hazel Creek-Blue Lake Corridor 345 kV double circuit and complete second circuit on the Brookings Co.-Hampton Corner 345 kV lines). Instead of the 500 kV line a double circuit 345 kV line would perform the similar without the transformation at both ends of the line. The second lowest incremental cost is Y2A, which is the Bison-Brookings 500 kV line. A chart showing the incremental cost is in Figure 4.2-2. The scenario with the highest incremental cost is Y6B. The Y6B scenario does not provide for an independent transmission path for the wind injection at Fargo should the CapX Fargo-Twin Cities 345 kV line have an outage, the underlying 230 kV and 115 kV transmission grid requires upgrading to accommodate the increased power flow.

Figure 4.2-2 Incremental Transfer Cost with Iron Range Option for Fargo Wind Injection



4.2.3 Comparison of Options Fargo Wind Injection

The least incremental cost scenario is Y6A, which involves building up an extensive 500 kV system. The second least incremental cost is Y2A Iron Range option with 500 kV line Bison-Brookings County. The 500 kV line only goes from Bison to Brookings County with transformers required at both ends. The same would be accomplished with a double circuit 345 kV line from Bison-Brookings County and it would not require the transformers. It provides to two independent outlets from Fargo for the wind injection. The Iron Range option with only 345 kV line instead is ranked fourth. A chart showing the incremental cost is in Table 4.2-3.

The most costly incremental is Y1A, there are no additional independent outlets for the wind injections and upgrades to the 115 and 230 kV system are extensive. The west scenarios are not able to inject more than 490 MW of North Dakota wind. A graph comparing the wind injection options is shown in Figure 4.2-4. The Fargo option does not always show up on the graph when it ends before zero or when the cost is zero, refer to Table 4.2-3 if this occurs. In order to compare easier the following graphs have the data separated into individual options with both the Fargo wind injection and the Fargo/Brookings wind injection Figure 4.2-4 to Figure 4.2-10.

The Iron Range option has the first limiters occurring at higher wind injection than the Fargo option. For the Fargo option the main limiter is the Roseau capacitor banks. See Table 4.2-12 for the complete list of first limiters.

The Iron Range options have fewer system intact overloads than the Fargo options. Also they occur at higher wind injection levels. A table showing the system intact overloads is in Table 4.2-13.

Most of the comparison is done with incremental cost between options. A chart showing the incremental cost on top of the build out cost for the two most comparable options is shown in Figure 4.2-11 . The Iron Range 500 kV line is the only option that can complete the 2000 MW transfer.

Table 4.2-3 Cost Comparison for Fargo Wind Injection (in $M)

	FARGO 500 MW	IRON RANGE 500 MW	FARGO 1000 MW	IRON RANGE 1000 MW	FARGO 1500 MW	IRON RANGE 1500 MW	FARGO 2000 MW	IRON RANGE 2000 MW
1A Base Bison-Quarry #2	*(273 @ 490 MW)*	0	NA	42.5	NA	176	N/A	604
1A 60% 60% Series Comp new 500 kV	294	N/A	*(294 @ 670 MW)*	NA	NA	NA	N/A	N/A
1AP Add Glenboro Phase Shifter	284	0	*(284 @ 680 MW)*	48	NA	177	N/A	604
1B Remove Bison-Quarry #2	*(285 @ 50 MW)*	0	N/A	43	NA	304	N/A	558
1B 60% 60% Series Comp new 500 kV	N/A	0	N/A	91	NA	360	N/A	614
1C Add All MVP	294	0	*(294 @ 630 MW)*	41	N/A	169	N/A	251
2A Add Bison-Brookings 500 kV with SC	(0 @ 375 MW)	0	*N/A*	0	N/A	9	N/A	193
2B Add Bison-Brookings 345 kV	*(0 @ 0MW)*	0	N/A	14	N/A	50	N/A	280
6A Add Corridor Project Add Bison-Split Rock 500 kV with SC	0	0	8	0	*(15 @ 1355 MW)*	6	N/A	190
6B Add Corridor Project	287	0	*(287 @ 580 MW)*	36	N/A	180	N/A	615

Figure 4.2-4 Incremental Transfer Cost for Fargo Wind Injection

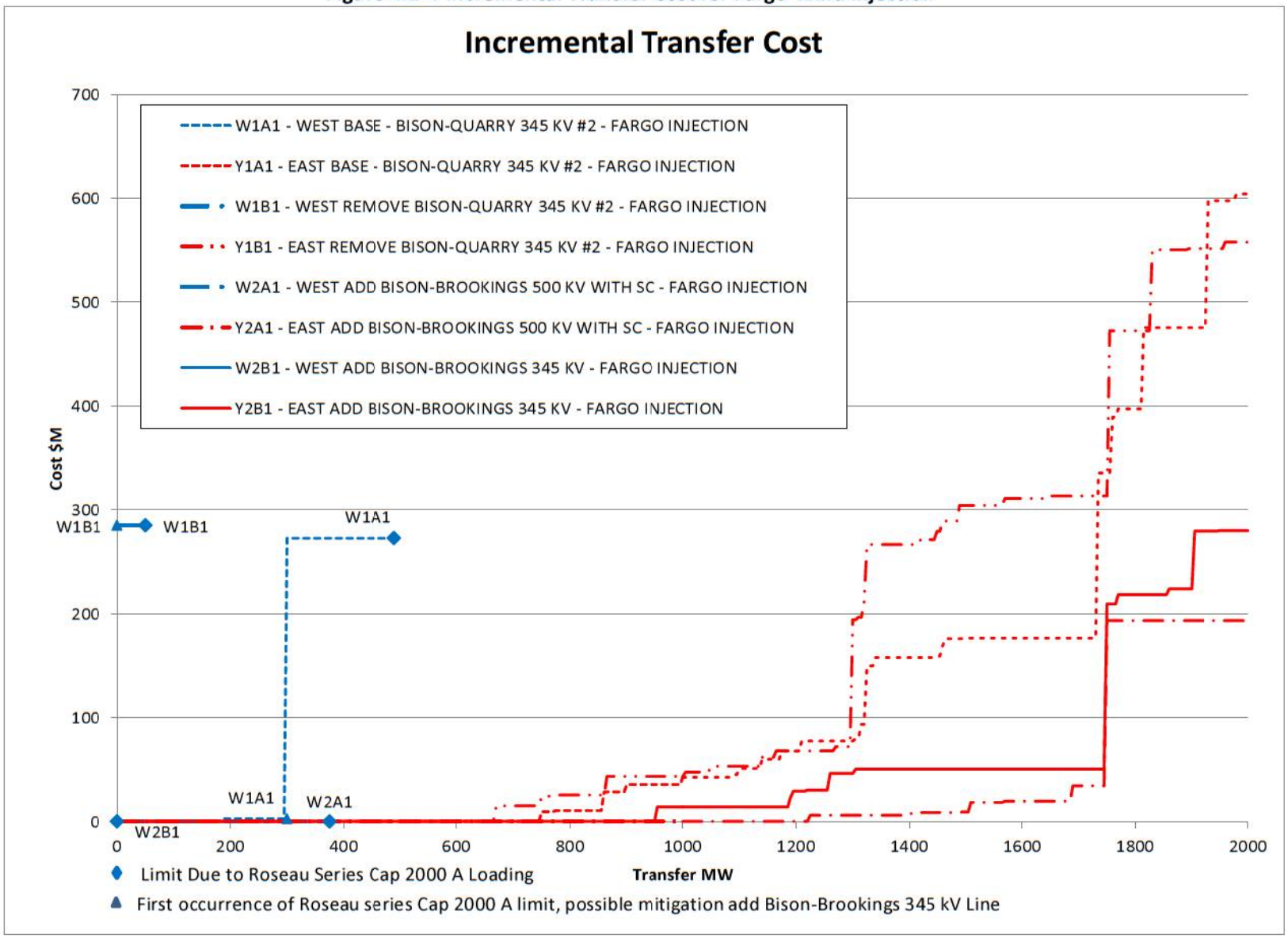


Figure 4.2-5 1A Base (Bison-Quarry 345 kV #2)

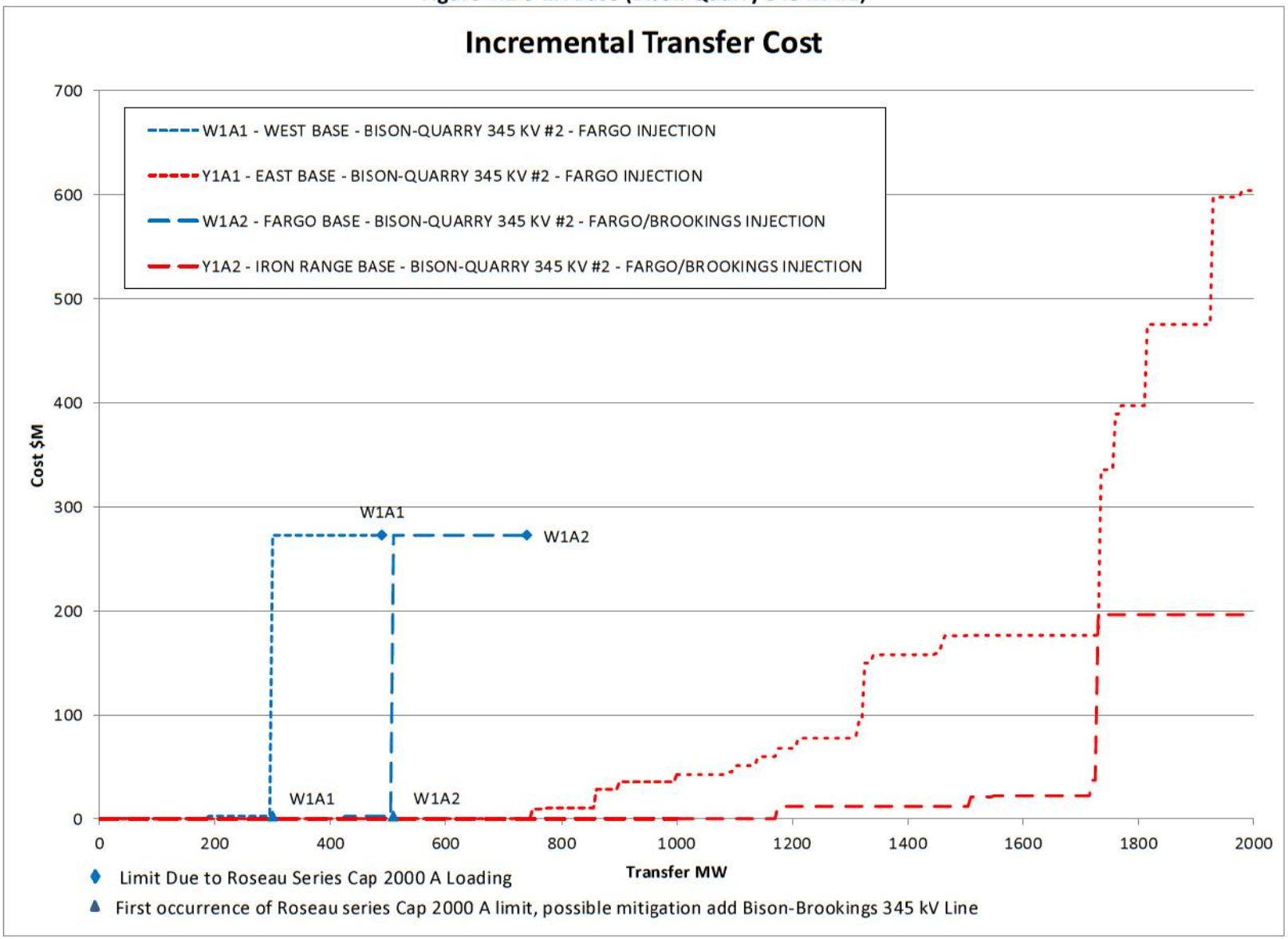


Figure 4.2-6 1B Remove Bison-Quarry 345 kV #2

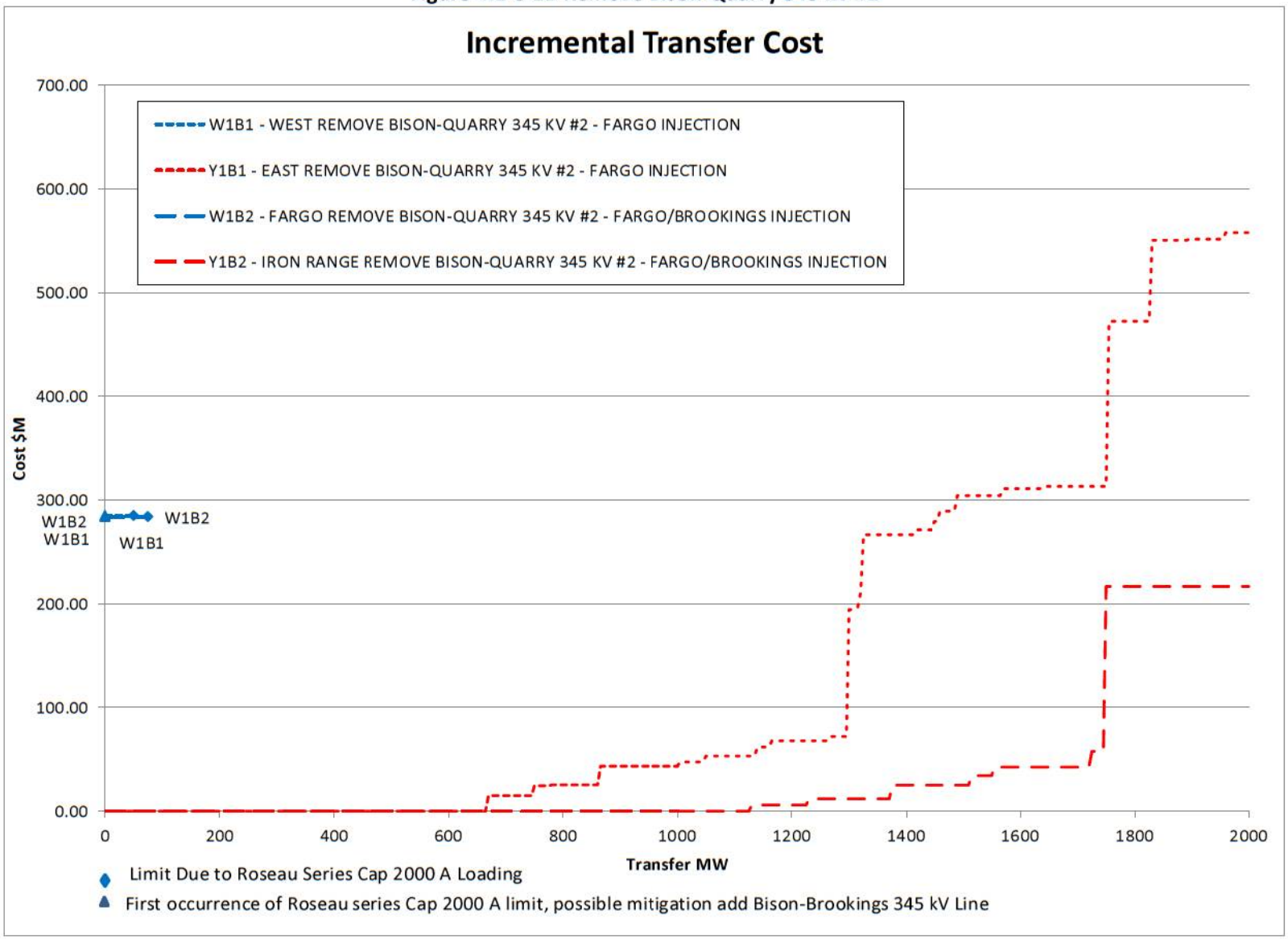


Figure 4.2-7 2A Add Bison-Brookings 500 kV with SC

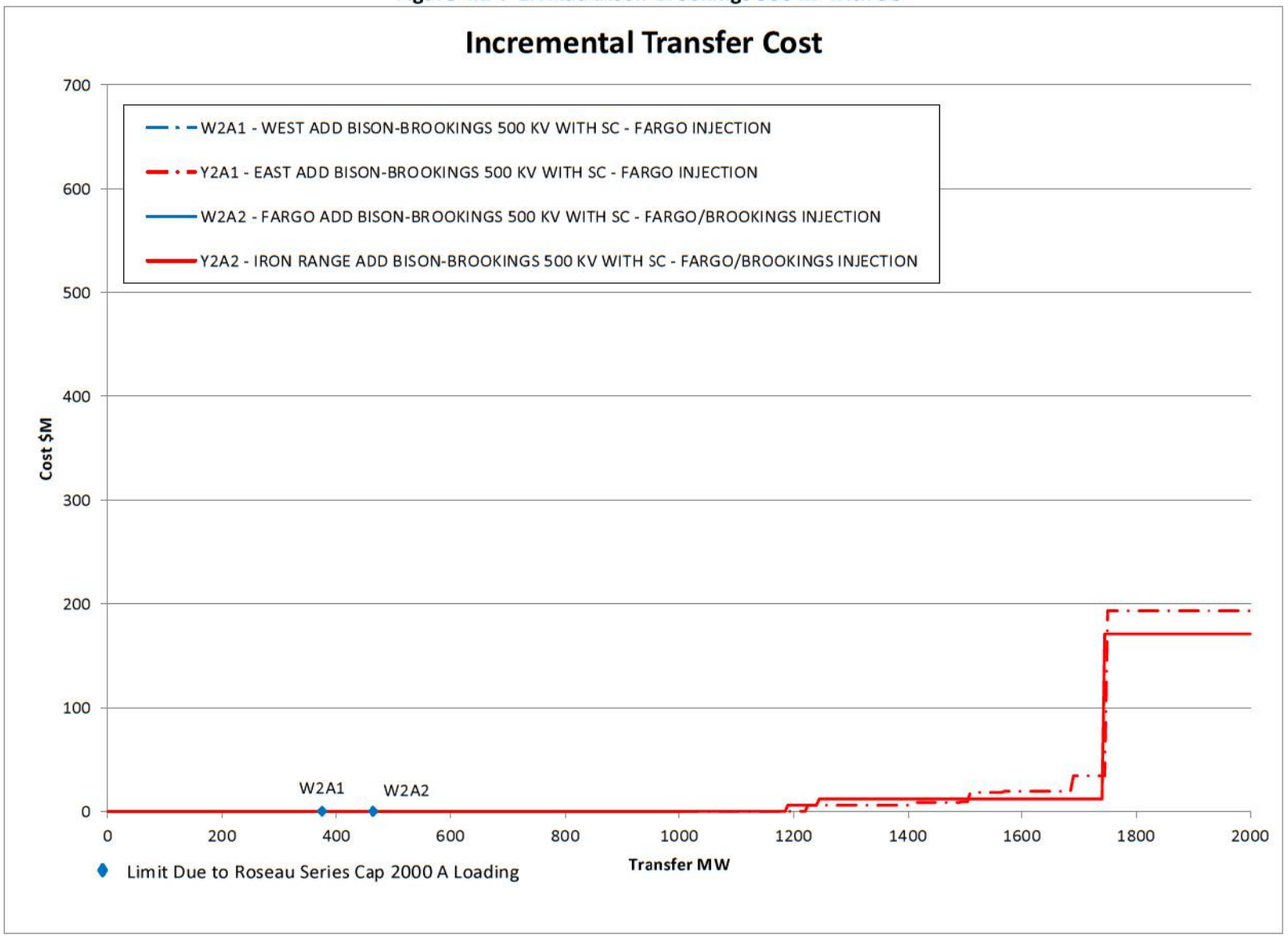


Figure 4.2-8 2B Add Bison-Brookings 345 kV

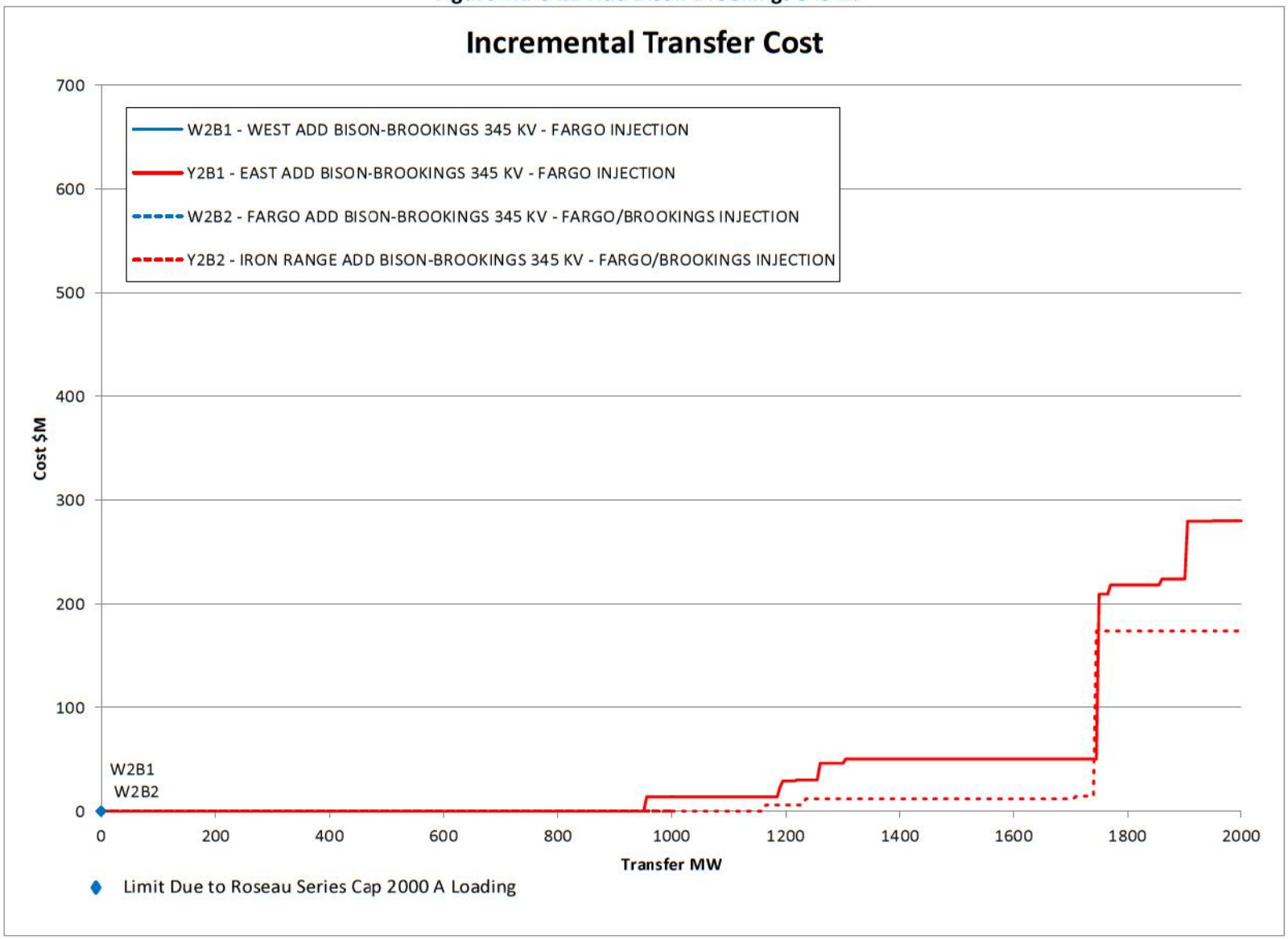


Figure 4.2-9 6A Corridor Projects and Bison-Brookings 500 kV with SC

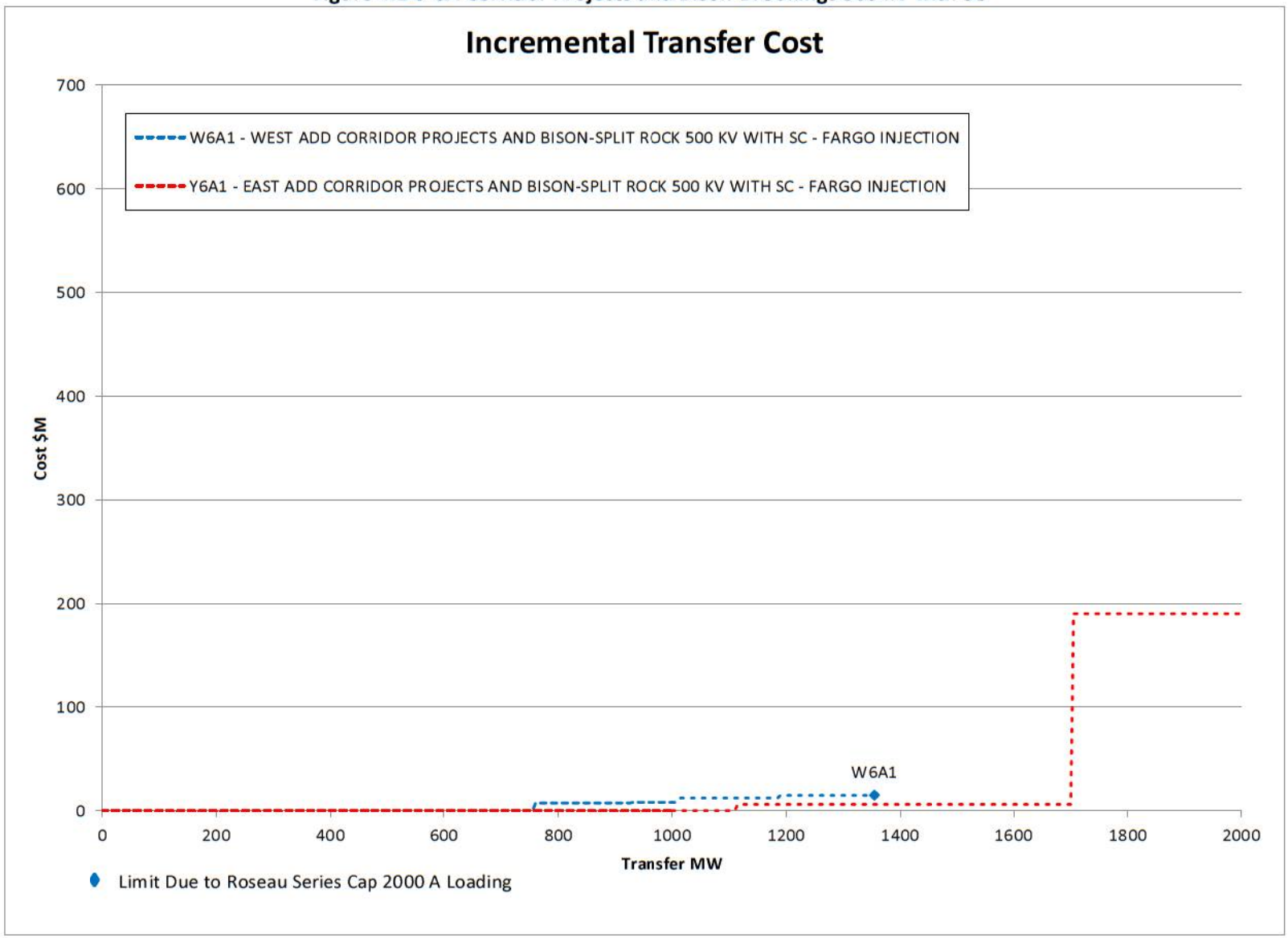


Figure 4.2-10 6B Corridor Projects

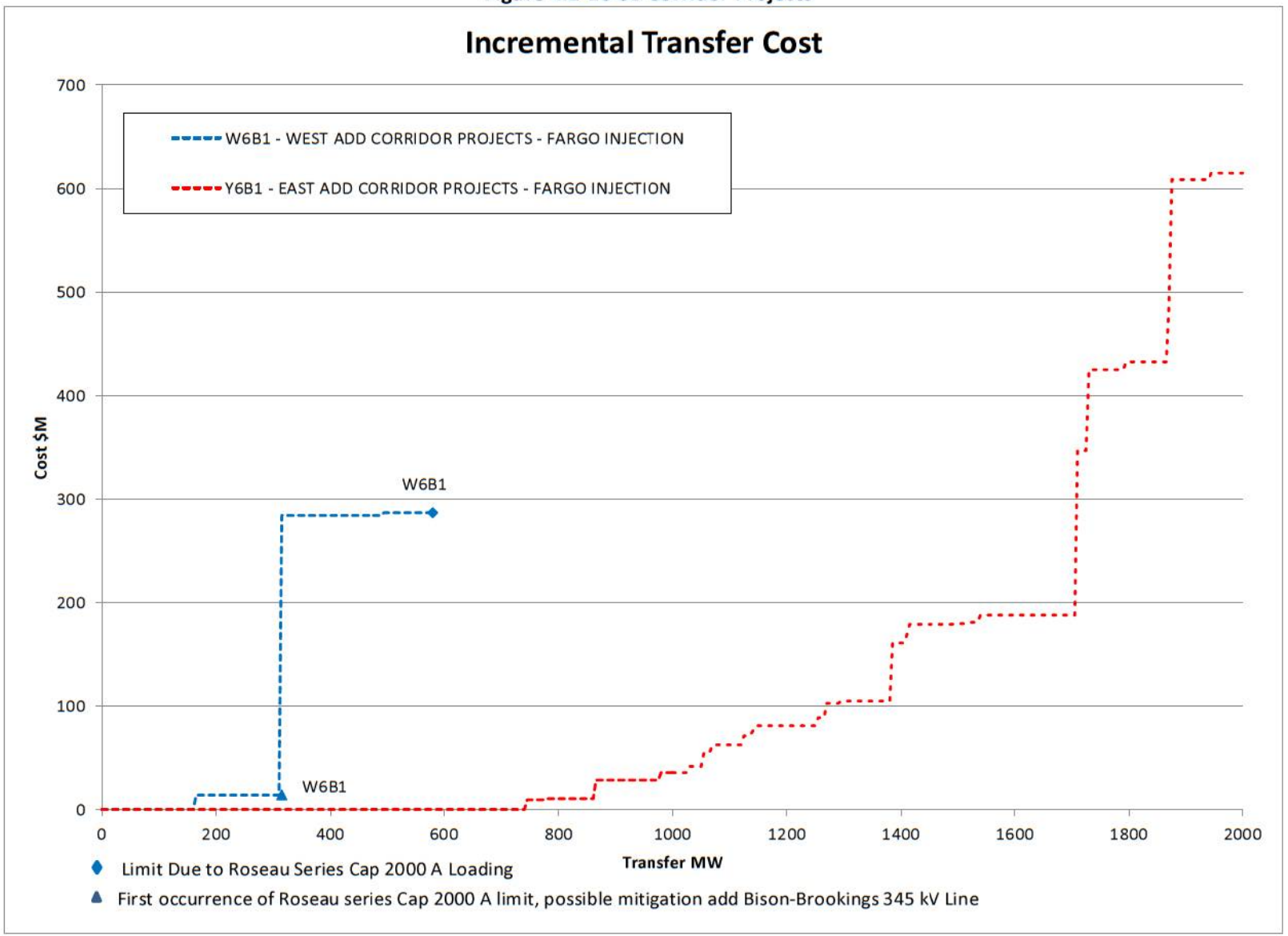


Figure 4.2-11 W1A and Y1B Incremental with Buildout Cost

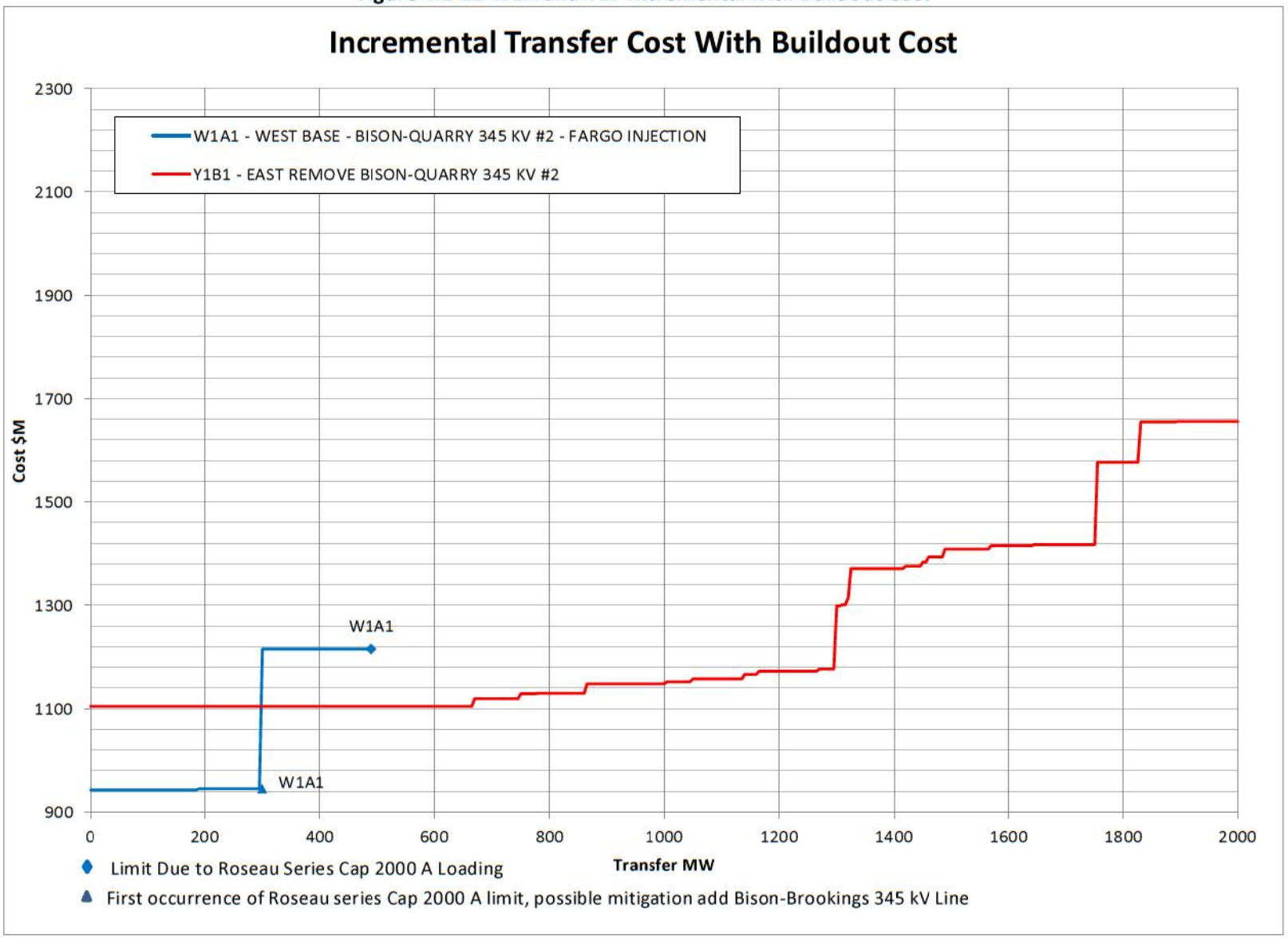


Table 4.2-12 First Limiters For All Options

Fargo Option				Iron Range Option			
Transfer MW	Limiting Facility	DF%	Outage	Transfer MW	Limiting Facility	DF%	Outage
W1A	Fargo - Base - Bison-Quarry 345 kV #2			Y1A	Iron Range - Base - Bison-Quarry 345 kV #2		
W1A1	Fargo Wind Injection			Y1A1	Fargo Wind Injection		
190	Bison-Maple River 230 kV at 100% of 520 MVA (1305 amps) Owner(s): MPC 10.37 Miles	23.0	Open Bison-Maple River 345 kV	750	Sheyenne-Maple River 230 at 110% of 459 MVA (1152 amps) Owner(s): XCEL ~7 Miles	38.5	Open 601046 ALEXSS3 345 601067 BISON 3 345 1 Open 601046 ALEXSS3 345 601067 BISON 3 345 2
W1A2	Fargo/Brookings Wind Injection			Y1A2	Fargo/Brookings Wind Injection		
-255	Roseau N-Roseau S Series Caps 500 kV at 110% of 1732 MVA (2000 amps) Owner(s): XCEL Zero Miles	19.0	Open 601046 ALEXSS3 345 601067 BISON 3 345 1 Open 601046 ALEXSS3 345 601067 BISON 3 345 2	1175	Split Rock-White 345 kV line 1 at 100% of 717 MVA (1200 amps) Owner(s): XCEL ~60 Miles	28.6	Open 601031 BRKNGCO3 345 601048 LYON CO 3 345 1
W1A60	Fargo - Base - Bison-Quarry 345 kV #2, use 60% series compensation on new 500 kV line						
W1A160	Fargo Wind Injection						
105	Bison-Maple River 230 kV at 100% of 520 MVA (1305 amps) Owner(s): MPC 10.37 Miles	22.3	Open Bison-Maple River 345 kV				
W1A260	Fargo/Brookings Wind Injection						
	DID NOT RUN						
W1AP	Fargo - Add Glenboro Phase Shifter			Y1AP	Iron Range - Add Glenboro Phase Shifter		
W1AP1	Fargo Wind Injection			Y1AP1	Fargo Wind Injection		
280	Bison-Maple River 230 kV at 100% of 520 MVA (1305 amps) Owner(s): MPC 10.37 Miles	23.0	Open Bison-Maple River 345 kV Open Maple River 345/230 kV tx 2 Open Maple River 345/230 kV tx 1	745	Sheyenne-Maple River 230 at 110% of 459 MVA (1152 amps) Owner(s): XCEL ~7 Miles	38.5	Open 601046 ALEXSS3 345 601067 BISON 3 345 1 Open 601046 ALEXSS3 345 601067 BISON 3 345 2
W1AP2	Fargo/Brookings Wind Injection			Y1AP2	Fargo/Brookings Wind Injection		
635	Bison-Maple River 230 kV at 100% of 520 MVA (1305 amps) Owner(s): MPC 10.37 Miles	10.2	Open Bison-Maple River 345 kV Open Maple River 345/230 kV tx 2 Open Maple River 345/230 kV tx 1	1160	Split Rock-White 345 kV line 1 at 100% of 717 MVA (1200 amps) Owner(s): XCEL ~60 Miles	28.6	Open 601031 BRKNGCO3 345 601048 LYON CO 3 345 1
W1B	Fargo - Remove Bison-Quarry 345 kV #2			Y1B	Iron Range - Remove Bison-Quarry 345 kV #2		

Fargo Option				Iron Range Option			
Transfer MW	Limiting Facility	DF%	Outage	Transfer MW	Limiting Facility	DF%	Outage
W1B1	Fargo Wind Injection			Y1B1	Fargo Wind Injection		
-240	Bison-Maple River 230 kV at 100% of 520 MVA (1305 amps) Owner(s): MPC 10.37 Miles	27.6	Open Bison-Maple River 345 kV	670	Bison-Maple River 230 kV at 100% of 520 MVA (1305 amps) Owner(s): MPC 10.37 Miles	42.6	Open Bison-Maple River 345 kV Open Maple River 345/230 kV tx 2 Open Maple River 345/230 kV tx 1
W1B2	Fargo/Brookings Wind Injection			Y1B2	Fargo/Brookings Wind Injection		
-530	Bison-Maple River 230 kV at 100% of 520 MVA (1305 amps) Owner(s): MPC 10.37 Miles	12.6	Open Bison-Maple River 345 kV	1130	Split Rock-White 345 kV line 1 at 100% of 717 MVA (1200 amps) Owner(s): XCEL ~60 Miles	29.1	Open Brookings Co - Lyon Co 345 kV
				Y1B60	Iron Range - Remove Bison-Quarry 345 kV #2, use 60% series compensation on new 500 kV line		
				Y1B160	Fargo Wind Injection		
				670	Bison-Maple River 230 kV at 100% of 520 MVA (1305 amps) Owner(s): MPC 10.37 Miles	42.6	Open Bison-Maple River 345 kV
				Y1B260	Fargo/Brookings Wind Injection		
					DID NOT RUN		
W1C	Fargo - Add All MVP			Y1C	Iron Range - Add All MVP		
W1C1	Fargo Wind Injection			Y1C1	Fargo Wind Injection		
125	Bison-Maple River 230 kV at 100% of 520 MVA (1305 amps) Owner(s): MPC 10.37 Miles	23.5	Open Bison-Maple River 345 kV	775	Sheyenne-Maple River 230 at 110% of 459 MVA (1152 amps) Owner(s): XCEL ~7 Miles	38.0	Open 601046 ALEXSS3 345 601067 BISON 3 345 1 Open 601046 ALEXSS3 345 601067 BISON 3 345 2
W1C2	Fargo/Brookings Wind Injection			Y1C2	Fargo/Brookings Wind Injection		
	DID NOT RUN				DID NOT RUN		
W2A	Fargo - Add Bison-Brookings 500 kV with SC			Y2A	Iron Range - Add Bison-Brookings 500 kV with SC		
W2A1	Fargo Wind Injection			Y2A1	Fargo Wind Injection		
375	Roseau N-Roseau S Series Caps 500 kV at 100% of 1732 MVA (2000 amps) Owner(s): XCEL Zero Miles	16.6	System Intact	1225	Arpin 345/138 kV Tx at 113% of 336 MVA Owner(s): 691	5.7	Open Arpin-Rocky run 345 kV

Fargo Option				Iron Range Option			
Transfer MW	Limiting Facility	DF%	Outage	Transfer MW	Limiting Facility	DF%	Outage
W2A2	Fargo/Brookings Wind Injection			Y2A2	Fargo/Brookings Wind Injection		
465	Roseau N-Roseau S Series Caps 500 kV at 100% of 1732 MVA (2000 amps) Owner(s): XCEL Zero Miles	13.4	System Intact	1190	Split Rock-White 345 kV line 1 at 100% of 717 MVA (1200 amps) Owner(s): XCEL ~60 Miles	31.3	Open 601031 BRKNGCO3 345 601048 LYON CO 3 345 1
W2B	Fargo - Add Bison-Brookings 345 kV			Y2B	Iron Range - Add Bison-Brookings 345 kV		
W2B1	Fargo Wind Injection			Y2B1	Fargo Wind Injection		
-1145	Roseau N-Roseau S Series Caps 500 kV at 110% of 1732 MVA (2000 amps) Owner(s): XCEL Zero Miles	6.7	Open Bison 500/345 kV Tx #1 Change bus 667033 DORSEYS4 230 load by 454.5 MW dispatch	955	Bison-Maple River 230 kV at 100% of 520 MVA (1305 amps) Owner(s): MPC 10.37 Miles	31.2	Open Bison-Maple River 345 kV Open Maple River 345/230 kV tx 2 Open Maple River 345/230 kV tx 1
W2B2	Fargo/Brookings Wind Injection			Y2B2	Fargo/Brookings Wind Injection		
-30	Roseau N-Roseau S Series Caps 500 kV at 100% of 1732 MVA (2000 amps) Owner(s): XCEL Zero Miles	14.2	System Intact	1165	Split Rock-White 345 kV line 1 at 100% of 717 MVA (1200 amps) Owner(s): XCEL ~60 Miles	30.3	Open 601031 BRKNGCO3 345 601048 LYON CO 3 345 1
W6A	Fargo - Add Corridor Project and Bison-Split Rock 500 kV with SC			Y6A	Iron Range - Add Corridor Project and Bison-Split Rock 500 kV with SC		
W6A1	Fargo Wind Injection			Y6A1	Fargo Wind Injection		
760	Arpin 345/138 kV Tx at 113% of 336 MVA Owner(s): 691	6.0	Open Arpin-Rocky run 345 kV	1115	Arpin 345/138 kV Tx at 113% of 336 MVA Owner(s): 691	5.7	Open Arpin-Rocky run 345 kV
W6A2	Fargo/Brookings Wind Injection			Y6A2	Fargo/Brookings Wind Injection		
	DID NOT RUN				DID NOT RUN		
W6B	Fargo - Add Corridor Project			Y6B	Iron Range - Add Corridor Project		
W6B1	Fargo Wind Injection			Y6B1	Fargo Wind Injection		
165	Bison-Maple River 230 kV at 100% of 520 MVA (1305 amps) Owner(s): MPC 10.37 Miles	23.2	Open Bison-Maple River 345 kV	745	Sheyenne-Maple River 230 at 110% of 459 MVA (1152 amps) Owner(s): XCEL ~7 Miles	38.5	Open 601046 ALEXSS3 345 601067 BISON 3 345 1 Open 601046 ALEXSS3 345 601067 BISON 3 345 2
W6B2	Fargo/Brookings Wind Injection			Y6B2	Fargo/Brookings Wind Injection		
	DID NOT RUN				DID NOT RUN		

Table 4.2-13 System Intact Overloads for All Options

Fargo Option			Iron Range Option		
Transfer MW	**Limiting Facility**	**DF%**	**Transfer MW**	**Limiting Facility**	**DF%**
W1A	**Fargo - Base - Bison-Quarry 345 kV #2**		**Y1A**	**Iron Range - Base - Bison-Quarry 345 kV #2**	
W1A1	**Fargo Wind Injection**		**Y1A1**	**Fargo Wind Injection**	
300	Roseau N-Roseau S Series Caps 500 kV at 100% of 1732 MVA (2000 amps) Owner(s): XCEL Zero Miles	21.8	1785	Maple River 345/230 kV tx 1 at 100% of 336 MVA Owner(s): OTP	15.7
490	Roseau N-Roseau S Series Caps 500 kV at 100% of 1732 MVA (2000 amps) Owner(s): XCEL after Bison-Brookings 345 kV added	18.8	1785	Maple River 345/230 kV tx 2 at 100% of 336 MVA Owner(s): OTP	15.7
1495	Maple River 345/230 kV tx 1 at 100% of 336 MVA Owner(s): OTP	9.2	1870	Sheyenne-Maple River 230 at 100% of 459 MVA (1152 amps) Owner(s): XCEL ~7 Miles	21.6
1500	Maple River 345/230 kV tx 2 at 100% of 336 MVA Owner(s): OTP	9.2	1940	Bison-Maple River 345 kV at 100% of 720 MVA (1205 amps) Owner(s): MPC ~10 Miles	31.4
1700	Sheyenne-Maple River 230 at 100% of 459 MVA (1152 amps) Owner(s): XCEL ~7 Miles	12.9			
1755	Bison-Maple River 345 kV at 100% of 720 MVA (1205 amps) Owner(s): MPC ~3 Miles	18.4			
W1A2	**Fargo/Brookings Wind Injection**		**Y1A2**	**Fargo/Brookings Wind Injection**	
510	Roseau N-Roseau S Series Caps 500 kV at 100% of 1732 MVA (2000 amps) Owner(s): XCEL Zero Miles	12.8			
740	Roseau N-Roseau S Series Caps 500 kV at 100% of 1732 MVA (2000 amps) Owner(s): XCEL after Bison-Brookings 345 kV added	12.4			

1970	Split Rock-White 345 kV line 1 at 100% of 717 MVA (1200 amps) Owner(s): XCEL ~4 Miles	22.9		**NONE**	
W1A160	**60% Series Comp New 500 kV Line**				
W1A160	**Fargo Wind Injection**				
440	Roseau N-Roseau S Series Caps 500 kV at 100% of 1732 MVA (2000 amps) Owner(s): XCEL Zero Miles	22.8		**DID NOT RUN**	
670	Roseau N-Roseau S Series Caps 500 kV at 100% of 1732 MVA (2000 amps) Owner(s): XCEL after Bison-Brookings 345 kV added	19.7			
1425	Maple River 345/230 kV tx 1 at 100% of 336 MVA Owner(s): OTP	9.0			
1430	Maple River 345/230 kV tx 2 at 100% of 336 MVA Owner(s): OTP	9.0			
1645	Sheyenne-Maple River 230 at 100% of 459 MVA (1152 amps) Owner(s): XCEL ~7 Miles	12.6			
1695	Bison-Maple River 345 kV at 100% of 720 MVA (1205 amps) Owner(s): MPC ~3 Miles	18.0			
W1A260	**Fargo/Brookings Wind Injection**				
	DID NOT RUN				
W1AP	**Fargo - Add Glenboro Phase Shifter**		**Y1AP**	**Iron Range - Add Glenboro Phase Shifter**	
W1AP1	**Fargo Wind Injection**		**Y1AP1**	**Fargo Wind Injection**	
460	Roseau N-Roseau S Series Caps 500 kV at 100% of 1732 MVA (2000 amps) Owner(s): XCEL Zero Miles	21.8	1790	Maple River 345/230 kV tx 1 at 100% of 336 MVA Owner(s): OTP	15.7
680	Roseau N-Roseau S Series Caps 500 kV at 100% of 1732 MVA (2000 amps) Owner(s): XCEL after Bison-Brookings 345 kV added	18.8	1790	Maple River 345/230 kV tx 2 at 100% of 336 MVA Owner(s): OTP	15.7

1600	Maple River 345/230 kV tx 1 at 100% of 336 MVA Owner(s): OTP	9.2	1890	Sheyenne-Maple River 230 at 100% of 459 MVA (1152 amps) Owner(s): XCEL ~7 Miles	21.5
1600	Maple River 345/230 kV tx 2 at 100% of 336 MVA Owner(s): OTP	9.2	1945	Bison-Maple River 345 kV at 100% of 720 MVA (1205 amps) Owner(s): MPC ~10 Miles	31.4
1830	Sheyenne-Maple River 230 at 100% of 459 MVA (1152 amps) Owner(s): XCEL ~7 Miles	12.9			
1860	Bison-Maple River 345 kV at 100% of 720 MVA (1205 amps) Owner(s): MPC ~3 Miles	18.4			
W1AP2	**Fargo/Brookings Wind Injection**		**Y1AP2**	**Fargo/Brookings Wind Injection**	
785	Roseau N-Roseau S Series Caps 500 kV at 100% of 1732 MVA (2000 amps) Owner(s): XCEL Zero Miles	12.8		**NONE**	
1030	Roseau N-Roseau S Series Caps 500 kV at 100% of 1732 MVA (2000 amps) Owner(s): XCEL after Bison-Brookings 345 kV added	12.4			
1980	Split Rock-White 345 kV line 1 at 100% of 717 MVA (1200 amps) Owner(s): XCEL ~4 Miles	22.9			
W1B	**Fargo - Remove Bison-Quarry 345 kV #2**		**Y1B**	**Iron Range - Remove Bison-Quarry 345 kV #2**	
W1B1	**Fargo Wind Injection**		**Y1B1**	**Fargo Wind Injection**	
-135	Roseau N-Roseau S Series Caps 500 kV at 100% of 1732 MVA (2000 amps) Owner(s): XCEL Zero Miles	26.2	1265	Maple River 345/230 kV tx 1 at 100% of 336 MVA Owner(s): OTP	19.6
50	Roseau N-Roseau S Series Caps 500 kV at 100% of 1732 MVA (2000 amps) Owner(s): XCEL after Bison-Brookings 345 kV added	22.0	1265	Maple River 345/230 kV tx 2 at 100% of 336 MVA Owner(s): OTP	19.6

930	Maple River 345/230 kV tx 1 at 100% of 336 MVA Owner(s): OTP	10.6	1340	Sheyenne-Maple River 230 at 100% of 459 MVA (1152 amps) Owner(s): XCEL ~7 Miles	26.8
930	Maple River 345/230 kV tx 2 at 100% of 336 MVA Owner(s): OTP	10.6	1385	Bison-Maple River 345 kV at 100% of 720 MVA (1205 amps) Owner(s): MPC ~10 Miles	39.1
1130	Sheyenne-Maple River 230 at 100% of 459 MVA (1152 amps) Owner(s): XCEL ~7 Miles	14.9	1740	Frontier-Maple River 230 kV at 100% of 265 MVA (665 amps) Owner(s): MPC ~11 Miles	13.0
1155	Bison-Maple River 345 kV at 100% of 720 MVA (1205 amps) Owner(s): MPC ~3 Miles	21.3	1745	Wahpeton-Frontier 230 kV at 100% of 265 MVA (665 amps) Owner(s): MPC ~44 Miles	13.0
1785	Frontier-Maple River 230 kV at 100% of 265 MVA (665 amps) Owner(s): MPC ~11 Miles	7.6			
1810	Wahpeton-Frontier 230 kV at 100% of 265 MVA (665 amps) Owner(s): MPC ~44 Miles	7.6			
W1B2	**Fargo/Brookings Wind Injection**		**Y1B2**	**Fargo/Brookings Wind Injection**	
-235	Roseau N-Roseau S Series Caps 500 kV at 100% of 1732 MVA (2000 amps) Owner(s): XCEL Zero Miles	15.2			
75	Roseau N-Roseau S Series Caps 500 kV at 100% of 1732 MVA (2000 amps) Owner(s): XCEL after Bison-Brookings 345 kV added	14.4			
1755	Maple River 345/230 kV tx 1 at 100% of 336 MVA Owner(s): OTP	5.6			
1755	Maple River 345/230 kV tx 2 at 100% of 336 MVA Owner(s): OTP	5.6			
1855	Split Rock-White 345 kV line 1 at 100% of 717 MVA (1200 amps) Owner(s): XCEL ~4 Miles	23.4		**NONE**	

			Y1B60	**60% Series Comp New 500 kV Line**	
			Y1B160	**Fargo Wind Injection**	
			1265	Maple River 345/230 kV tx 1 at 100% of 336 MVA Owner(s): OTP	19.6
			1265	Maple River 345/230 kV tx 2 at 100% of 336 MVA Owner(s): OTP	19.6
			1340	Sheyenne-Maple River 230 at 100% of 459 MVA (1152 amps) Owner(s): XCEL ~7 Miles	26.8
			1385	Bison-Maple River 345 kV at 100% of 720 MVA (1205 amps) Owner(s): MPC ~3 Miles	39.1
			1750	Frontier-Maple River 230 kV at 100% of 265 MVA (665 amps) Owner(s): MPC ~11 Miles	13.0
			1750	Wahpeton-Frontier 230 kV at 100% of 265 MVA (665 amps) Owner(s): MPC ~44 Miles	13.0
			Y1B260	**Fargo/Brookings Wind Injection**	
				DID NOT RUN	
W1C	**Fargo - Add All MVP**		**Y1C**	**Iron Range - Add All MVP**	
W1C1	**Fargo Wind Injection**		**Y1C1**	**Fargo Wind Injection**	
1265	Maple River 345/230 kV tx 1 at 100% of 336 MVA Owner(s): OTP	19.6	1735	Maple River 345/230 kV tx 1 at 100% of 336 MVA Owner(s): OTP	15.9
1265	Maple River 345/230 kV tx 2 at 100% of 336 MVA Owner(s): OTP	19.6	1735	Maple River 345/230 kV tx 2 at 100% of 336 MVA Owner(s): OTP	15.9
1340	Sheyenne-Maple River 230 at 100% of 459 MVA (1152 amps) Owner(s): XCEL ~7 Miles	26.8	1870	Sheyenne-Maple River 230 at 100% of 459 MVA (1152 amps) Owner(s): XCEL ~7 Miles	21.5

1385	Bison-Maple River 345 kV at 100% of 720 MVA (1205 amps) Owner(s): MPC ~3 Miles	39.1	1885	Bison-Maple River 345 kV at 100% of 720 MVA (1205 amps) Owner(s): MPC ~10 Miles	31.8
1750	Frontier-Maple River 230 kV at 100% of 265 MVA (665 amps) Owner(s): MPC ~11 Miles	13.0			
1750	Wahpeton-Frontier 230 kV at 100% of 265 MVA (665 amps) Owner(s): MPC ~44 Miles	13.0			
W1C2	**Fargo/Brookings Wind Injection**		**Y1C2**	**Fargo/Brookings Wind Injection**	
	DID NOT RUN			**DID NOT RUN**	
W2A	**Fargo - Add Bison-Brookings 500 kV with SC**		**Y2A**	**Iron Range - Add Bison-Brookings 500 kV with SC**	
W2A1	**Fargo Wind Injection**		**Y2A1**	**Fargo Wind Injection**	
375	Roseau N-Roseau S Series Caps 500 kV at 100% of 1732 MVA (2000 amps) Owner(s): XCEL Zero Miles	16.6		**NONE**	
1605	Maple River 345/230 kV tx 1 at 100% of 336 MVA Owner(s): OTP	8.6			
1605	Maple River 345/230 kV tx 2 at 100% of 336 MVA Owner(s): OTP	8.6			
1860	Sheyenne-Maple River 230 at 100% of 459 MVA (1152 amps) Owner(s): XCEL ~7 Miles	11.9			
1885	Bison-Maple River 345 kV at 100% of 720 MVA (1205 amps) Owner(s): MPC ~10 Miles	17.1			
1945	Split Rock-White 345 kV line 1 at 100% of 717 MVA (1200 amps) Owner(s): XCEL ~4 Miles	19.2			
W2A2	**Fargo/Brookings Wind Injection**		**Y2A2**	**Fargo/Brookings Wind Injection**	

465	Roseau N-Roseau S Series Caps 500 kV at 100% of 1732 MVA (2000 amps) Owner(s): XCEL Zero Miles	13.4	1990	Split Rock-White 345 kV line 1 at 100% of 717 MVA (1200 amps) Owner(s): XCEL ~4 Miles	25.6
1550	Split Rock-White 345 kV line 1 at 100% of 717 MVA (1200 amps) Owner(s): XCEL ~4 Miles	24.0			
W2B	**Fargo - Add Bison-Brookings 345 kV**		**Y2B**	**Iron Range - Add Bison-Brookings 345 kV**	
W2B1	**Fargo Wind Injection**		**Y2B1**	**Fargo Wind Injection**	
-20	Roseau N-Roseau S Series Caps 500 kV at 100% of 1732 MVA (2000 amps) Owner(s): XCEL Zero Miles	21.6	1675	Maple River 345/230 kV tx 1 at 100% of 336 MVA Owner(s): OTP	14.9
965	Maple River 345/230 kV tx 1 at 100% of 336 MVA Owner(s): OTP	10.8	1680	Maple River 345/230 kV tx 2 at 100% of 336 MVA Owner(s): OTP	14.9
965	Maple River 345/230 kV tx 2 at 100% of 336 MVA Owner(s): OTP	10.8	1785	Sheyenne-Maple River 230 at 100% of 459 MVA (1152 amps) Owner(s): XCEL ~7 Miles	20.4
1160	Sheyenne-Maple River 230 at 100% of 459 MVA (1152 amps) Owner(s): XCEL ~7 Miles	15.0	1840	Bison-Maple River 345 kV at 100% of 720 MVA (1205 amps) Owner(s): MPC ~10 Miles	29.8
1185	Bison-Maple River 345 kV at 100% of 720 MVA (1205 amps) Owner(s): MPC ~10 Miles	21.5			
1800	Frontier-Maple River 230 kV at 100% of 265 MVA (665 amps) Owner(s): MPC ~11 Miles	7.6			
1825	Wahpeton-Frontier 230 kV at 100% of 265 MVA (665 amps) Owner(s): MPC ~44 Miles	7.6			
W2B2	**Fargo/Brookings Wind Injection**		**Y2B2**	**Fargo/Brookings Wind Injection**	

-30	Roseau N-Roseau S Series Caps 500 kV at 100% of 1732 MVA (2000 amps) Owner(s): XCEL Zero Miles	14.2		**NONE**	
1815	Maple River 345/230 kV tx 1 at 100% of 336 MVA Owner(s): OTP	5.7			
1820	Maple River 345/230 kV tx 2 at 100% of 336 MVA Owner(s): OTP	5.7			
1870	Split Rock-White 345 kV line 1 at 100% of 717 MVA (1200 amps) Owner(s): XCEL ~4 Miles	23.4			
W6A	**Fargo - Add Corridor Project and Bison-Split Rock 500 kV with SC**		**Y6A**	**Iron Range - Add Corridor Project and Bison-Split Rock 500 kV with SC**	
W6A1	**Fargo Wind Injection**		**Y6A1**	**Fargo Wind Injection**	
1355	Roseau N-Roseau S Series Caps 500 kV at 100% of 1732 MVA (2000 amps) Owner(s): XCEL Zero Miles	13.0		**NONE**	
W6A2	**Fargo/Brookings Wind Injection**		**Y6A2**	**Fargo/Brookings Wind Injection**	
	DID NOT RUN			**DID NOT RUN**	
W6B	**Fargo - Add Corridor Project**		**Y6B**	**Iron Range - Add Corridor Project**	
W6B1	**Fargo Wind Injection**		**Y6B1**	**Fargo Wind Injection**	
315	Roseau N-Roseau S Series Caps 500 kV at 100% of 1732 MVA (2000 amps) Owner(s): XCEL Zero Miles	21.4	1750	Maple River 345/230 kV tx 1 at 100% of 336 MVA Owner(s): OTP	15.7
580	Roseau N-Roseau S Series Caps 500 kV at 100% of 1732 MVA (2000 amps) Owner(s): XCEL after Bison-Brookings 345 kV added	18.2	1750	Maple River 345/230 kV tx 2 at 100% of 336 MVA Owner(s): OTP	15.7
1525	Maple River 345/230 kV tx 1 at 100% of 336 MVA Owner(s): OTP	9.3	1825	Sheyenne-Maple River 230 at 100% of 459 MVA (1152 amps) Owner(s): XCEL ~7 Miles	21.6

1525	Maple River 345/230 kV tx 2 at 100% of 336 MVA Owner(s): OTP	9.3	1900	Bison-Maple River 345 kV at 100% of 720 MVA (1205 amps) Owner(s): MPC ~10 Miles	31.4
1705	Sheyenne-Maple River 230 at 100% of 459 MVA (1152 amps) Owner(s): XCEL ~7 Miles	13.1			
1780	Bison-Maple River 345 kV at 100% of 720 MVA (1205 amps) Owner(s): MPC ~3 Miles	18.6			
W6B2	**Fargo/Brookings Wind Injection**		**Y6B2**	**Fargo/Brookings Wind Injection**	
	DID NOT RUN			**DID NOT RUN**	