



## **APPENDIX A CONNECTION ASSESSMENT**

# ATCO Heartland Pump Station Connection Project P1410

The attached engineering study report has been prepared by a third party as part of the AESO's connection process. The AESO has reviewed the report and the conclusions that it contains, and finds it acceptable for the purpose of assessing potential impacts of the proposed connection on the transmission system.

Information regarding the AESO's connection process can be found at: <http://www.aeso.ca/8602.html>

Date: August 18, 2015

Function	Name	Company	Signature	Date
Senior Engineer	Maz Mazadi PhD, P.Eng.	Alberta Electric System Operator		Aug. 18, 2015
Manager, Projects & System Access Studies	Mohamed Kamh PhD, P.Eng.	Alberta Electric System Operator		Aug 21, 2015

While the DFO's plans are considered during the transmission planning process, the AESO, in exercising its duties to plan the transmission system, does not oversee distribution planning or the development of specific DFO planning criteria.

Public



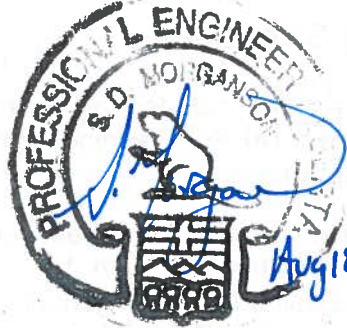
# Connection Engineering Study Report for AUC Application

## ATCO Heartland Pump Station Connection

File No. 1410

Revision: 3

Revision Date: August, 2015

	Name	Date	Signature
Reviewed and Approved by:	Sharon Morganson, P. Eng.	August 18, 2015	 A circular professional engineer seal for Sharon Morganson, P. Eng. The seal contains the text "PROFESSIONAL ENGINEER" at the top and "S. D. MORGANSON" in the center. A blue ink signature is written across the seal, and the date "Aug 18, 2015" is handwritten in blue ink at the bottom right of the seal. APEGGA Permit to Practice # P0850

# Executive Summary

## Project Overview

ATCO Electric as the Distribution Facility Owner (DFO) in the area was approached by a customer (TransCanada PipeLines Limited) to provide supply to their Heartland pump station (the Facilities) to be located at LSD 31SEC-50 TWP-13 REG-W4 which is within the Vegreville area (AESO Planning Area 56). The Facilities consists of a 20 MW load (based upon 4x6500 horsepower (hp) motors running with 1x6500 hp installed spare) with an In-Service Date (ISD) of November 2017.

The Project is to connect these Facilities to the Alberta Interconnected Electric System (AIES).

## Existing System

The Vegreville 709S substation is connected to three 144kV lines: 7L77 to North Holden 395S, 7L92 to Whitby Lake 819S, and 7L65 to Vermilion 710S. The Vegreville area is primarily supplied by the Battle River generation in the Alliance/Battle River area (AESO Planning Area 36) and by the generation sources at Foster Creek 877S, Primrose 859S, and Mahkeses 889S, and Nabiye 942S substations in the Cold Lake area (AESO Planning Area 28).

In the adjacent Alliance/Battle River area, Thermal Protection Scheme RASs exist on 144 kV lines 7L50 and 7L701. In the Cold Lake area, RASs exist to mitigate thermal as well as voltage collapse issues.

The Central East Transmission Development<sup>1</sup> (CETD) consists of several 138/144 kV enhancements in the Wainwright (AESO Planning Area 32) and Lloydminster (AESO Planning Area 13) areas to serve increasing load and generation, and 240 kV and 144 kV enhancements in the Cold Lake area to serve oil sands expansions. Some of the Stage 1 developments have been cancelled; the rest will be in service prior to this connection ISD.

## Study Summary

The study area included the Vegreville area and the adjacent areas of Lloydminster, Cold Lake, Wetaskiwin (AESO Planning Area 31), Alliance/Battle River, Wainwright and Provost (AESO Planning Area 37).

Two transmission alternatives were identified to supply the new load. Alternative 1 is to add a 144/25 kV, 30/40/50 MVA LTC transformer at Vegreville 709S substation and supply the Facilities using two 25 kV feeders plus distribution 25/6.9 kV transformers. Since the load centre is approximately 25 km from the Vegreville 709S substation, multiple distribution regulators would be required to maintain the voltage profile. The DFO advised that this alternative would not meet their power quality standards due to high voltages during load rejection and due to high feeder losses. This alternative was, therefore, rejected.

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<sup>1</sup> The Central East Region Transmission Development Needs Identification Document, Application No. 1606218, was approved by the Commission in Approval No. U2011-57

Alternative 2 is to build a new pump station point-of-delivery (POD) substation (Vincent 2019S) and connect it to the 144 kV transmission line 7L65 using a T-tap configuration. The new Vincent 2019S substation will include a 144/6.9 kV 20/26/33.3 MVA LTC transformer. Alternative 2 was assessed in this report.

Load flow analysis was performed for the 2017SP and 2017WP conditions to assess the impact of the Project and its associated load on the AIES. Voltage stability analysis was completed for the 2017WP conditions. Short-circuit analysis was performed for the 2017WP and the 2023WP case to determine the short-circuit levels in the vicinity of the Vincent 2019S substation.

The voltage stability criterion was met for all Category A and Category B contingencies studied. The following is a summary of the load flow analysis findings:

Pre- Connection scenarios:

2017SP

- No Category A condition violations were identified.

*Category B and C5 Contingencies*

- The loss of the 138 kV line 749L from Metiskow 648S to Edgerton 899S causes a marginal thermal violation on the 144 kV line 7L130 between Vermilion 710S and Kitscoty 705S. This line has clearance issues and continuous flow above the stated ratings cannot be sustained; however, since the line loading is less than 100.5% this will be managed by real time operational practices.

2017WP

- No Category A condition violations were identified.

*Category B and C5 Contingencies*

- The loss of the 144 kV line 7L53 from Bonnyville 700S to Irish Creek 706S causes a transmission low voltage criteria violation (124.2 kV) and POD bus deviations at Irish Creek 706S.

Post-Connection scenarios:

2017SP

- No Category A condition violations were identified.

*Category B and C5 Contingencies*

- Similar to the pre-connection 2017SP scenario, the loss of the 138 kV line 749L from Metiskow 648S to Edgerton 899S causes a marginal thermal violation on the 144 kV line 7L130 between Vermilion 710S and Kitscoty 705S.
- The loss of the 144 kV line 7L53 from Bonnyville 700S to Irish Creek 706S causes a transmission low voltage criteria violation (128 kV) at Irish Creek 706S.

2017WP

- No Category A condition violations were identified.

*Category B and C5 Contingencies*

- The loss of the 144 kV line 7L50 from Battle River 757S to Buffalo Creek 726S causes thermal violations above the emergency winter rating (Rate B) on the 144 kV line 7L53 from Bonnyville 700S to Irish Creek 706S. This line has clearance issues and continuous flow above the stated ratings cannot be sustained; however, since the line loading is less than 100.5% this will be managed by real time operational practices.

- The loss of the 144 kV line 7L53 from Bonnyville 700S to Irish Creek 706S causes a transmission low voltage criteria violation (122.3 kV) and POD bus deviations at Irish Creek 706S, similar to those noted in the pre-connection 2017WP but with increased magnitude.

The Project connection does not contribute to the short-circuit level in the adjacent substations.

#### Mitigation Strategy and Sensitivity Analysis:

With the inclusion of a 25 MVar 144 kV capacitor at Irish Creek 706S, as identified in the AESO 2013 Long-term Plan (2013LTP),<sup>2</sup> all voltage and thermal violations identified in the load flow analysis are mitigated.

### **Alternative Selected**

Alternative 2 was selected. This involves building a new POD substation named Vincent 2019S and connecting it to the 144 kV transmission line 7L65 using a T-tap.

### **Recommendation**

The recommended alternative to connect the Facilities is Alternative 2, building the new 144/6.9 kV POD substation Vincent 2019S. The Project will include:

- Tapping the 144 kV line 7L65 and building 0.15 km of 144 kV line to connect the new Vincent 2019S POD substation.
- Installing one 20/26.6/33.3 MVA, 144 to 6.9 kV LTC transformer, one 144 kV transformer breaker, and associated equipment.

The 25 MVar 144 kV capacitor at Irish Creek 706S, as identified in the 2013LTP, is required prior to the Project ISD, since the inclusion of this capacitor bank mitigates all criteria violations noted in the pre- and post-connection results.

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<sup>2</sup> The Central Region portion of the AESO 2013 Long-term plan, which includes this study area, can be found on the AESO website at: <http://www.aeso.ca/transmission/30379.html>

# Contents

<b>Executive Summary .....</b>	<b>1</b>
<b>1. Introduction .....</b>	<b>7</b>
1.1. Project.....	7
1.1.1. Project Overview.....	7
1.1.2. Load Component .....	7
1.1.3. Generation Component .....	7
1.2. Study Scope .....	7
1.2.1. Study Objectives.....	7
1.2.2. Study Area .....	8
1.2.3. Studies Performed.....	13
1.3. Report Overview.....	13
<b>2. Criteria, System Data, and Study Assumptions.....</b>	<b>13</b>
2.1. Criteria, Standards and Requirements .....	13
2.1.1. AESO Transmission Reliability Criteria and Standards.....	13
2.1.2. AESO Information documents (IDs), Operating Policies and Procedures (OPPs) and Authoritative Documents (ADs) .....	14
2.2. Load and Generation Assumptions .....	15
2.2.1. Load Assumptions .....	15
2.2.2. Generation Assumptions .....	15
2.2.3. Intertie Flow Assumptions .....	16
2.3. System Projects.....	16
2.4. Customer Connection Projects.....	16
2.5. Facility Ratings and Shunt Elements.....	16
2.6. Voltage Profile Assumptions .....	18
<b>3. Study Methodology .....</b>	<b>19</b>
3.1. Study Objectives.....	19
3.2. Study Scenarios .....	19
3.3. Connection Studies Carried Out.....	20
3.4. Load Flow Analysis.....	20
3.4.1. Contingencies Studied.....	20
3.5. Voltage Stability (PV) Analysis .....	21
3.5.1. Contingencies Studied.....	21
3.6. Short-Circuit Analysis .....	21
<b>4. Pre-Connection System Assessment .....</b>	<b>22</b>
4.1. Pre-Connection Load Flow Analysis .....	22
4.1.1. Scenario 1: 2017SP Pre-Project.....	22
4.1.2. Scenario 2: 2017WP Pre-Project.....	23
4.2. Voltage Stability Analysis .....	23
4.2.1. Scenario 2: 2017WP Pre-Project.....	23
<b>5. Connection Alternatives .....</b>	<b>24</b>
5.1. Overview.....	24
5.2. Connection Alternatives Identified.....	24
5.2.1. Connection Alternatives Selected for Further Studies.....	26
5.2.2. Connection Alternatives Not Selected for Further Studies .....	26

<b>6. Technical Analysis of the Connection Alternative .....</b>	<b>26</b>
6.1. Summary .....	26
6.1.1. Load Flow Analysis.....	27
6.1.2. Voltage Stability Analysis .....	28
6.1.3. Sensitivity Study: Inclusion of the Irish Creek Capacitor .....	29
6.1.4. Mitigation Measures for Identified Issues .....	29
<b>7. Short-Circuit Analysis.....</b>	<b>30</b>
7.1. Pre-Connection.....	30
7.2. Post-Connection .....	30
<b>8. Project Interdependencies .....</b>	<b>31</b>
<b>9. Summary and Conclusion .....</b>	<b>32</b>

## Attachments

Attachment A	Pre-Connection PV Curves and Load Flow Plots
Attachment B	Post-Connection PV Curves and Load Flow Plots
Attachment C	Sensitivity Analysis: Post-Connection Load Flow Plots with the Irish Creek 706S Capacitor

## Figures

Figure 1-1: Study Area Transmission Network for 2017.....	9
Figure 1-2: AESO 2013 Long-term Plan for Central East Sub-Region.....	12
Figure 5-1: Alternative 1: Vegreville 709S substation capacity upgrade and 25kV feeders .....	25
Figure 5-2: Alternative 2: New Pump Station Substation Vincent 2019S .....	26

## Tables

Table 1-1: Summary of Central East Transmission Developments Not Already In-Service .....	10
Table 1-2: Summary of AESO 2013 LTP System Projects within the Study Area.....	11
Table 2-1: Acceptable Post Contingency Voltage Deviation .....	14
Table 2-2: Load Forecast (2014 LTO).....	15
Table 2-3: Summary of Existing Non-wind Generators in the Study area .....	16
Table 2-4: Customer Selected Projects.....	16
Table 2-5: Summary of Key Transmission Line Ratings in the Study Area (MVA using 138 kV base).....	17
Table 2-6: Summary of Existing Shunt Elements in the Study Area.....	18
Table 2-7: Key Bus Voltages in the Study Cases.....	18
Table 3-1: List of the Connection Study Scenarios .....	19
Table 3-2: Summary of Studies Performed .....	20
Table 3-3: Summary of Monitored Areas and Contingency Areas for Load Flow Analysis .....	20
Table 3-4: Listing of Selected Category C5 Contingencies Studied for Load Flow Analysis .....	20
Table 4-1: Scenario 1 – 2017SP Pre-Project N-G-1 Line Loadings Above Rate A .....	22
Table 4-2: Scenario 2 – 2017WP Pre-Project N-G-1 Voltage Violations and POD bus Deviations.....	23
Table 4-3: Scenario 2 – 2017WP Pre-Project: PV Analysis Results (Min Transfer = 53.1 MW).....	23



Table 6-1: Scenario 3 – 2017SP Post-Project N-G-1 Voltage Violations and POD bus Deviations .....27  
Table 6-2: Scenario 3 – 2017SP Post-Project N-G-1 Line Loadings Above Rate A.....27  
Table 6-3: Scenario 4 – 2017WP Post-Project N-G-1 Voltage Violations and POD bus Deviations .....28  
Table 6-4: Scenario 4 – 2017WP Post-Project N-G-1 Line Loading Above Rate B.....28  
Table 6-5: Scenario 6 – 2017WP Post-Project: PV Analysis Results (Min Transfer = 53.9 MW) .....29  
Table 7-1: Summary of Short-Circuit Current Levels – 2017WP Pre-Connection .....30  
Table 7-2: Summary of Short-Circuit Current Levels – 2017WP Post-Connection (Alternative 2) .....30  
Table 7-3: Summary of Short-Circuit Current Levels – 2023WP Post-Connection (Alternative 2) .....31

# 1. Introduction

This Customer Connection Engineering Study Report presents the results of the study conducted to analyze the recommended connection alternative of the Heartland pump station (the Project) to the Alberta Interconnected Electrical System (AIES).

## 1.1. Project

### 1.1.1. Project Overview

ATCO submitted a SASR to the AESO for a DTS of 20 MW to support TransCanada PipeLines Limited's new Facilities located at LSD 31SEC-50 TWP-13 REG-W4.

The requested ISD is November 2017.

### 1.1.2. Load Component

The load will be comprised of 4x6500 hp motors running with 1x6500 hp installed spare for a total peak load of 20 MW. All 6500 hp motors will be only started using variable frequency drives. All new loads will be studied using an expected power factor of 0.90.

### 1.1.3. Generation Component

There is no generation component associated with the Project.

## 1.2. Study Scope

### 1.2.1. Study Objectives

The objective of the study is as follows:

1. Assess the impact of the Project on the AIES.
2. Propose mitigation measures to address any system performance concerns to enable the reliable integration of the Project into the AIES.
3. Evaluate and recommend the Project connection alternative.

## 1.2.2. Study Area

### 1.2.2.1. Study Area Description

The proposed Heartland pump station is located approximately 25 km southeast of Vegreville 709S substation located in the Vegreville area. The Study Area will include the Vegreville area well as the adjacent areas of Lloydminster, Cold Lake, Wetaskiwin, Battle River/Alliance, Wainwright, and Provost.

The Vegreville 709S substation is connected to three 144kV lines: 7L77 to North Holden 395S, 7L92 to Whitby Lake 819S, and 7L65 to Vermilion 710S. The Vegreville area is primarily supplied by the Battle River generation in the Alliance/Battle River area and by the generation sources at Foster Creek 877S, Primrose 859S, and Mahkeses 889S, and Nabiye 942S substations in the Cold Lake area.

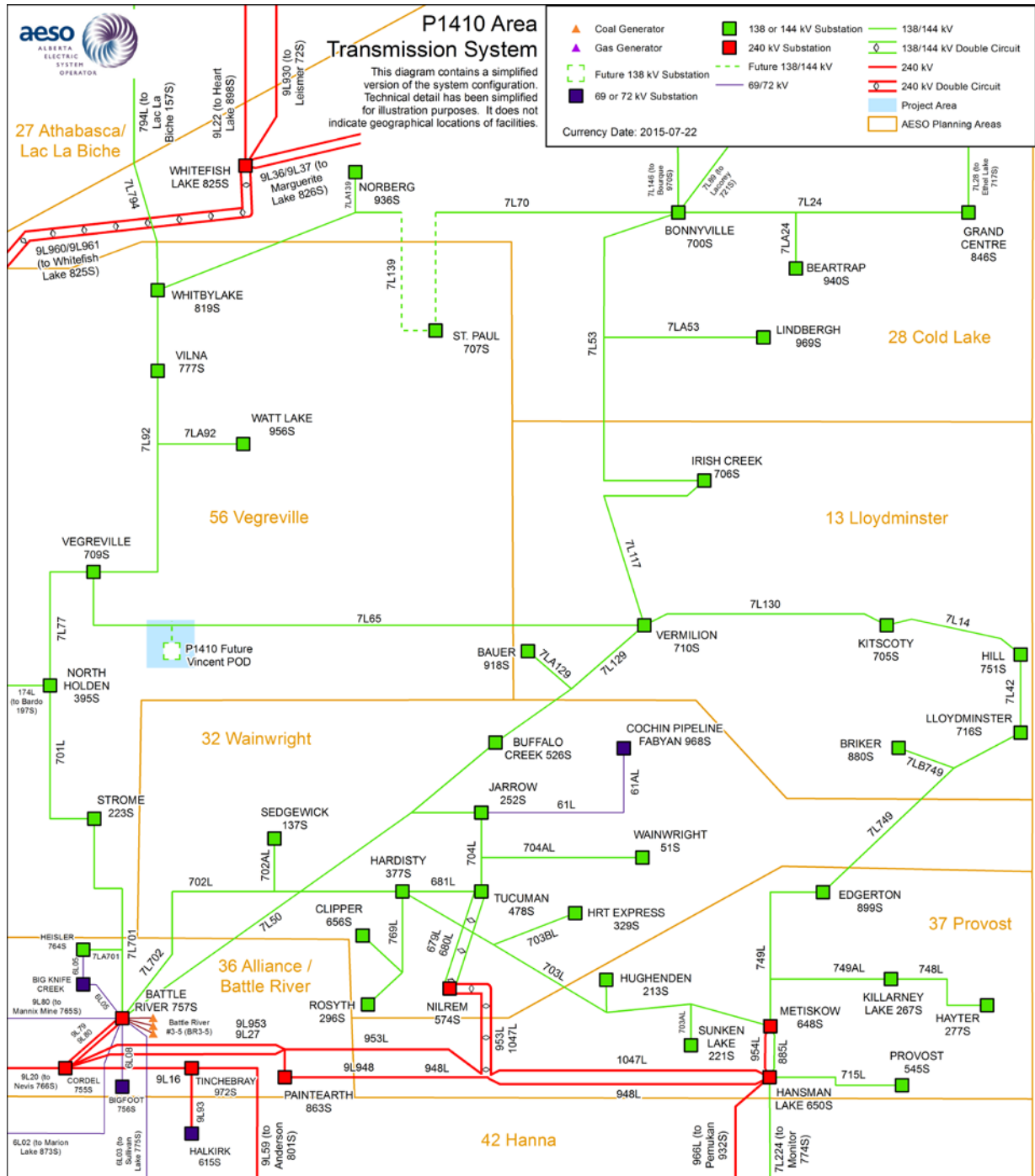
Vegreville 709S has two supply transformers: 701T and 702T. The 701T transformer is rated at 25/33/41.7 MVA 144-25 kV and is connected to the 501VR voltage regulator, rated at 25/33/41.6 MVA and is a normal supply source for the distribution system.

The 702T transformer is rated at 18.75/25/33 MVA 144/72 kV and is connected to the 72/25 kV 6/8 MVA transformers 603T and 604T. The 603T and 604T transformers are energized spares disconnected from the 25 kV bus that will be tied to the 25 kV bus if the 701T fails or is required to be isolated.

The CETD consists of several 138/144 kV enhancements in the Wainwright and Lloydminster areas to serve increasing load and generation, and 240 kV and 144 kV enhancements in the Cold Lake area to serve oil sands expansions. Some of the Stage 1 developments have been cancelled. The rest will be in service by Q3-2015. Please refer to Table 1-1.

Figure 1-1 shows the study area transmission network assumed in place for 2017 along with the proposed Project.

Figure 1-1: Study Area Transmission Network for 2017



### 1.2.2.2. Existing Constraints

There are no constraints that presently exist within the Vegreville area.

In the adjacent Alliance/Battle River area, thermal protection RASs exist on 7L50 and 7L701. Both of these will runback either Battle River units 3 or 4. The overload of 7L50 also trips 704L line which links Jarrow 252S to 7L50.

The Cold Lake area has a RAS in place to mitigate transmission line loading under certain contingencies. RASs are also in place within the Cold Lake area to shed load at CNRL Primrose and disconnect Cenovus Foster Creek from the AIES to prevent voltage collapse during critical contingencies. A brief description can be found in the Information Document (ID) for the Cold Lake Area Transmission Constraint Management (ID# 2012-015R).<sup>3</sup> Following the completion of the approved CETD, the need for these will be reviewed by the AESO and be removed if they are no longer required.

### 1.2.2.3. AESO Long-Term Plans

#### Existing AUC Approved Plans:

The CETD developments that are not already in service but due to be in service within the connection study timeframe are shown in Table 1-1.

**Table 1-1: Summary of Central East Transmission Developments Not Already In-Service**

Project	Project Name	ISD	Included in 2017SP	Included in 2017WP
811-4	St. Paul 707S & 7L139/7L70	April 2016	YES	YES
811-8	7L749 Replacement	Cancelled	NO	NO
811-22	Line Clearance Mitigation 7L14/7L130	Cancelled	NO	NO
811-23	Line Clearance Mitigations 7L53/7L117*	Cancelled	NO	NO
811-25	Bonnyville 700S Transformer addition	May-2016	YES	YES
811-30	Stage 2 of Central East 7L50 Buffalo Creek substation connection	Cancelled	NO	NO
811-40	Stage 2 of Central East Cold Lake Reinforcement 240kV, 2017	Canceled	NO	NO
811-14	Build new 415L from Wainwright to Edgerton	Cancelled	NO	NO
811-15	Rebuild 749L to service boundary	Canceled	NO	NO
811-17	Rebuild 704/704AL	Cancelled	NO	NO

\* Line 7L117 clearance mitigation was completed prior the cancelation; however, a CT restriction still exists limiting the rating for this line.

<sup>3</sup> Cold Lake Area Transmission Constraint Management (ID#2012-015R) document is available at: [http://www.aeso.ca/downloads/Cold\\_Lake\\_ID\\_2012-015R.pdf](http://www.aeso.ca/downloads/Cold_Lake_ID_2012-015R.pdf)

AESO 2013 Long-term Transmission Plan:

The AESO has reassessed the need for approved developments in the CETD as part of the regional plan assessments. The regional plan for Central East sub-region is part of published AESO 2013 Long-term Transmission Plan (LTP), and is shown in Table 1-2. The detailed development can be found in the Central Region Plan<sup>4</sup>. Since these developments have an ISD that is after the Project, they are not included in the study scenarios unless advanced to address connection project constraints. This will be presented within the project study scenarios if necessary.

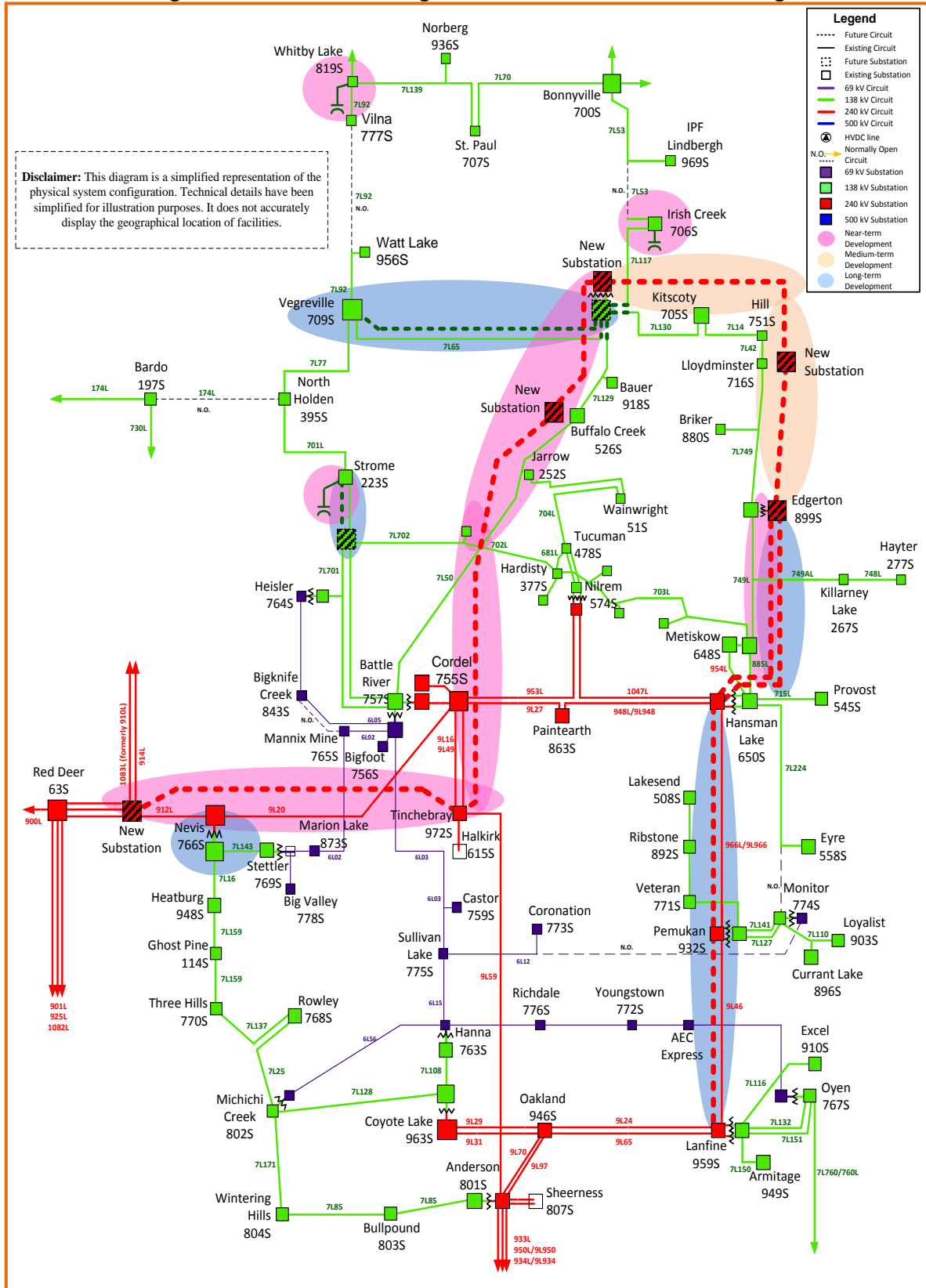
**Table 1-2: Summary of AESO 2013 LTP System Projects within the Study Area**

<b>Components</b>	<b>In Service Date (Anticipated)</b>
New Vermillion 240/138 kV Substation	2018
New 240 kV Rolette 2027S Substation	2018
New 240 kV Edgerton Substation	2018
240 kV line from Tinchebray 972S to Red Deer 63S	2018
240 kV line from Tinchebray 972S to Rolette	2018
240 kV line from Rolette 2027S to New Vermillion	2018
240 kV line from Hansman Lake 650S to new Edgerton	2018
2x25 MVar Reactor at new Vermillion 710S	2018
2x25 MVar Reactor at Tinchebray 972S	2018
2x25 MVar Reactor at Oakland 946S	2018
25 MVar Capacitor Bank at Irish Creek 706S	2018
25 MVar Capacitor Bank at Whitby Lake 819S	2018
25 MVar Capacitor Bank at Strome 223S	2018

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<sup>4</sup> AESO 2013 Long-term Transmission Plan is available at:  
[http://www.aeso.ca/downloads/Central\\_LRP\\_Report\\_11Apr2014\\_signed.pdf](http://www.aeso.ca/downloads/Central_LRP_Report_11Apr2014_signed.pdf)

Figure 1-2: AESO 2013 Long-term Plan for Central East Sub-Region



### 1.2.3. Studies Performed

The following studies were performed in the connection study:

1. Load flow (Category A, B, and selected C5) in all scenarios with the critical generator off.
2. Voltage stability analysis (Category A, B and selected C5) using the winter peak scenarios only with the critical generator off.
3. Short-circuit analysis using the pre- and post-connection winter peak scenarios plus the 2023 winter peak case with the critical generator on.

## 1.3. Report Overview

The Executive Summary provides a high-level summary of the report and its conclusions. Section 1 introduces the ATCO Heartland Pump Station Connection engineering study report. Section 2 describes the reliability criteria, system data, and other study assumptions used in this report. Section 3 describes the study methodology. Section 4 discusses the pre-connection assessment of the system. Section 5 presents the connection alternatives considered and studied. Section 6 provides a technical analysis of the connection alternative selected for further study. Section 7 provides the results of the short-circuit analysis. Section 8 discusses the project interdependencies. Section 9 presents a summary and conclusions of this study.

## 2. Criteria, System Data, and Study Assumptions

### 2.1. Criteria, Standards and Requirements

#### 2.1.1. AESO Transmission Reliability Criteria and Standards

The Alberta Reliability Standards and the AESO's *Transmission Planning Criteria – Basis and Assumptions* (Reliability Criteria) were applied in this study to assess the system performance following Category A (i.e., all elements in service) and Category B (i.e., one element out of service) contingencies. Below is a summary of Category A and Category B system conditions as well as a summary of Category C5 system conditions.

**Category A** represents a normal system with no contingencies and all facilities in service. This is often referred to as the N-0 condition, or with the most critical generator out of service, an N-G event. The system must be able to supply all firm load and firm transfers to other areas. All equipment must operate within its applicable rating, voltages must be within their applicable ratings and the system must be stable with no cascading outages.

**Category B** events result in the loss of any specified single system element under specified fault conditions and normal clearing. The specified elements are a generator, a transmission circuit, a transformer or a single pole of a DC transmission line. This is often referred to as an N-1 event, or with the most critical generator out of service, an N-G-1 event. The acceptable



impact on the system is the same as Category A. Planned or controlled interruptions of electric supply to radial customers or some local network customers, connected to or supplied by the faulted element or by the affected area, may occur in certain areas without impacting the overall reliability of the interconnected transmission systems. To prepare for the next contingency, system adjustments are permitted, including curtailments of contracted firm (non-recallable reserved) transmission service electric power transfers.

**Category C5** events results in loss of two circuits of a multiple circuit tower. All equipment must operate within its applicable rating, voltages must be within their applicable range, and the system must be stable with no cascading outages. For the Category C5, the controlled interruption of electric supply to customers (load shedding), the planned removal from service of certain generators, and/or the curtailment of contracted firm (non-recallable reserved) transmission service electric power transfers may be necessary to maintain the overall reliability of the interconnected transmission systems

The Alberta Reliability Standards include the Transmission Planning (TPL) standards that specify the desired system performance under different contingency categories with respect to the Applicable Ratings. The transmission system under various system conditions is defined in Appendix 1 of the TPL standards. For the purpose of applying the TPL standards to this study, the Applicable Ratings shall mean:

- Seasonal continuous thermal rating of the line’s loading limits.
- Highest specified loading limits for transformers.
- For Category A conditions: Voltage range under normal operating condition per AESO Information Document ID# 2010-007RS.
- For Category B conditions: the extreme voltage range values per Table 1-1 in the *Transmission Planning Criteria – Basis and Assumptions*.
- Acceptable post-contingency voltage change limits for three defined post event timeframes as provided in Table 2-1.

**Table 2-1: Acceptable Post Contingency Voltage Deviation**

Time Period	Post Transient (Up to 30 sec)	Post Auto Control (30 sec to 5 min)	Post manual Control (Steady State)
Voltage Deviation from Steady State at POD Low Voltage Bus	± 10%	± 7%	± 5%

**2.1.2. AESO Information documents (IDs), Operating Policies and Procedures (OPPs) and Authoritative Documents (ADs)**

ISO rules Section 304.4 ID #2010-007RS was used to set the system pre-contingency voltages at critical buses to be within the desired range. The ISO Rules Section 302.1 (Real Time Transmission Constraint Management) is currently applied to manage real time thermal violations on the transmission facilities.

## 2.2. Load and Generation Assumptions

### 2.2.1. Load Assumptions

The Vegreville area, Central Region and Alberta Interconnected Load (AIL) load forecasts presented in this report is shown in Table 2-2 and is from the AESO 2014 Long-term Outlook (2014 LTO).

The Vegreville area includes the project load; however, the remainder of load in the Central Region was scaled to match the load shown in the 2014 LTO for this region. For the pre-connection scenarios, the Project load was taken out of the total Vegreville area load; however, the total Central Region load level was kept at the level as specified in Table 2-2. Real to reactive power ratios represented in the study cases were maintained when developing the study scenarios.

**Table 2-2: Load Forecast (2014 LTO)**

Region Name and Season		Forecast Peak Load (MW)
		2017
Vegreville area (56)	SP	103
	WP	109
Central*	SP	1602
	WP	1847
AIL Without Losses	SP	11444
	WP	12795

\*The Central Region comprises of the following AESO planning areas: 56,13,32,37,36,42,35,39,38,30,29 and 34

### 2.2.2. Generation Assumptions

The existing non-wind generators and their dispatch levels in the study area are listed in Table 2-3. The low generation dispatch scenarios studied for this connection project have 0 MW of generation on by the wind turbines. The Battle River unit #5 is the critical generator and its status is off in all cases studied.

**Table 2-3: Summary of Existing Non-wind Generators in the Study area**

Generator	Bus	Fuel Type	Summer Peak 2017	Winter Peak 2017
<b>Area 36</b>				
Battle River #3	1495	Coal	144.7	144.7
Battle River #4	1496	Coal	151.8	151.8
Battle River #5	1497	Coal	0	0
<b>Area 28</b>				
Mahkeses #1	3248	Cogen	63.9	85.5
Mahkeses #2	2248	Cogen	63.9	85.5
Foster Creek #1	3301	Cogen	33.3	44.6
Foster Creek #2	3302	Cogen	33.4	44.6
Primrose	18302	Cogen	72.1	90.2
Nabiye #1	19351	Cogen	63.9	75.9
Nabiye #2	18351	Cogen	63.9	75.9

### 2.2.3. Intertie Flow Assumptions

The intertie flow between Alberta and WECC system will not impact this study and will be considered at zero import.

## 2.3. System Projects

All Stage 1 CETD sub-projects that have not been cancelled, are to be in service prior to this connection project and are included in all study scenarios. Please refer to Table 1-1. AESO 2013 LTP components identified in Table 1-2 are not included in the connection study scenarios.

## 2.4. Customer Connection Projects

The customer connection projects that are not already in service which are included in the connection study scenarios are shown in Table 2-4. Customer project ISDs are subject to change.

**Table 2-4: Customer Selected Projects**

Project	Project Name	ISD	Included in 2017SP	Included in 2017WP
1284	Nilrem 574S Expansion (formerly Lagstaff)	Dec. 2014	YES	YES
1349	Enbridge Queensland 301S Substation	May 2015	YES	YES

## 2.5. Facility Ratings and Shunt Elements

Table 2-5 provide the ratings of key transmission lines in the study area. The ratings are on a 138 kV and 240 kV system nominal voltage level.

**Table 2-5: Summary of Key Transmission Line Ratings in the Study Area (MVA using 138 kV base)**

Transmission Line	Summer (MVA)	Winter (MVA)
7L130 (Vermilion 710S to Kitscoty 705S)	72	86
7L14 (Hill 751S to Kitscoty 705S)	72	86
7L53 (Bonnyville 700S to Irish Creek 706S)	72	86
7L117 (Vermilion 710S to Irish Creek 706S)	95.6	95.6
701L (North Holden – Strome)	119	146
701L ( Strome – Heisler tap)	139.9	179.2
7L701(Battle River 757S- Heisler tap)	139.9	179.2
7L50 (Jarrow Tap – Battle River)	109.3	139.9
7L702 (Battle River – Sedgewick)	109.3	139.9
9L79 (Battle River – Cordel)	498	498
9L80 (Battle River – Cordel)	415	415
681L (Tucuman – Hardisty)	143	172
702L (Hardisty – Sedgewick)	112	118
704L (Tucuman – Wainwright)	85	90
953L (Nilrem – Hansman Lake)	499	549
1047L (Nilrem – Cordel)	499	499
7L65 (Vermilion – Vegreville)	94.9	94.9
7L77 (Vegreville – Holden)	109.3	139
174L (Holden to Bardo)	85	90
7L92 (Vegreville to Whitby Lake)	94.9	94.9
7L794 (Whitby Lake to Lac La Biche)	94	94
7L139 (Whitby Lake to St. Paul)	109.3	139
7L70 (Bonnyville to St. Paul)	109.3	139

\*7L117 clearance mitigation was completed prior to cancellation by the AESO; however, a CT ratio still restricts the flow on this line.

Table 2-6 provides the existing shunt elements that are relevant for this connection study. These shunt elements are switched on or off as required to maintain the voltage limits in the Reliability Criteria or ISO Rules Section 304.4 ID #2010-007RS.

**Table 2-6: Summary of Existing Shunt Elements in the Study Area**

Substation Name and Number	Nominal Bus Voltage (kV)	Capacitors			
		Number of Switched Shunt Blocks	Total at nominal voltage (MVar)	2017SP All Scenarios Status	2017WP All Scenarios Status
Hardisty 377S	138	1x27 1x44.9	71.9	27 ON	27 ON
Tucuman 478S	138	1x27.17	27.17	OFF	OFF
Battle River 757S	69	1x9.19	9.19	OFF	OFF
Buffalo Creek	138	1x15	15	ON	ON
Hill 751S	144	1x20 1x25	45	Both ON (45)	Both ON (45)
Lloydminster 716S	144	1x20	20	ON	ON
St. Paul 707S	25	3x2.4	7.2	All ON (7.2)	All ON (7.2)
Vermillion 710S	144	1x25	25	ON	ON

## 2.6. Voltage Profile Assumptions

Table 2-7 provides the ISO Rules Section 304.4 ID #2010-007RS requirements for voltages at the key buses in the study region. Bus voltages for buses not included in the ID #2010-007RS are covered by the Reliability Criteria. Comparing the 2017SP post connection voltages with 2017WP post connection shows reduced voltage profiles in and around the Project connection area. The voltage at Hill 751S substation in the post-connection is marginally below the desired range as well as at Bonnyville 700S in the post-connection 2017SP.

**Table 2-7: Key Bus Voltages in the Study Cases**

Substation	AESO ID# 2010-007RS				Voltage in the Study Case (kV)			
	Nominal Voltage (kV)	Minimum Operating Limit (kV)	Desired Range (kV)	Maximum Operating Limit (kV)	Pre-connection		Post-connection	
					2017SP	2017WP	2017SP	2017WP
Lloydminster 716S	144	137	142-149	151	144.7	143.7	142.8	142.9
Hill 751S	144	137	143-149	151	144.7	143.7	142.8	142.9
Bonnyville 700S	144	140	147-150	155	146.8	148.1	146.9	148
Leming Lake 715S	144	140	144-150	155	146.4	148.0	146.6	148
Whitefish Lake 825S	240	253	255-265	275	263.0	265.5	263.5	265.7
Marguerite Lake 826S	240	252	255-268	275	258.9	263.6	259.8	263.7
	144	141	148-151	155	150.1	150.7	150.9	150.7

Substation	AESO ID# 2010-007RS				Voltage in the Study Case (kV)			
	Nominal Voltage (kV)	Minimum Operating Limit (kV)	Desired Range (kV)	Maximum Operating Limit (kV)	Pre-connection		Post-connection	
					2017SP	2017WP	2017SP	2017WP
Hardisty 377S	138	140	140-144	145	142.3	141.9	142.6	142.4
Battle River 757S	144	144	146-150	155	148.5	148.9	148.3	148.8

### 3. Study Methodology

All the following analysis was completed using PTI PSS/E version 33.

#### 3.1. Study Objectives

The objectives of the study are as follows:

1. Assess the impact of the Project on the AIES.
2. Propose mitigation measures that will address any system performance concerns and will enable the reliable integration of the Project into the AIES.
3. Evaluate and recommend the Project connection alternative.

#### 3.2. Study Scenarios

The study cases were derived from the AESO's 2013 Planning Base Case Suite and related Auxiliary Data Files. The load and generation dispatches for the study years were provided by the AESO to adjust the load and generation in the base cases.

The study scenarios considered for the Project are outlined in Table 3-1. Given there are no topology changes considered in the Study Area between the 2017SP and 2018SP, the 2017SP was used for this connection study.

**Table 3-1: List of the Connection Study Scenarios**

Scenario	Study Cases for Alternatives Considered	Heartland pump station load, MW
1	2017SP – Pre-Project	0
2	2017WP – Pre-Project	0
3	2017SP – Post-Project	20
4	2017WP – Post-Project	20

### 3.3. Connection Studies Carried Out

The following studies were carried out for this connection study:

**Table 3-2: Summary of Studies Performed**

Study Cases	Studies Performed	Contingencies Included
All Scenarios	Load Flow	Category A, B, and C5
Scenario 2 and 4	Voltage Stability	Category A and B
Scenarios 2, 4 and 2023WP	Short-Circuit	Category A

### 3.4. Load Flow Analysis

Load flow analysis was completed on all study scenarios to identify any thermal or transmission voltage violations as per the AESO's TPL Standards.

Point of delivery (POD) low voltage bus deviations were also assessed by first locking all tap changers and area capacitors to identify any post transient voltage deviations above 10%. Tap changers were then allowed to move while capacitors remained locked to determine if any voltage deviations above 7% were found in the area. Once all taps and capacitor controls were allowed to adjust, voltage deviations above 5% were reported for both the pre-connection and post-connection networks.

#### 3.4.1. Contingencies Studied

The AESO's planning areas monitored for voltage and thermal violations during contingency analysis are shown in Table 3-3. The contingencies studied include all lines and transformers in the area as well as ties into the study area. Table 3-4 provides a list of selected Category C5 contingencies studied in all scenarios for this project.

**Table 3-3: Summary of Monitored Areas and Contingency Areas for Load Flow Analysis**

Area Number	Area Name	Voltage Range
56	Vegreville	69kV and above
13	Lloydminster	69kV and above
28	Cold Lake	69kV and above
31	Wetaskiwin	69kV and above
32	Wainwright	69kV and above
36	Alliance	69kV and above

**Table 3-4: Listing of Selected Category C5 Contingencies Studied for Load Flow Analysis**

Outage	From Substation	To Substation
9L36/9L37	Marguerite Lake 826S	Whitefish Lake 825S

Outage	From Substation	To Substation
948L/1047L	Hansman 650S /Cordel 755S	Nilrem 574S
679L/680L	Tucuman 478S	Nilrem 574S
803L/804L	Bigstone 86S	Wetaskiwin 40S

### 3.5. Voltage Stability (PV) Analysis

PV (Power-Voltage) analysis was performed according to the Western Electricity Coordinating Council (WECC) Voltage Stability Assessment Methodology. WECC voltage stability criteria states, “for load areas, post-transient voltage stability is required for the area modeled at a minimum of 105% of the reference load level for system normal conditions (Category A) and for single contingencies (Category B)”. For Category C5, the minimum criterion is 102.5% of the reference load level. For this standard, the reference load level is the maximum established planned load.

The voltage stability analysis was performed by increasing load in the Central Region using areas 13, 28, 31, 32, 36, and 56 while increasing the corresponding generation in the Wabamun area (Area 40) and Sheerness area (Area 43).

The objective of the PV curve is to determine the ability of the network to maintain voltage stability at all the busses in the system under normal and abnormal system conditions. The PV curve is a representation of voltage change as a result of increased power transfer between two systems. The reported incremental transfers will be to the collapse point. As per the AESO requirements, no assessment based upon other criteria such as minimum voltage will be made at the PV minimum transfer.

As per the voltage stability criteria, post transient techniques (all tap changers, all discrete capacitors locked, but SVCs were allowed to adjust) were used in applying the criteria and this information is reflected in all tables and graphs. Also for this analysis, no limits were selected for the generation sources, non-negative active power constant MVA loads was enforced and the existing power factor for the reference area was maintained.

#### 3.5.1. Contingencies Studied

The voltage stability analysis will consider the Category B contingencies in the Study Area. Transformer tap and switched shunt adjustments will be disabled in the voltage stability analysis.

### 3.6. Short-Circuit Analysis

The short-circuit analysis was performed prior to and following the project connection for the 2017WP and the 2023WP study case. For this analysis, the critical generator identified for this connection study was in-service. The short-circuit analysis includes three phase and single line to ground faults. Fault levels are provided for all of the buses at 2019S Vincent and adjacent substations in the form of currents in kilo amperes and per unit positive and zero sequence impedances.



## 4. Pre-Connection System Assessment

### 4.1. Pre-Connection Load Flow Analysis

The following is a summary of the pre-connection analysis for scenarios 1 and 2. No Category A condition or selected Category C5 contingency transmission criteria violations were noted. The following Category B analysis items were noted:

- 2017SP: Line flow above the emergency summer ratings on 7L130 (100.1%) occurs when 749L is out of service. This contingency causes 7L130 to radially feed the area load. Due to clearance restrictions on 7L130 and risk to public safety, no flow above the stated limits are permitted. However, this flow is marginally above the limit and will be managed using existing real time operational practices. It is noted that the voltage at Irish Creek 706S in the summer peak scenario is marginally above the minimum criteria with the loss of 7L53 at 130.6 kV
- 2017WP: The study area is a winter peaking area. In the winter peak scenario, the loss of 7L53 from Bonnyville 700S to Irish Creek 706S causes local low transmission voltage (124.2 kV) along with POD bus voltage deviations. This will also result in low POD bus voltages and load curtailment at Irish Creek 706S in the summer peak condition.

It is noted that Ethel Lake 717S has thermal violations on one 72-25 kV POD transformer when the parallel 72-25 kV POD transformer is out of service. This is caused by the substation configuration. Industrial load fed off this substation will be shed to manage this contingency. No further mention of this will be made in this report.

The voltage stability criteria margin is met for incremental power transfer in 2017WP pre-connection scenario 2. PV curves and load flow diagrams for Category A and Category B contingencies that exhibited criteria violations are included in Attachment A.

#### 4.1.1. Scenario 1: 2017SP Pre-Project

No criteria violations for the Category A condition were found. No thermal or voltage violations for the selected Category C5 contingencies were found.

No transmission voltage criteria violations for the Category B contingencies were found. Transmission line flows above the emergency summer rating (Rate A) were identified for the Category B contingency as shown in Table 4-1. 749L contingency leaves 7L130 to radially feed the area load which causes a slight overload on this line. Due to clearance restrictions on 7L130 and risk to public safety, no flow above the limit is permitted. However, this violation is marginal and will be managed using existing real time operational practices.

**Table 4-1: Scenario 1 – 2017SP Pre-Project N-G-1 Line Loadings Above Rate A**

Contingency	Limiting Branch	Line Rating Normal/ Emergency (MVA)*	Pre-Contingency		Post-Contingency		% Loading Difference
			Load Flow (MVA*)	% Loading	Load Flow (MVA*)	% Loading	
749L (Metiskow 267S – Edgerton 899S)	7L130 (Vermillion 710S- Kitscoty 705S)	72 / 72	53.3	74	72.1	100.1	26.1

\*MVA using 138 kV base.

#### 4.1.2. Scenario 2: 2017WP Pre-Project

No criteria violations for the Category A condition were found. No thermal violations for the Category B or selected Category C5 contingencies were found.

For the 7L53 Category B contingency, POD bus voltage deviations and transmission voltage criteria violations were identified at Irish Creek 706S as shown in Table 4-2.

**Table 4-2: Scenario 2 – 2017WP Pre-Project N-G-1 Voltage Violations and POD bus Deviations**

Contingency	Substation Name and Number	Bus No.	Base kV	Initial Voltage (kV)	Voltage Deviations are for POD Busses Only				Post Manual (kV)	% Change for POD busses only
					Post Transient (kV)	% Change	Post Auto (kV)	% Change		
7L53 (Bonnyville 700S to Irish Creek 706S)	Irish Creek 706S	1377	144	139	N/A				124.2	--
		18377	25	26	23	11.9	23.6	9.5	23.6	9.5
		19377	25	26.2	23.1	12.3	23.7	10	23.7	10

## 4.2. Voltage Stability Analysis

### 4.2.1. Scenario 2: 2017WP Pre-Project

The voltage stability analysis was completed for pre-connection 2017 winter peak scenario 2.

In the 2017WP case without the Project addition, the reference load level for the Study Area is 1062 MW. The minimum incremental load transfer for Category B contingencies is 5% of the reference load or 53.1 MW to meet the voltage stability criteria ( $0.05 \times 1062 = 53.1$ ). The voltage stability analysis results show that in 2017WP pre-connection there were no Category B voltage stability issues in the study area. The worst contingencies are shown in Table 4-3 to illustrate no Category B contingency transfer criteria violation exists in this scenario.

**Table 4-3: Scenario 2 – 2017WP Pre-Project: PV Analysis Results (Min Transfer = 53.1 MW)**

Contingency	From	To	Maximum incremental transfer (MW)	Meets 105% transfer criteria?
N-G	System Normal		346.9	Yes
749L	Metiskow 648S	Edgerton 899S	183.8	Yes
7L95	Loss of Mahkeses plant (two generators)		195	Yes
7L117	Vermilion 710S	Irish Creek 706S	195	Yes
	Primrose Generator		218.1	Yes
7L86	Wolf Lake 822S	Foster Creek 877S	221.9	Yes
7L50	Battle River 757S	Buffalo Creek 526S	226.9	Yes

\*For information, the loss of 7L53 results in an incremental transfer of 287.5 MW and passes the PV criteria.

The PV curves for 749L, 7L95, 7L117 and 7L50 contingencies in the study area for the pre-connection scenario 2 are included in Attachment A.

## 5. Connection Alternatives

### 5.1. Overview

Two connection alternatives were identified for this Project:

**Alternative 1:** Upgrade the Vegreville 709S substation with dedicated 25 kV distribution feeders to serve the Customer load located approximately 25 km southeast of this substation.

**Alternative 2:** Build a new pump station POD substation, Vincent 2019S, located adjacent to the Customer facility and connect it to the 144 kV transmission line 7L65.

### 5.2. Connection Alternatives Identified

The following transmission alternatives were identified to accommodate the Facilities load in the Vegreville area.

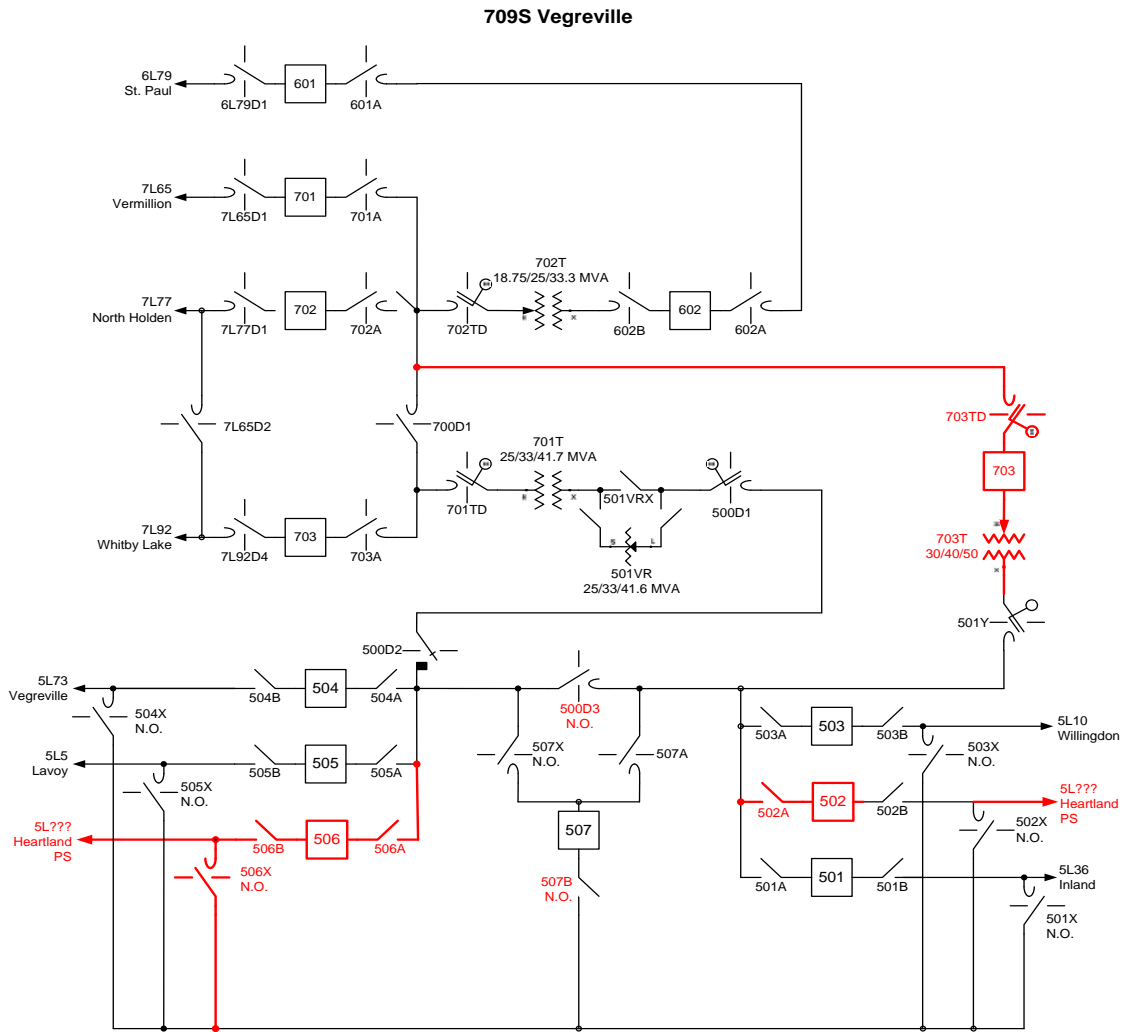
#### **Alternative 1: Upgrade the Vegreville 709S substation and 25kV feeders**

Add a new 30/40/50 MVA LTC transformer at Vegreville 709S substation and two 25kV feeders from Vegreville 709S substation to the new Heartland pump station.

#### Transmission scope of work:

- Install one 144 kV transformer circuit breaker complete with (c/w) 144 kV motor operated gang switch.
- Install one 30/40/50 MVA, 144 to 25 kV, LTC transformer c/w motorized low side disconnect switch.
- Install two 25 kV outdoor circuit breakers and associated equipment.

Figure 5-1: Alternative 1: Vegreville 709S substation capacity upgrade and 25kV feeders



**Alternative 2: Build a new pump station POD substation**

T-tap transmission line 7L65 to connect a new POD substation. <sup>5</sup> Build a new POD substation, consisting of a 144/6.9kV 20/26.6/33.3 MVA LTC transformer and 6.9 kV breaker, near the new customer’s pump station location.

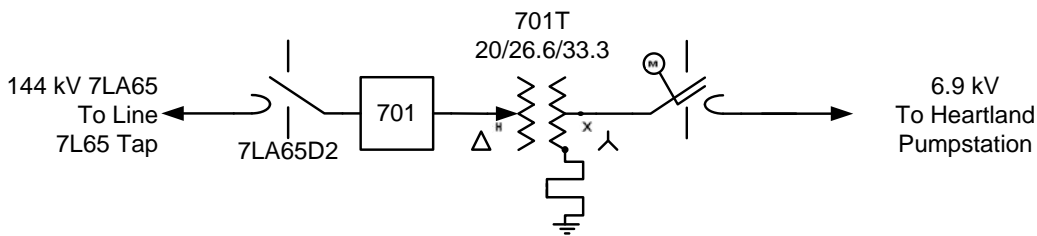
Transmission scope of work:

- Tap line 7L65 and build 0.15 km of 144 kV line.
- Install three 144 kV gang switches.
- Install one 144 kV transformer circuit breaker c/w 144 kV gang switch.
- Install one 20/26.6/33.3 MVA, 144 to 6.9 kV LTC transformer.

<sup>5</sup> The ultimate configuration for this substation will be an in-and-out connection on 7L65 required in the event that another connection is required on this transmission line.

Figure 5-2: Alternative 2: New Pump Station Substation Vincent 2019S

2019S Vincent  
Substation



5.2.1. Connection Alternatives Selected for Further Studies

Alternative 2 was selected for further study.

5.2.2. Connection Alternatives Not Selected for Further Studies

Alternative 1 was further assessed by the DFO to ensure the power quality standards would be met. A piece of key information for this assessment is that the load center is 25 km away from the nearest substation, Vegreville 709S. Due to the distance and future load expansion for this customer, two sets of distribution regulators would be required per feeder. During load rejection, over voltages above the criteria would occur. This combined with the high losses and the distance to the load center has eliminated this alternative from future consideration

6. Technical Analysis of the Connection Alternative

Only Alternative 2 will be discussed further in the remainder of this report.

6.1. Summary

The following is a summary of the post-connection analysis for scenarios 3 and 4.

No Category A condition or selected Category C5 contingency transmission criteria violations were noted. The following Category B analysis items were noted:

- 2017SP: As identified in the pre-connection summer peak scenario, maximum line flow limits for the summer ratings on 7L130 (100%) occurs when 749L is out of service. This flow will be managed using real time operational practices.
- 2017SP and 2017WP: As found in the pre-connection winter peak scenario, the loss of 7L53 from Bonnyville 700S to Irish Creek 706S causes local low transmission voltage along with POD bus voltage deviations in both the post-connection summer and winter peak scenarios.
- 2017WP: In the post-connection winter peak scenario, an additional line loading marginally above the emergency line rating on 7L53 was identified with the loss of 7L50. This will be managed using real time operational practices.

The voltage stability criteria margin is met for incremental power transfer in the 2017WP post-connection scenario 4.

Load flow plots for Category A and Category B contingencies that exhibited criteria violations are included in Attachment B.

### 6.1.1. Load Flow Analysis

#### 6.1.1.1. Scenario 3: 2017SP Post-Project

No criteria violations for the Category A condition were found. No thermal or voltage violations for the selected Category C5 contingencies were found.

For the 7L53 Category B contingency, POD bus voltage deviations and transmission voltage criteria violations were identified at the Irish Creek 706S substation as shown in Table 6-1.

Transmission line flow to the emergency summer rating (Rate A) limit on 7L130 was noted for the 749L Category B contingency as identified in Table 6-2. This contingency causes 7L130 to radially feed the area load, and connection of the project does not contribute to this loading.

**Table 6-1: Scenario 3 – 2017SP Post-Project N-G-1 Voltage Violations and POD bus Deviations**

Contingency	Substation Name and Number	Bus No.	Base kV	Initial Voltage (kV)	Voltage Deviations are for POD Busses Only				Post Manual (kV)	% Change for POD busses only
					Post Transient (kV)	% Change	Post Auto (kV)	% Change		
7L53 (Bonnyville 700S to Irish Creek 706S)	Irish Creek 706S	1377	144	139.2	N/A				128*	--
		18377	25	25.9	--	--	--	--	24.6	5.3
		19377	25	26	--	--	--	--	24.8	4.7

\*For reference, in the pre-connection Irish Creek 706S voltage is marginally above the minimum criteria at 130.6 kV for this contingency.

**Table 6-2: Scenario 3 – 2017SP Post-Project N-G-1 Line Loadings Above Rate A**

Contingency	Limiting Branch	Line Rating Normal/Emergency (MVA)*	Pre-Connection		Post-Connection		% Loading Difference
			Load Flow (MVA*)	% Loading	Load Flow (MVA*)	% Loading	
749L (Metiskow 267S – Edgerton 899S)	7L130 (Vermilion 710S- Kitscoty 705S)	72 / 72	42.1	100.1	72	100	-0.1

\*MVA using 138 kV base.

In addition, load flow studies using the ultimate Vincent 2019S in-and-out configuration showed no additional thermal or voltage violations.

#### 6.1.1.2. Scenario 4: 2017WP Post-Project

No criteria violations for the Category A condition were found. No thermal or voltage violations for the selected Category C5 contingencies were found.

Similar to Pre-Project 2017WP scenario, for the 7L53 Category B contingency, POD bus voltage deviations and transmission voltage criteria violations were identified at the Irish Creek 706S substation as shown in Table 6-3.

A transmission line flow marginally above the emergency winter rating limit was noted on 7L53 for the 7L50 Category B contingency as identified in Table 6-4. This will be managed using real time operational practices.

**Table 6-3: Scenario 4 – 2017WP Post-Project N-G-1 Voltage Violations and POD bus Deviations**

Contingency	Substation Name and Number	Bus No.	Base kV	Initial Voltage (kV)	Voltage Deviations are for POD Busses Only				Post Manual (kV)	% Change for POD busses only
					Post Transient (kV)	% Change	Post Auto (kV)	% Change		
7L53 (Bonnyville 700S to Irish Creek 706S)	Irish Creek 706S	1377	144	138.1	N/A				122.3*	--
		18377	25	26.2	22.9	13	23.5	11.7	23.2	11.7
		19377	25	26.1	22.7	13.3	23.3	11	23.3	11

\*For reference, in the pre-connection Irish Creek 706S voltage is 124.2 kV for this contingency.

**Table 6-4: Scenario 4 – 2017WP Post-Project N-G-1 Line Loading Above Rate B**

Contingency	Limiting Branch	Line Rating Normal/Emergency (MVA)*	Pre-Connection		Post-Connection		% Loading Difference
			Load Flow (MVA*)	% Loading	Load Flow (MVA*)	% Loading	
7L50 (Battle River 757S to Buffalo Creek 526S)	7L53 (Bonnyville 700S to Irish Creek 706S)	86 / 86	82.4	95.8	86.3	100.3	4.5

\*MVA using 138 kV base.

In addition, load flow studies using the ultimate Vincent 2019S in-and-out configuration showed no additional thermal or voltage violations.

## 6.1.2. Voltage Stability Analysis

### 6.1.2.1. Scenario 4: 2017WP Post-Project

In the 2017WP case with the Project, the reference load level for the Study Area is 1078.6 MW. The minimum incremental load transfer for Category B contingencies is 5% of the reference load or 53.9 MW to meet the voltage stability criteria ( $0.05 \times 1078.6 = 53.9$ ).

The voltage stability analysis results show that for the 2017WP post-connection there were no Category B voltage stability issues in the study area. The worst contingencies are shown in Table 6-5 to illustrate no Category B contingency transfer criteria violation exists in this scenario. In addition, voltage stability analysis using the ultimate Vincent 2019S in-and-out configuration showed no additional voltage stability issue.

**Table 6-5: Scenario 6 – 2017WP Post-Project: PV Analysis Results (Min Transfer = 53.9 MW)**

Contingency	From	To	Maximum incremental transfer (MW)	Meets 105% transfer criteria?
N-G	System Normal		341.3	Yes
749L	Edgerton 899S	Metiskow 648S	165	Yes
7L95	Leming Lake 715S	Mahkeses 889S	190.6	Yes
7L50	Battle River 757S	Buffalo Creek 526S	195.6	Yes
7L117	Vermilion 710S	Irish Creek 706S	196.9	Yes
	Primrose Generator		213.8	Yes
7L86	Wolf Lake 822S	Foster Creek 877S	217.5	Yes

\*For information, the loss of 7L53 results in an incremental transfer of 269.4 MW and passes the PV criteria.

The PV curves for 749L, 7L95, 7L50 and 7L117 contingencies in the study area for the post-connection 2017 WP are included in Attachment B.

### 6.1.3. Sensitivity Study: Inclusion of the Irish Creek Capacitor

The AESO 2013LTP identified the need for a 144 kV 25 MVAR capacitor at the Irish Creek 706S substation. Load flow analysis was completed using the post-connection 2017SP and 2017WP scenarios including the 144 kV 25 MVAR capacitor at Irish Creek 706S to ensure this system reinforcement would mitigate the criteria violations identified.

With the 25 MVAR 144 kV Irish Creek 706S capacitor included in the 2017SP and 2017WP post-connection scenarios, no Category A, Category B or selected Category C5 criteria violations were noted. Please refer to Attachment C for load flow plots with the Irish Creek 706S capacitor included.

### 6.1.4. Mitigation Measures for Identified Issues

In the pre-connection 2017WP, it was identified that with the loss of 7L53 from Bonnyville 700S to Irish Creek 706S, local transmission voltage criteria violations and POD bus deviations will occur at Irish Creek 706S substation. With the project load addition in the area, the voltage profile for this contingency is degraded further depressing the Irish Creek 706S transmission bus voltage in the winter peak and causing transmission voltage violations as well in the summer peak scenario.

Line loading on 7L130 from Vermilion 710S to Kitscoty 705S are at, or marginally above the emergency rating with the loss of 749L from Metiskow 648S to Edgerton 899S both pre- and post-connection in the summer scenarios. The Project does not impact this line loading. Due to the marginal overload level identified (0.1%); this will be managed in real time with existing system operating practices. The post-connection additional flow 0.3% above the emergency ratings on 7L53 for the loss of 7L50 will also be managed using existing real operational practices.

The AESO 2013LTP system projects for this study area were identified in Table 1-2. Sensitivity testing in the post-connection 2017SP and 2017WP cases with the Irish Creek 706S 25 MVAR capacitor included mitigated all criteria voltage and line loadings above emergency ratings identified. Hence, to mitigate the criteria violations noted it is



recommended that the 25 MVAR 144 kV capacitor at Irish Creek 706S be installed prior to this project ISD.

## 7. Short-Circuit Analysis

The short-circuit analysis was performed for Alternative 2 for the winter peak scenarios as specified in Table 3-2. The critical generator was turned on. No wind was dispatched. The 2023 winter peak study case is used for the long-term short-circuit outlook.

### 7.1. Pre-Connection

Table 7-1 provides the 2017WP short-circuit levels without the project addition.

**Table 7-1: Summary of Short-Circuit Current Levels – 2017WP Pre-Connection**

Substation	Base Voltage (kV)	Pre-fault Voltage (kV)	3-Φ Fault (kA)	Positive Sequence Thevenin Source Impedance (R1+jX1) (p.u.) <sup>1</sup>	1-Φ Fault (kA)	Zero Sequence Thevenin Source Impedance (R0+jX0) (p.u.) <sup>1</sup>
Vermilion 710S	144	142.01	3.93	0.054788+j0.094952	4.49	0.007664+j0.072558
Vegreville 709S	144	139.83	3.82	0.049236+j0.09952	2.47	0.057928+j0.292088
Holden 395S	138	140.51	4.49	0.038727+j0.086677	2.73	0.064655+j0.272958

Note 1: pu calculated using 138 kV voltage and 100 MVA

### 7.2. Post-Connection

Table 7-2 and Table 7-3 provide the 2017WP and 2023WP short-circuit levels with the project addition.

It should be noted that the short-circuit information provided for the 2017WP was completed with the AESO 2013 LTP 25 MVAR 144 kV capacitor at Irish Creek 706S.

**Table 7-2: Summary of Short-Circuit Current Levels – 2017WP Post-Connection (Alternative 2)**

Substation	Base Voltage (kV)	Pre-fault Voltage (kV)	3-Φ Fault (kA)	Positive Sequence Thevenin Source Impedance (R1+jX1) (p.u.) <sup>1</sup>	1-Φ Fault (kA)	Zero Sequence Thevenin Source Impedance (R0+jX0) (p.u.) <sup>1</sup>
Vermilion 710S	144	142.02	4.12	0.050554+j0.091474	4.72	0.007816+j0.068259
Vegreville 709S	144	138.88	3.86	0.049206+j0.097341	2.86	0.048344+j0.221825
Holden 395S	138	139.98	4.53	0.038392+j0.085535	2.88	0.06199+j0.248831
Vincent 2019S	144	138.57	3.22	0.059179+j0.116195	2.28	0.070508+j0.286943
Vincent 2019S	6.9	7.19	19.56	0.117119+j0.43048	0.41	63.034889+j0.32585

Note 1: pu calculated using 138kV or 69 kV voltage and 100 MVA

**Table 7-3: Summary of Short-Circuit Current Levels – 2023WP Post-Connection (Alternative 2)**

Substation	Base Voltage (kV)	Pre-fault Voltage (kV)	3-Φ Fault (kA)	Positive Sequence Thevenin Source Impedance (R1+jX1) (p.u.) <sup>1</sup>	1-Φ Fault (kA)	Zero Sequence Thevenin Source Impedance (R0+jX0) (p.u.) <sup>1</sup>
Vermilion 710S	144	140.85	4.21	0.046489+j0.090009	4.53	0.00777+j0.079438
Vegreville 709S	144	137.92	4.23	0.045229+j0.087807	2.49	0.077685+j0.299307
Holden 395S	138	140.37	4.65	0.038113+j0.083113	2.72	0.072742+j0.277847
Vincent 2019S	144	137.54	3.40	0.055673+j0.109314	2.11	0.088391+j0.337286
Vincent 2019S	6.9	7.18	19.81	0.113495+j0.424786	0.41	63.034889+j0.32585

Note 1: pu calculated using 138kV or 6.9 kV voltage and 100 MVA

## 8. Project Interdependencies

Transmission voltage criteria violations identified both pre- and post-connection indicate the need for the Irish Creek 706S capacitor addition, as identified in the 2013LTP, prior to the 2017WP.

## 9. Summary and Conclusion

ATCO Electric as the DFO in the Vegreville area was approached by TransCanada PipeLines Limited to provide supply to their Heartland pump station Facilities to be located at LSD 31SEC-50 TWP-13 REG-W4 which is within the Vegreville area. The Facilities consists of 20 MW load (based upon 4x6500 hp motors running with 1x6500 hp installed spare) with an ISD of November 2017.

Two transmission alternatives were identified to supply the new load. Alternative 1 is to add a new 30/40/50 MVA LTC transformer at Vegreville 709S substation and supply the new facilities using two 25 kV feeders. The load centre is approximately 25 km from the Vegreville 709S substation and will require multiple distribution regulators to maintain the voltage profile. Analysis by the DFO determined that this alternative would not meet the power quality standard due to high voltages during load rejection and due to high feeder losses. This alternative was, therefore, rejected.

Alternative 2 is to build a new pump station POD substation (Vincent 2019S) and connect it to transmission line 7L65 using a T-tap. The new Vincent 2019S substation will include a 144/6.9 kV 20/26/33.3 MVA LTC transformer.

Load flow analysis was performed for the 2017SP and 2017WP cases to assess the impact of the Project and its associated load on the AIES. Voltage stability analysis was completed for the winter peak scenarios. Short-circuit analysis was also performed for the winter scenarios, in addition to the 2023WP case to determine the short-circuit levels in the vicinity of the Vincent 2019S substation.

There were no voltage stability criteria violations identified for the Category A or Category B contingencies studied.

The following is a summary of the load flow analysis findings:

### Pre- Connection scenarios:

#### 2017SP

- No Category A condition violations were identified.

#### *Category B and C5 Contingencies*

- The loss of the 138 kV line 749L from Metiskow 648S to Edgerton 899S causes a marginal thermal violation on the 144 kV line 7L130 between Vermilion 710S and Kitscoty 705S. This line has clearance issues and continuous flow above the stated ratings cannot be sustained; however, since loading is less than 100.5% this will be managed by real time operational practices.

#### 2017WP

- No Category A condition violations were identified.

#### *Category B and C5 Contingencies*

- The loss of the 144 kV line 7L53 from Bonnyville 700S to Irish Creek 706S causes a transmission low voltage criteria violation (124.2 kV) and POD bus deviations at Irish Creek 706S.

Post-Connection scenarios:

2017SP

- No Category A condition violations were identified.

*Category B and C5 Contingencies*

- Similar to the pre-connection 2017SP scenario, the loss of the 138 kV line 749L from Metiskow 648S to Edgerton 899S causes a marginal thermal violation on the 144 kV line 7L130 between Vermilion 710S and Kitscoty 705S.
- The loss of the 144 kV line 7L53 from Bonnyville 700S to Irish Creek 706S causes a transmission low voltage criteria violation (128 kV) at Irish Creek 706S.

2017WP

- No Category A condition violations were identified.

*Category B and C5 Contingencies*

- The loss of the 144 kV line 7L50 from Battle River 757S to Buffalo Creek 726S causes thermal violations above the emergency winter rating (Rate B) on the 144 kV line 7L53 from Bonnyville 700S to Irish Creek 706S. This line has clearance issues and continuous flow above the stated ratings cannot be sustained; however, since loading is less than 100.5% this will be managed by real time operational practices.
- The loss of the 144 kV line 7L53 from Bonnyville 700S to Irish Creek 706S causes a transmission low voltage criteria violation (122.3 kV) and POD bus deviations at Irish Creek 706S, similar to those noted in the pre-connection 2017WP but with increased magnitude.

The Project connection does not contribute to the short-circuit level in the adjacent substations.

Mitigation Strategy and Sensitivity Analysis:

With the inclusion of a 25 MVAR 144 kV capacitor at Irish Creek 706S, as identified in the AESO 2013LTP,<sup>6</sup> all voltage and thermal violations identified in the load flow analysis are mitigated.

The recommended alternative to connect the Facilities is Alternative 2, building the new 144/6.9 kV POD substation Vincent 2019S. The Project will include:

- Tapping the 144 kV line 7L65 and building 0.15 km of 144 kV line to connect the new Vincent 2019S POD substation.
- Installing one 20/26.6/33.3 MVA, 144 to 6.9 kV LTC transformer, one 144 kV transformer breaker, and associated equipment.

The 25 MVAR 144 kV capacitor at Irish Creek 706S, as identified in the 2103LTP, is required prior to the Project ISD, since the inclusion of this capacitor bank mitigates all criteria violations noted in the pre- and post-connection results.

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<sup>6</sup> The Central Region portion of the AESO 2013 Long-term plan, which includes this study area, can be found on the AESO website at: <http://www.aeso.ca/transmission/30379.html>

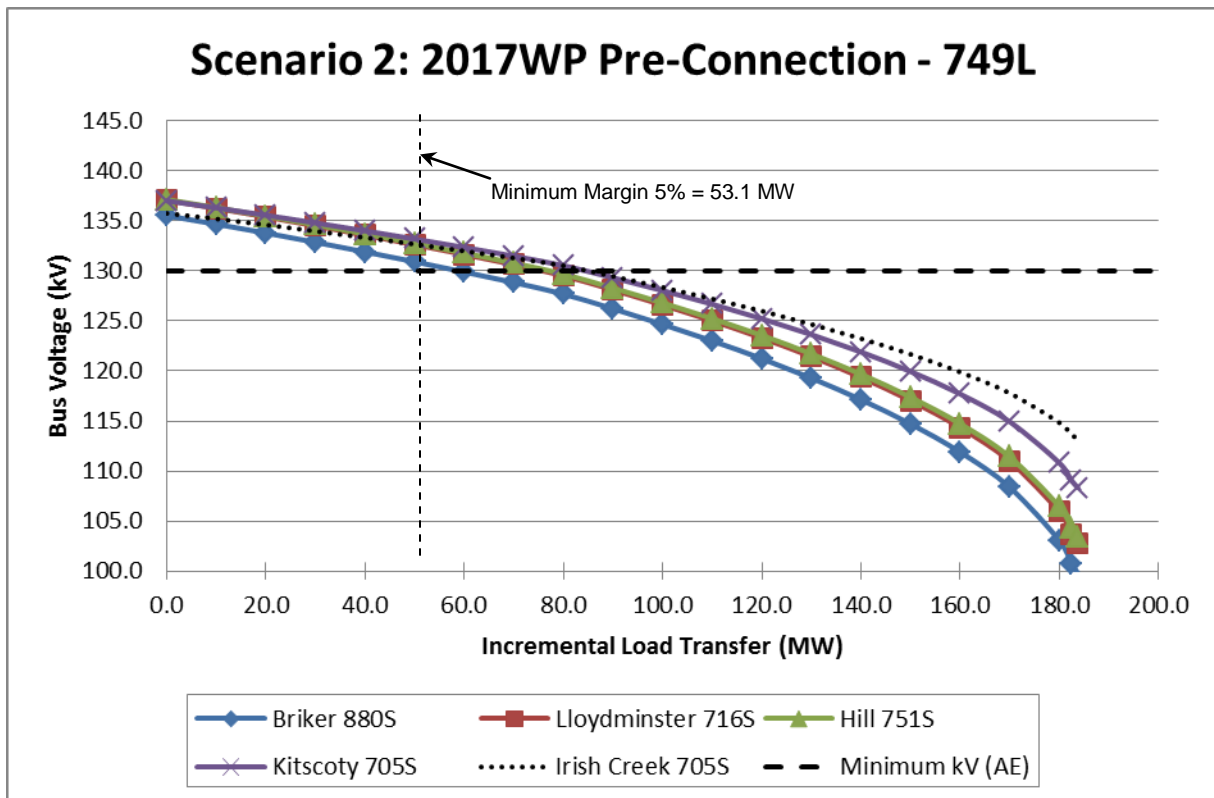
**ATTACHMENT A**  
**Pre-Connection PV Curves**  
**and Load Flow Plots**

# A-1 Pre-Connection System Voltage Stability Analysis Results

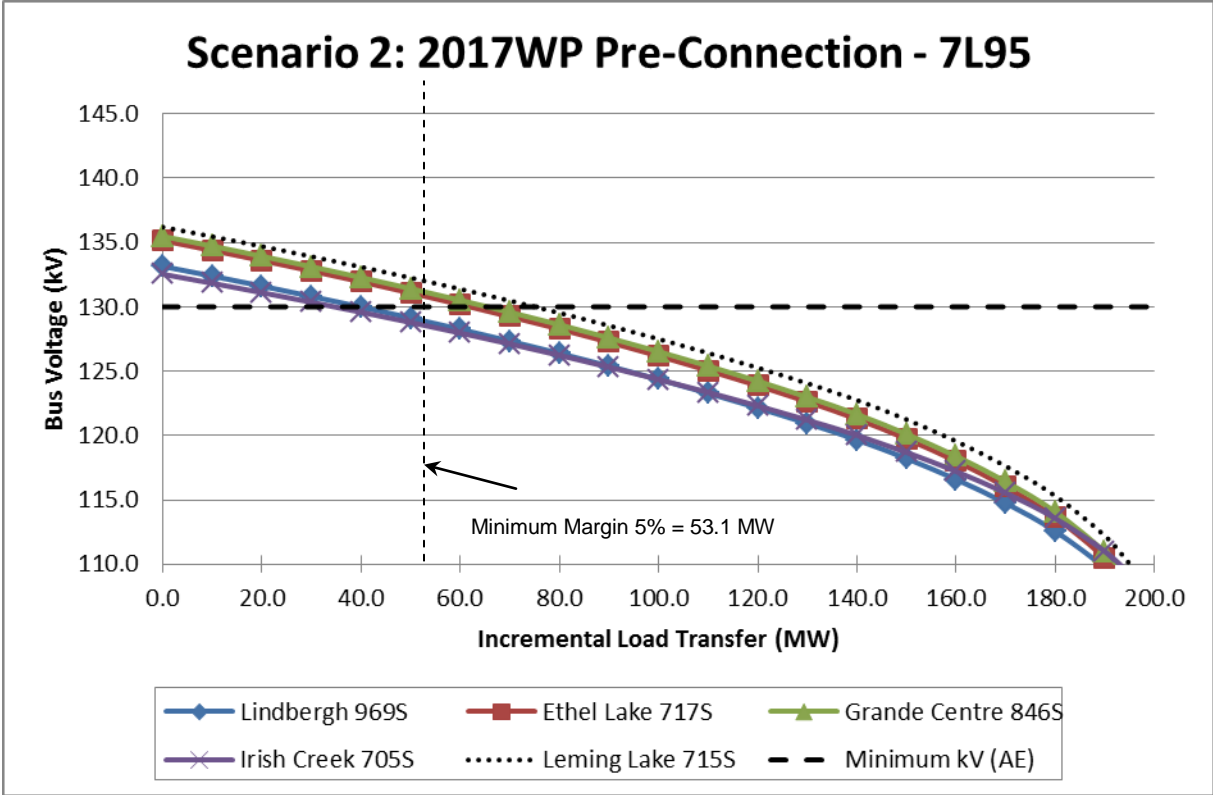
## Scenario 2: 2017WP Pre-Connection

Figure A-1 shows the P-V curves for 749L, 7L95, 7L117, and 7L50 contingencies in the pre-connection scenario 2, 2017WP. The worst Cold Lake area 28 contingency from the PV table in Section 4.2.1 was selected to be represented as well as the worst contingencies for PV margin in the rest of the study area.

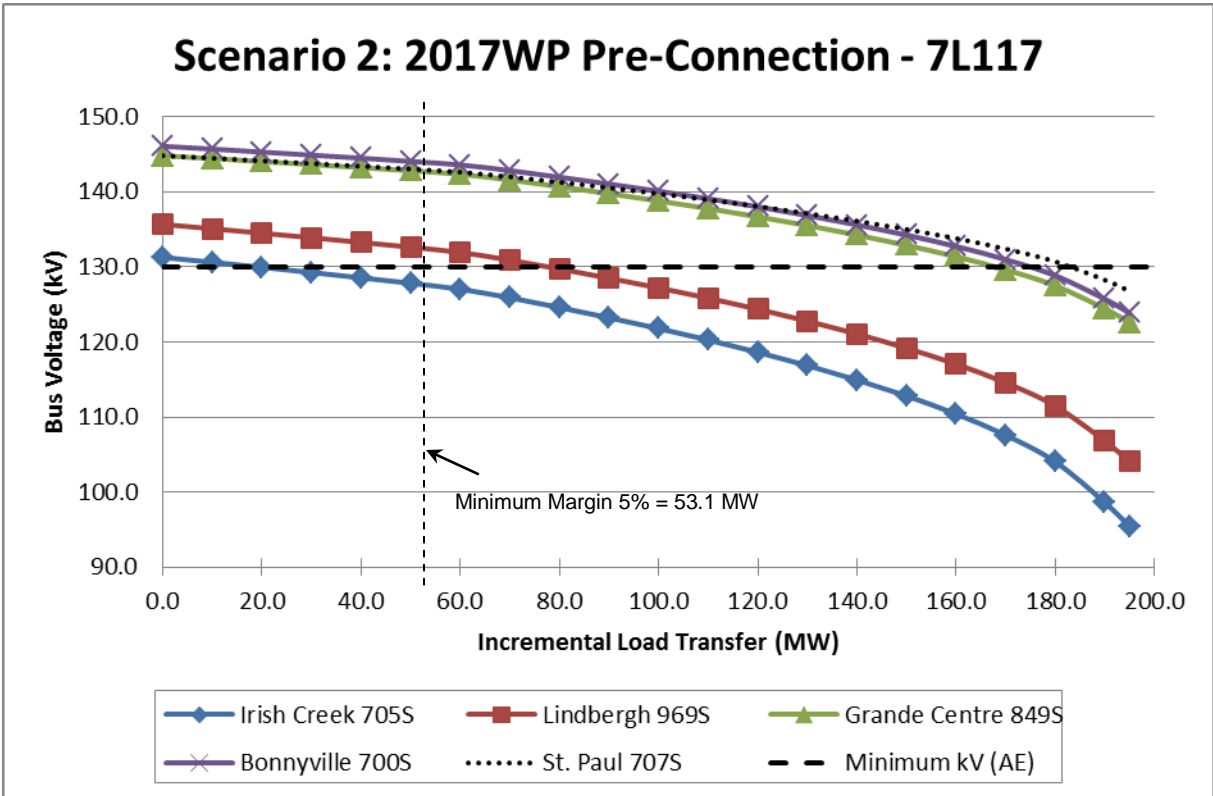
Figure A-1: Category B (N-G-1) P-V Curves for 2017WP Pre-Connection



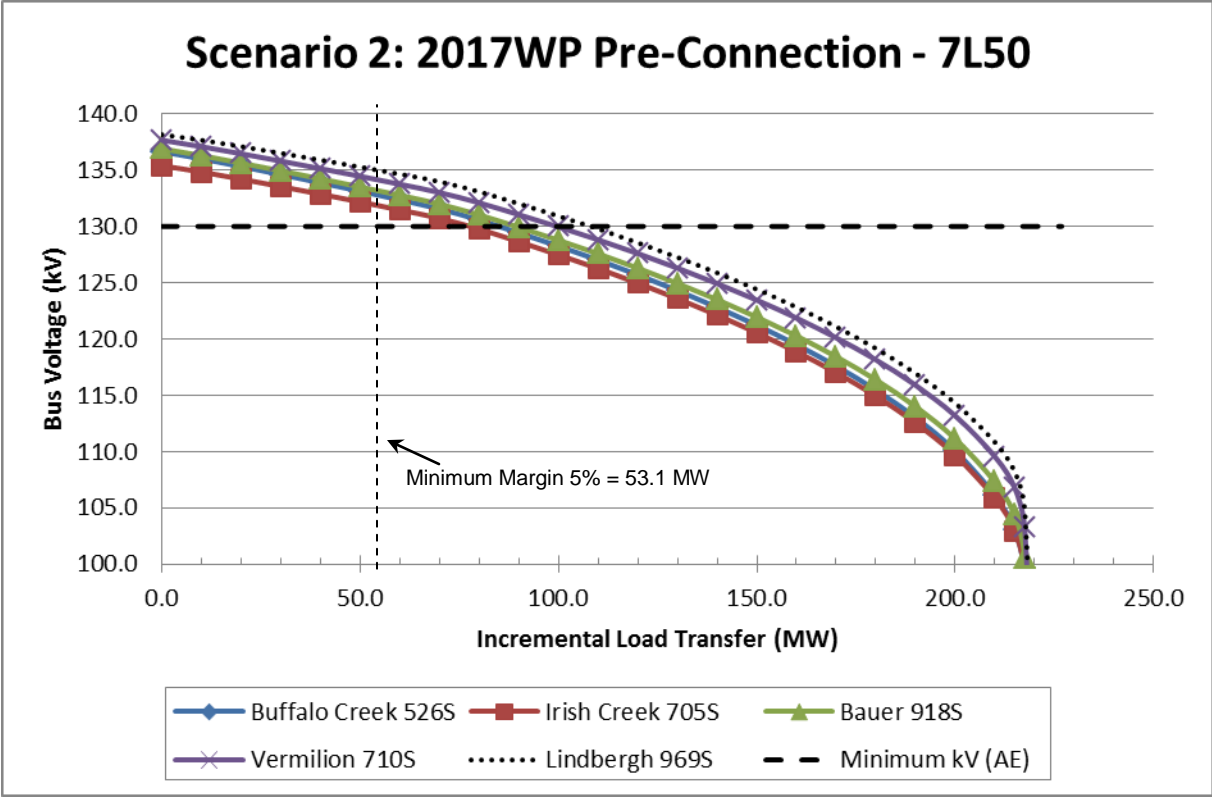
(a) 749L Contingency



(b) 7L95 Contingency



(c) 7L117 Contingency



(d) 7L50 Contingency



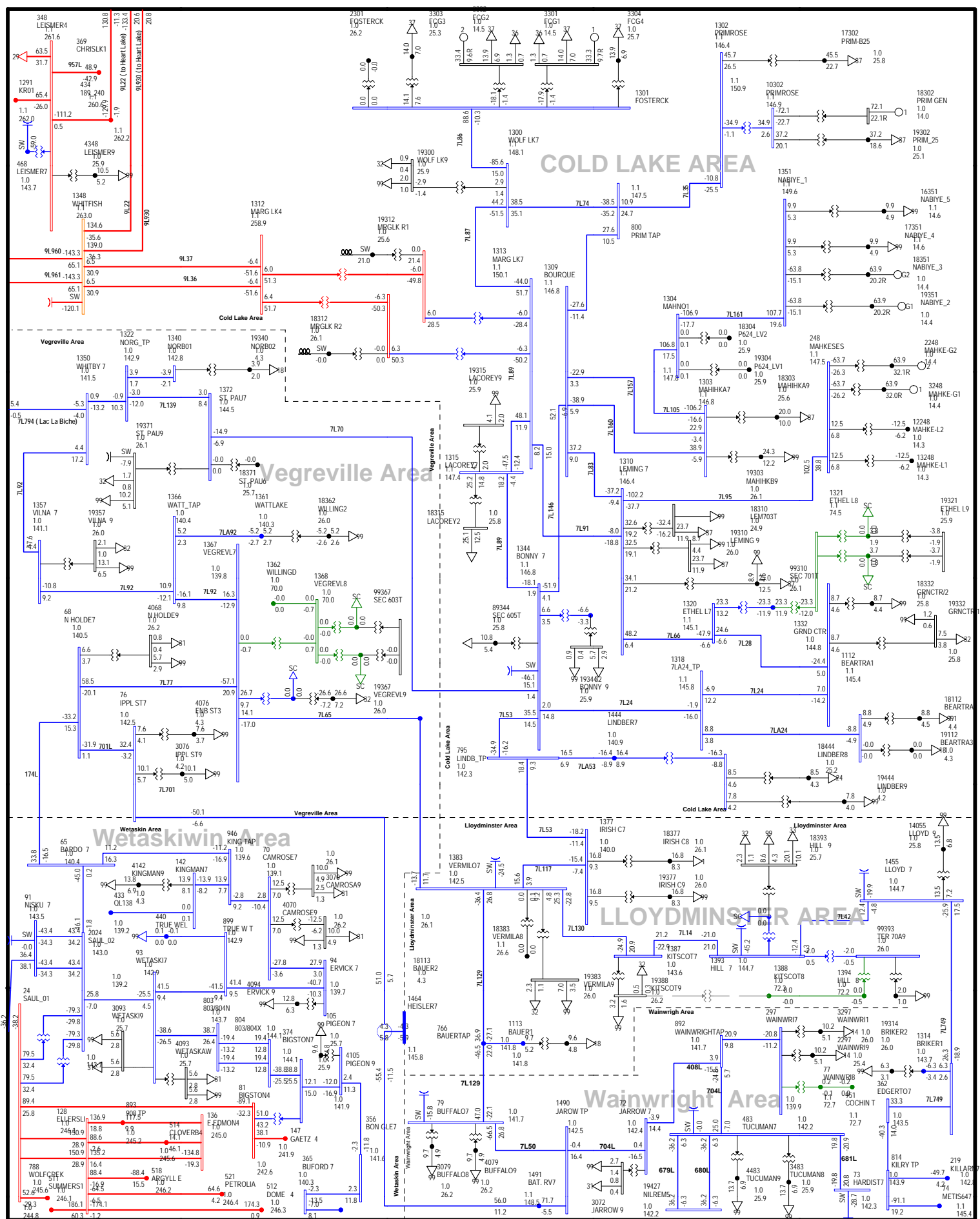
## A-2 Pre-Connection System Load Flow Results

### Load Flow Diagrams

The pre-connection load flow diagrams for Category A and selected Category B contingencies are provided in this section as listed in Table A-1.

**Table A-1: List of Pre-connection Load Flow diagrams**

<b>Scenario</b>	<b>Load flow diagram</b>	<b>Page number</b>
Scenario 1 2017SP	N-G, System Normal Condition	A-6
	N-G-1, Loss 7L53	A-7
	N-G-1, Loss 7L117	A-8
	N-G-1, Loss of 749L	A-9
	N-G-1, Loss of 7L50	A-10
Scenario 2 2017WP	N-G, System Normal Condition	A-11
	N-G-1, Loss 7L53	A-12
	N-G-1, Loss 7L117	A-13
	N-G-1, Loss of 749L	A-14
	N-G-1, Loss of 7L50	A-15



# P1410 - Heartland Pumpstation

2017SP Pre-Connection

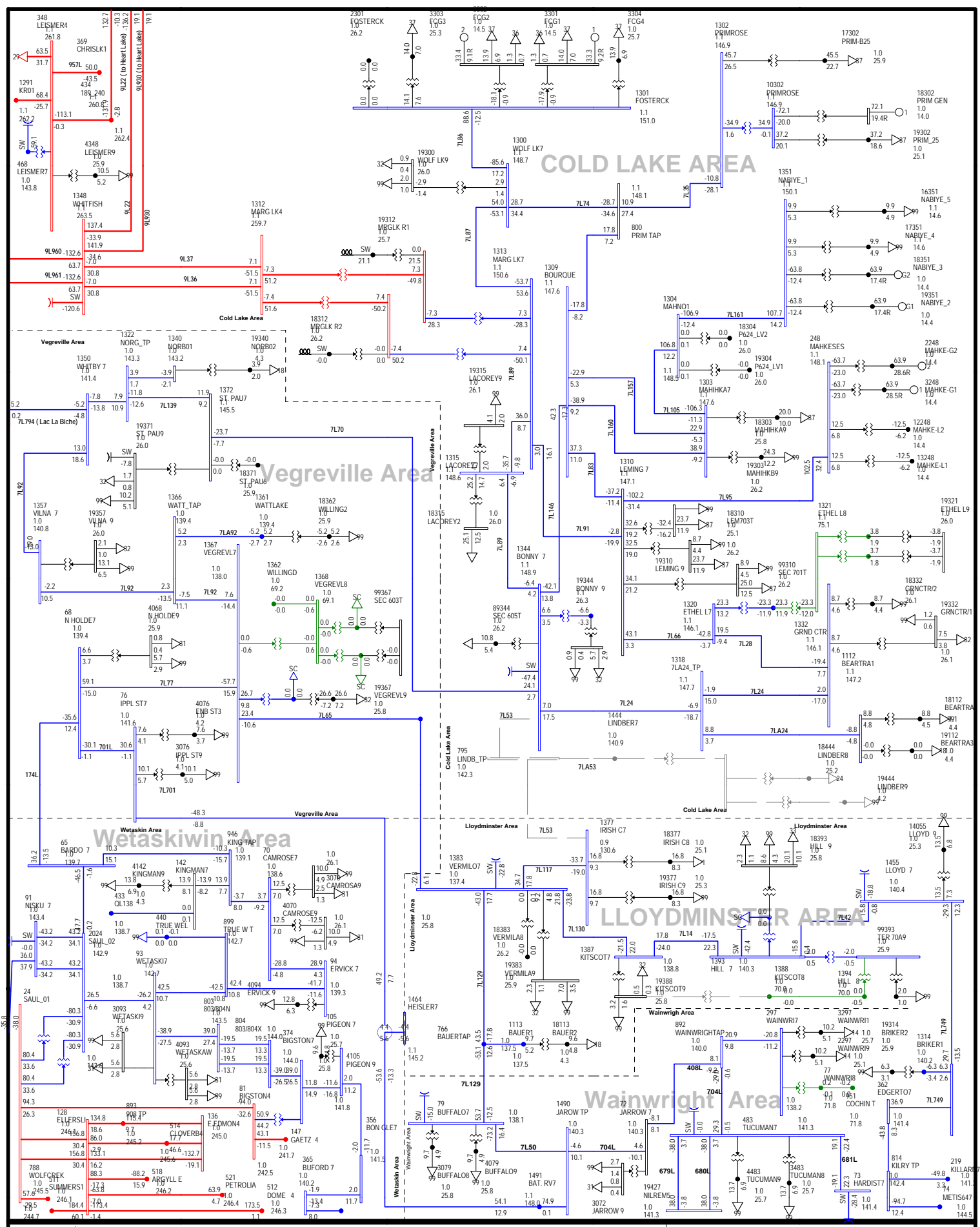
N-0, System Normal Condition

Bus - Voltage (kV/pu)  
 Branch - MW/Mvar  
 Equipment - MW/Mvar

100.0%Rate A

1.100OV 0.942LV

kV: <=25.000<=72.000 <=144.000 <=240.000<=500.000



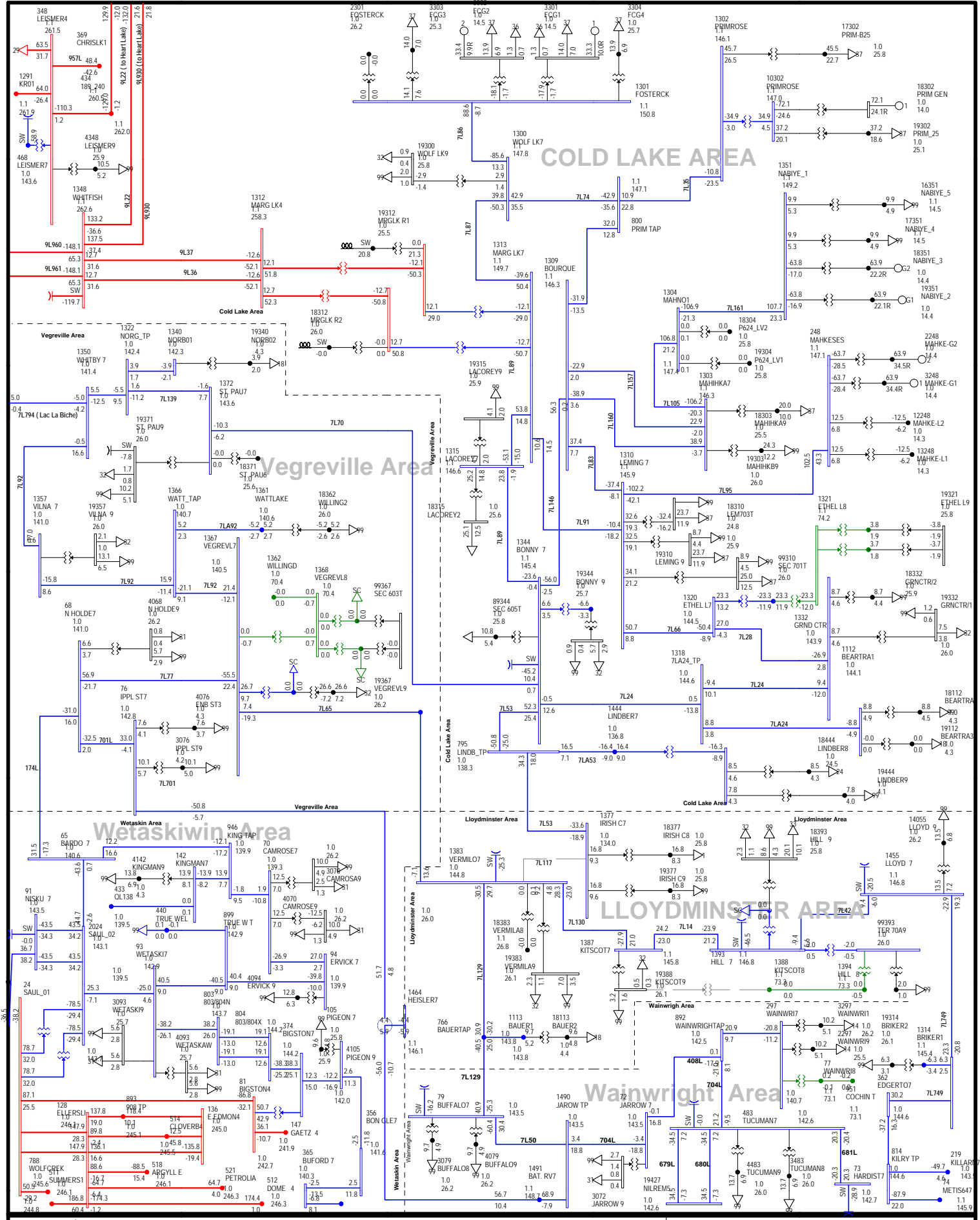
## P1410 - Heartland Pumpstation

2017SP Pre-Connection

N-G-1, Loss of 7L53 from Bonnyville 700S to Irish Creek 706S

A-7

Bus - Voltage (kV/pu)  
 Branch - MW/Mvar  
 Equipment - MW/Mvar  
 100.0%Rate A  
 1.100OV 0.942LV  
 kV: <math>\leq 25.000 <= 72.000 <= 144.000 <= 240.000 <= 500.000</math>



# P1410 - Heartland Pumpstation

A-8

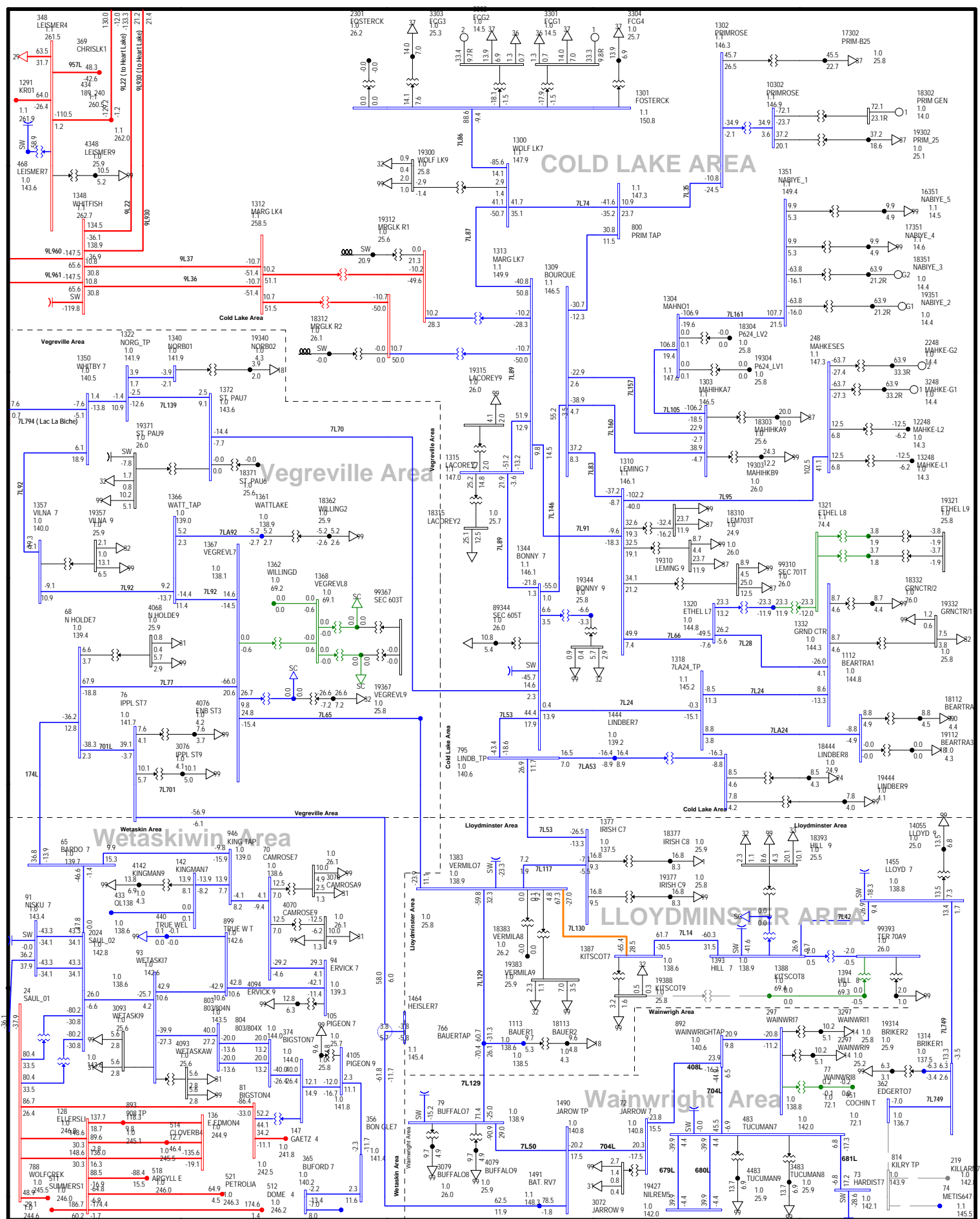
2017SP Pre-Connection

N-G-1, Loss of 7L117 from Vermilion 710S to Irish Creek 706S

Bus - Voltage (kV/pu)  
 Branch - MW/Mvar  
 Equipment - MW/Mvar

100.0%Rate A  
 1.100OV 0.942LV

kV: <=25.000<=72.000 <=144.000 <=240.000<=500.000



## P1410 - Heartland Pumpstation

2017SP Pre-Connection

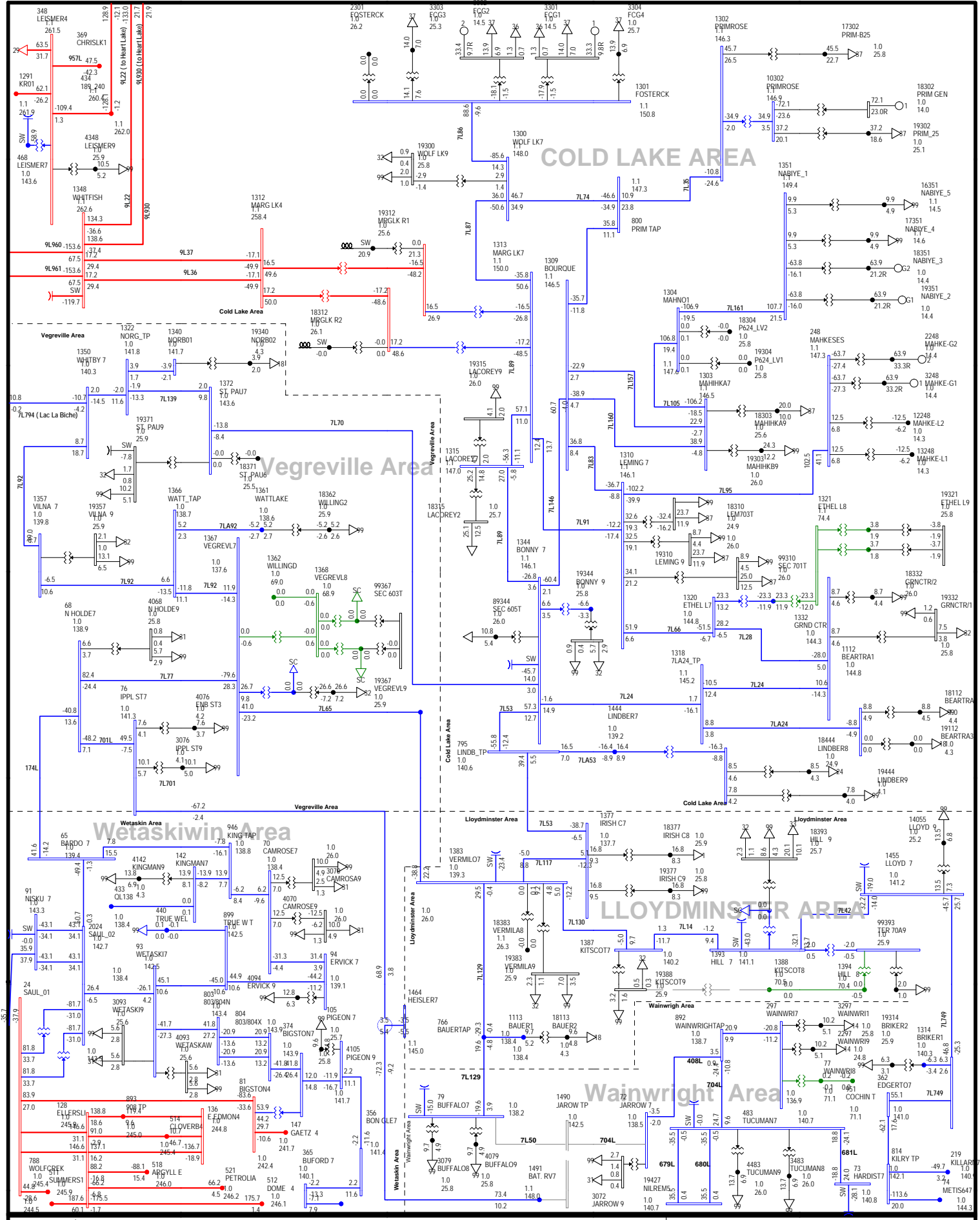
N-G-1, Loss of 749L from Metiskow 648S to Edgerton 899S

A-9

Bus - Voltage (kV/pu)  
 Branch - MW/Mvar  
 Equipment - MW/Mvar

100.0%Rate A  
 1.100OV 0.942LV

kV: <=25.000<=72.000 <=144.000 <=240.000<=500.000



# P1410 - Heartland Pumpstation

2017SP Pre-Connection

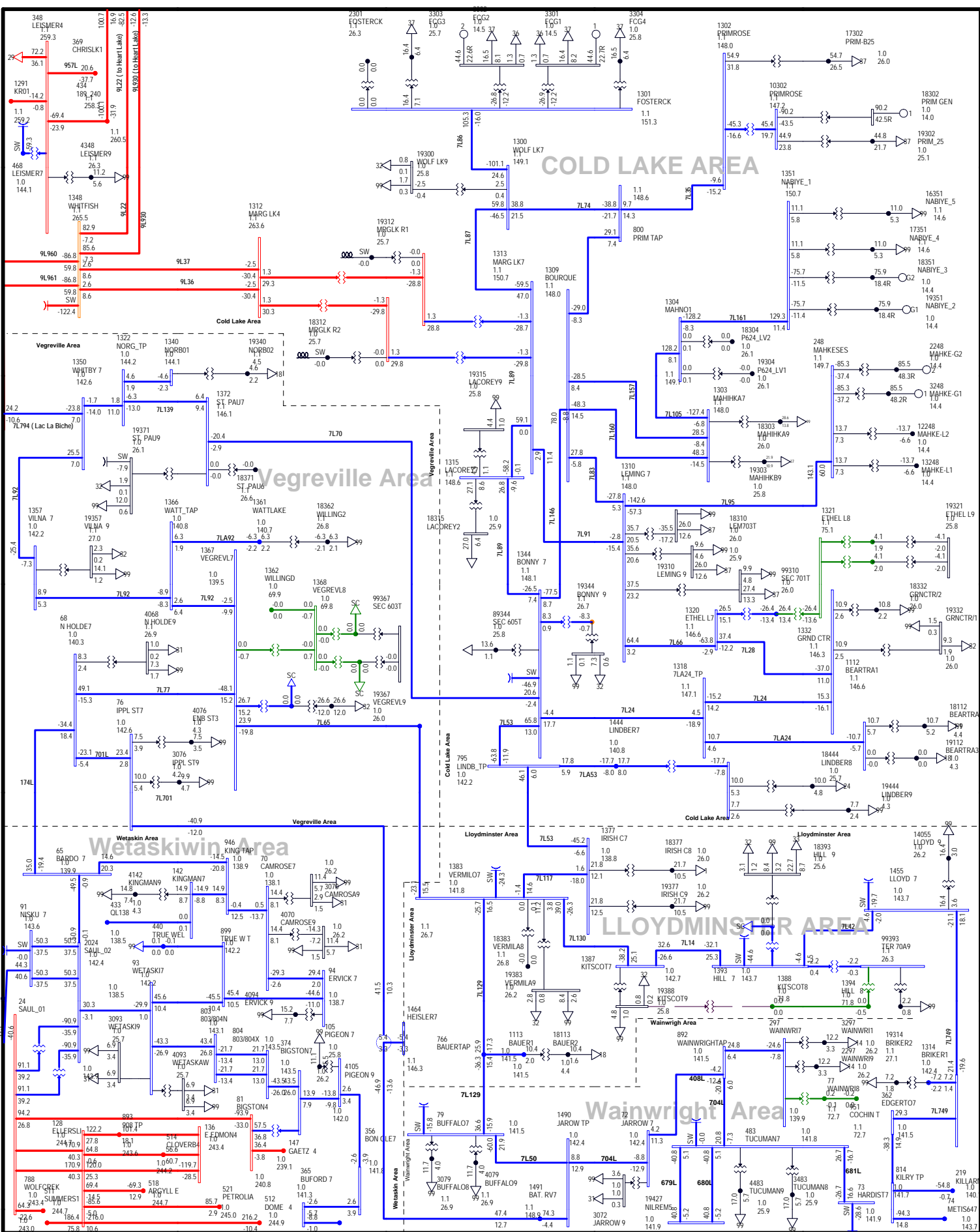
N-G-1, Loss of 7L50 from Battle River 757S to Buffalo Creek 526S

Bus - Voltage (kV/pu)  
 Branch - MW/Mvar  
 Equipment - MW/Mvar

100.0%Rate A  
 1.100OV 0.942LV

kV: <=25.000<=72.000 <=144.000 <=240.000<=500.000

A-10



# P1410 - Heartland Pumpstation

2017WP Pre-Connection

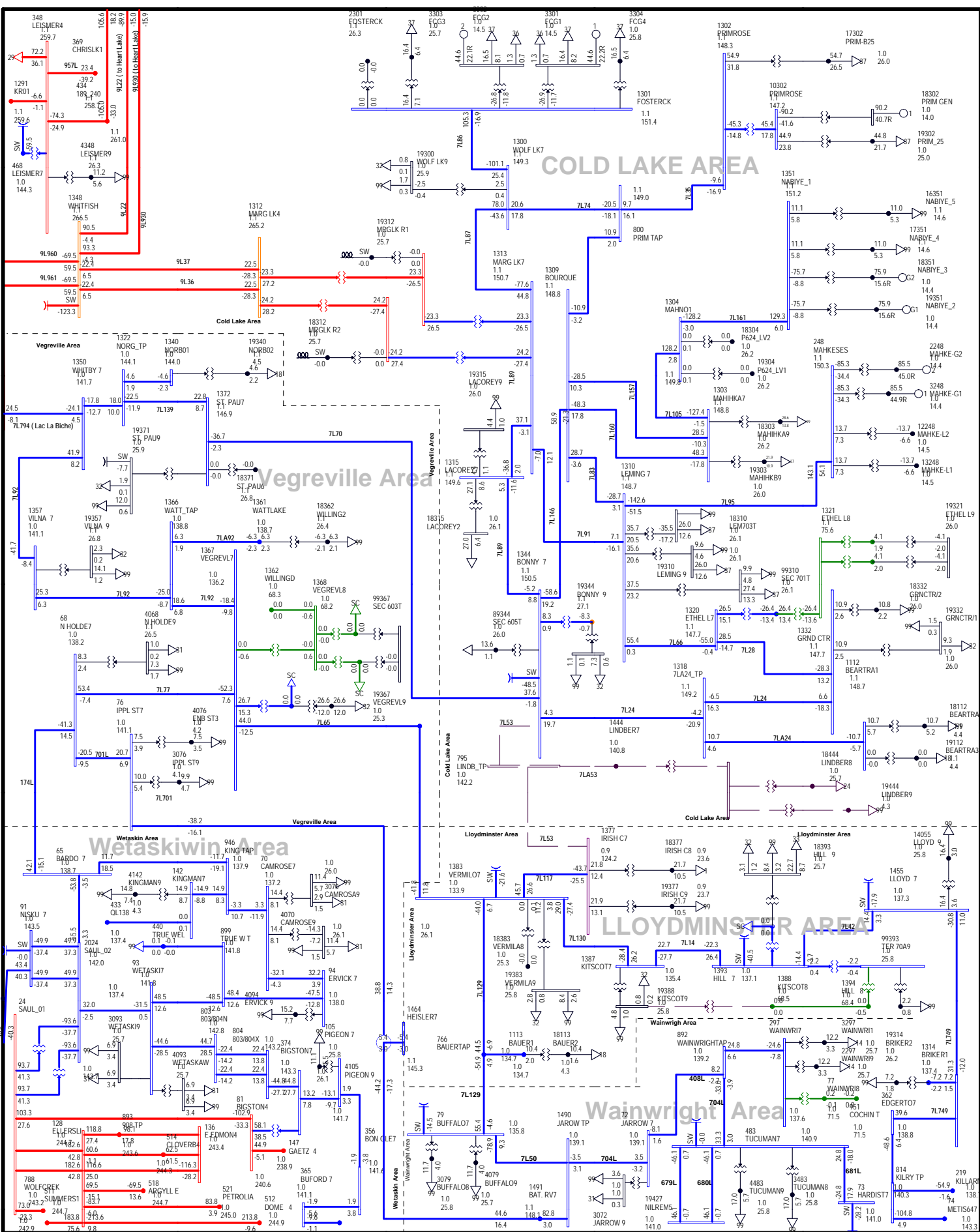
N-G, System Normal Condition

Bus - Voltage (kV/pu)  
 Branch - MW/Mvar  
 Equipment - MW/Mvar

100.0%Rate B

1:1000V 0.942UV

kV: <=25.000 <=72.000 <=144.000 <=240.000 <=500.000



# P1410 - Heartland Pumpstation

A-12

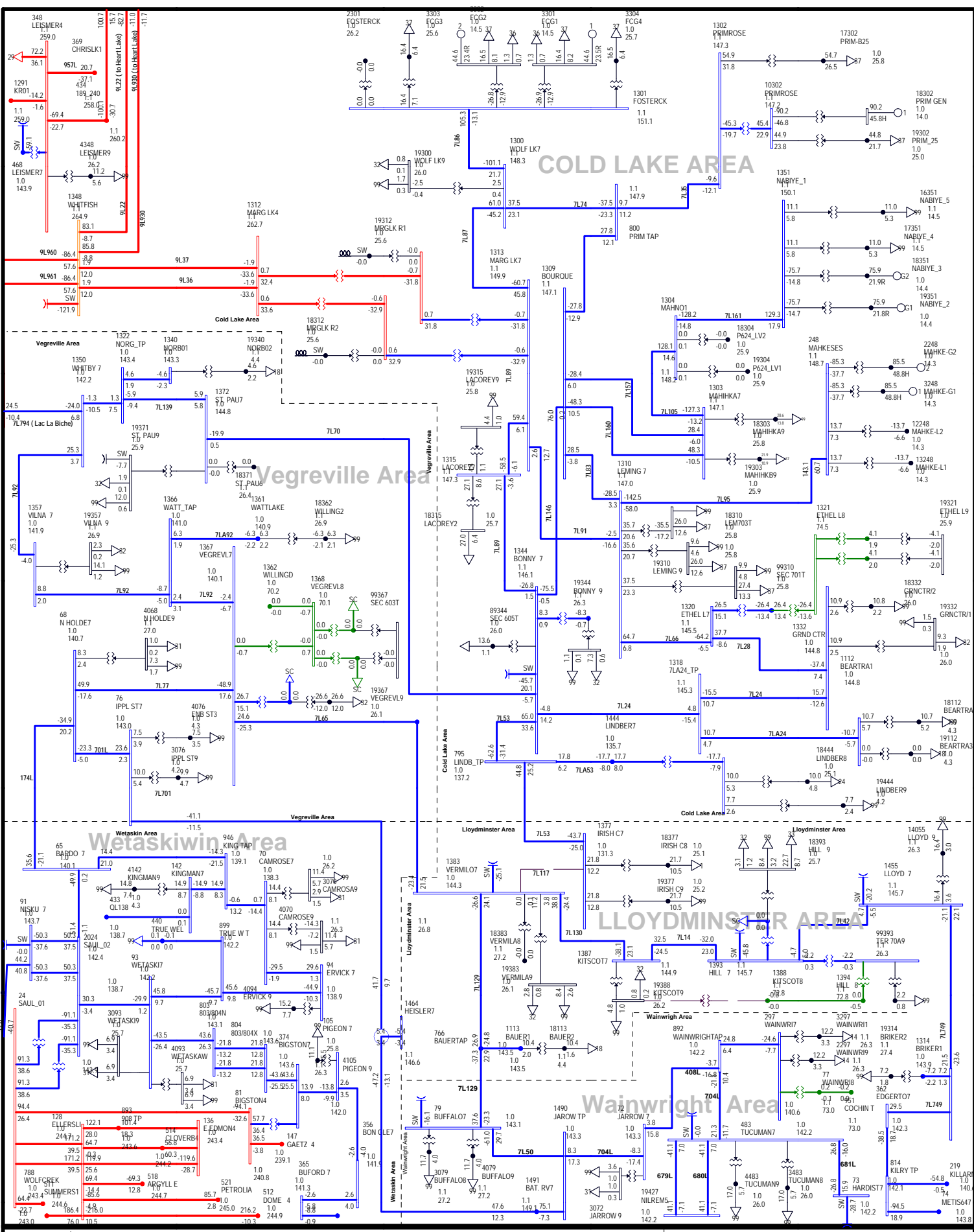
2017WP Pre-Connection

N-G-1, Loss of 7L53 from Bonnyville 700S to Irish Creek 706S

Bus - Voltage (kV/pu)  
 Branch - MW/Mvar  
 Equipment - MW/Mvar

100.0%Rate B  
 1:1000V 0.942UV  
 kV: <=25.000 <=72.000 <=144.000 <=240.000 <=500.000





# P1410 - Heartland Pumpstation

A-13

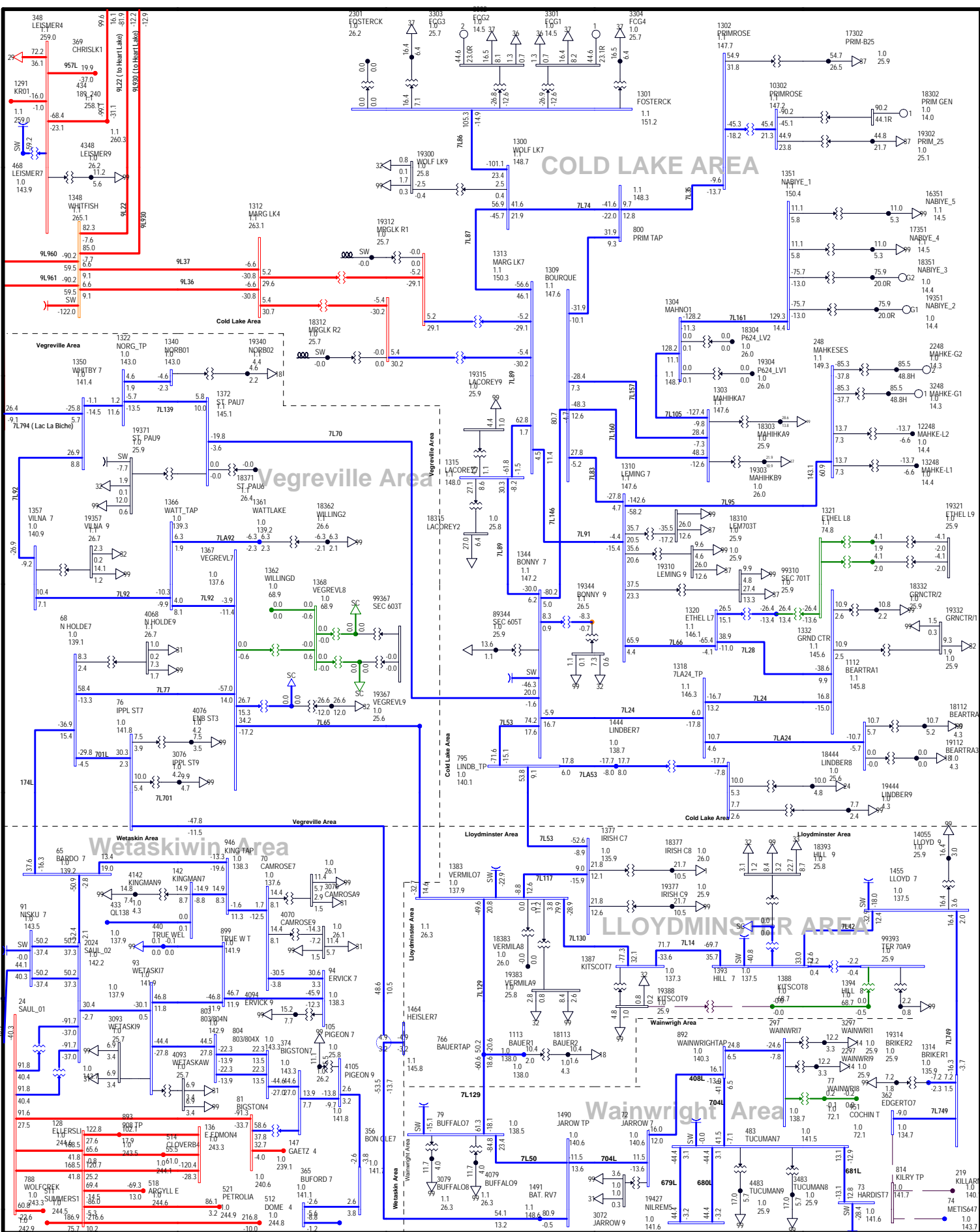
2017WP Pre-Connection

N-G-1, Loss of 7L117 from Vermilion 710S to Irish Creek 706S

Bus - Voltage (kV/pu)  
 Branch - MW/Mvar  
 Equipment - MW/Mvar

100.0%Rate B  
 1:1000V 0.942UV

kV: <=25.000 <=72.000 <=144.000 <=240.000 <=500.000



# P1410 - Heartland Pumpstation

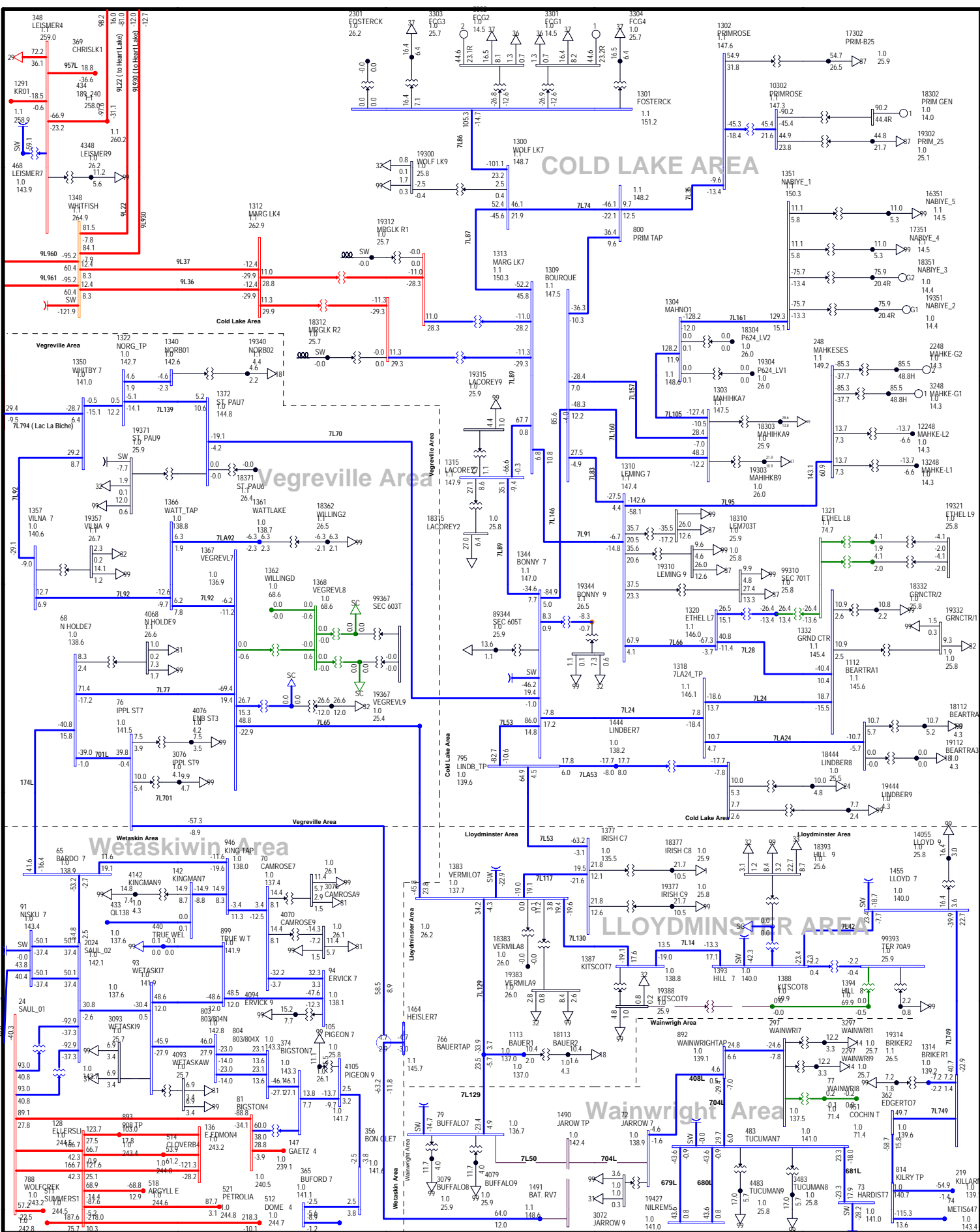
A-14

2017WP Pre-Connection

N-G-1, Loss of 749L from Metiskow 648S to Edgerton 899S

Bus - Voltage (kV/pu)  
 Branch - MW/Mvar  
 Equipment - MW/Mvar

100.0%Rate B  
 1:1000V 0.942UV  
 kV: <=25.000 <=72.000 <=144.000 <=240.000 <=500.000



# P1410 - Heartland Pumpstation

2017WP Pre-Connection

N-G-1, Loss of 7L50 from Battle River 757S to Buffalo Creek 526S

A-15

Bus - Voltage (kV/pu)  
 Branch - MW/Mvar  
 Equipment - MW/Mvar

100.0%Rate B  
 1:1000V 0.942UV

kV: <=25.000 <=72.000 <=144.000 <=240.000 <=500.000

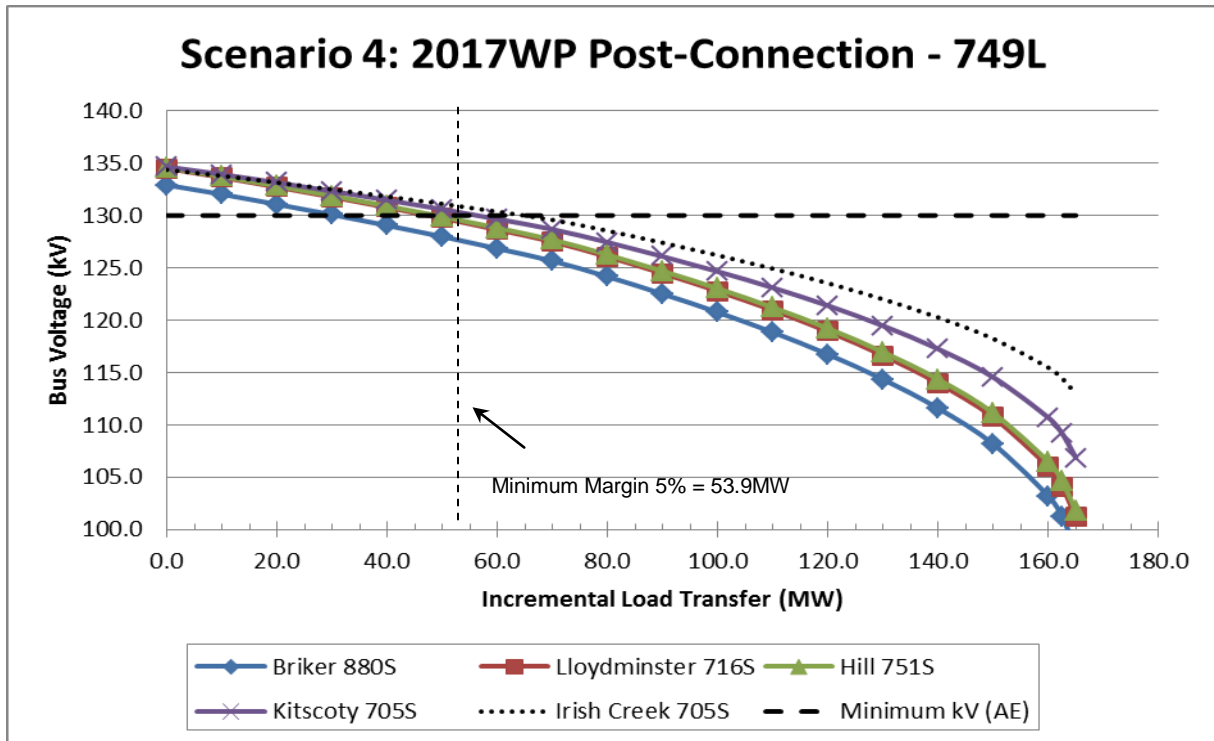
**ATTACHMENT B**  
**Post-Connection PV Curves**  
**and Load Flow Plots**

## B-1 Post-Connection System Voltage Stability Analysis Results

### Scenario 4: 2017WP Post-Connection

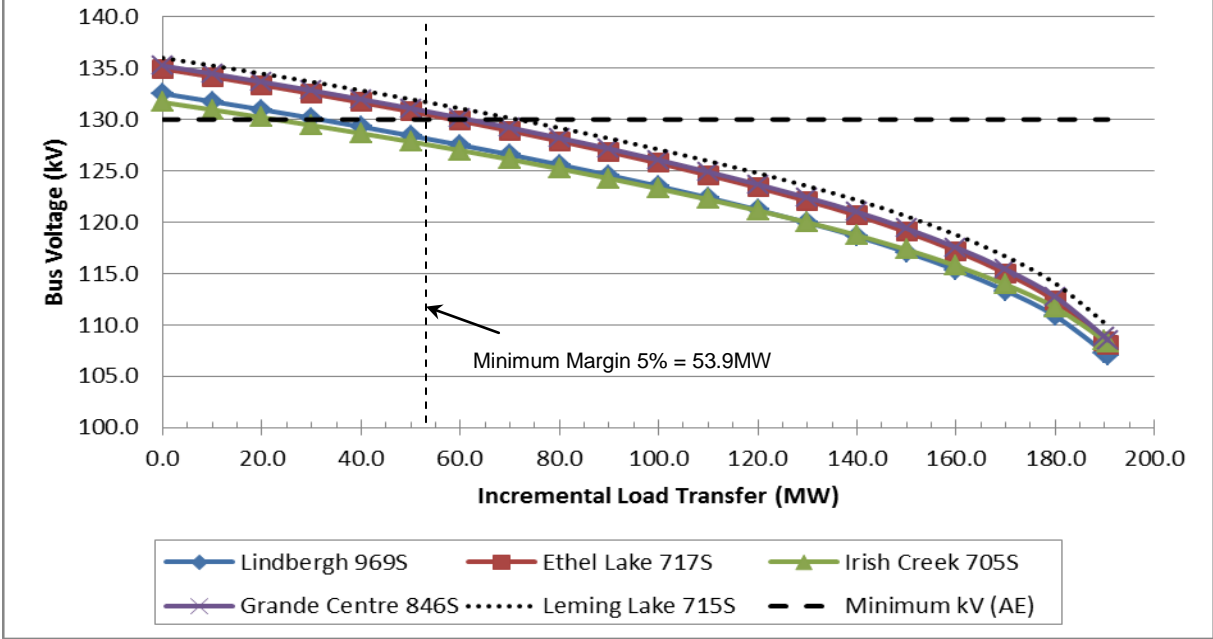
Figure B-2 shows the P-V curves for 749L, 7L95, 7L117 and 7L50 contingencies in the post-connection for scenario 4.

Figure B-1: P-V Curves for Scenario 4 – 2017WP Post-Connection



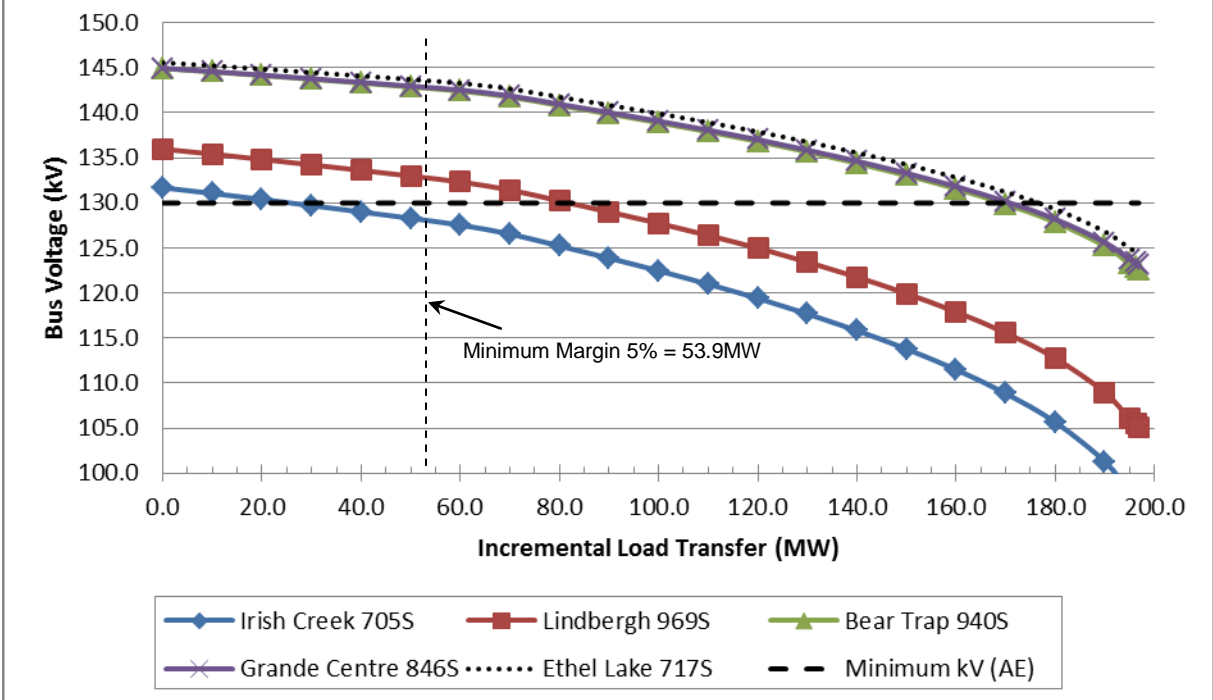
(a) 749L Contingency

### Scenario 4: 2017WP Post-Connection - 7L95

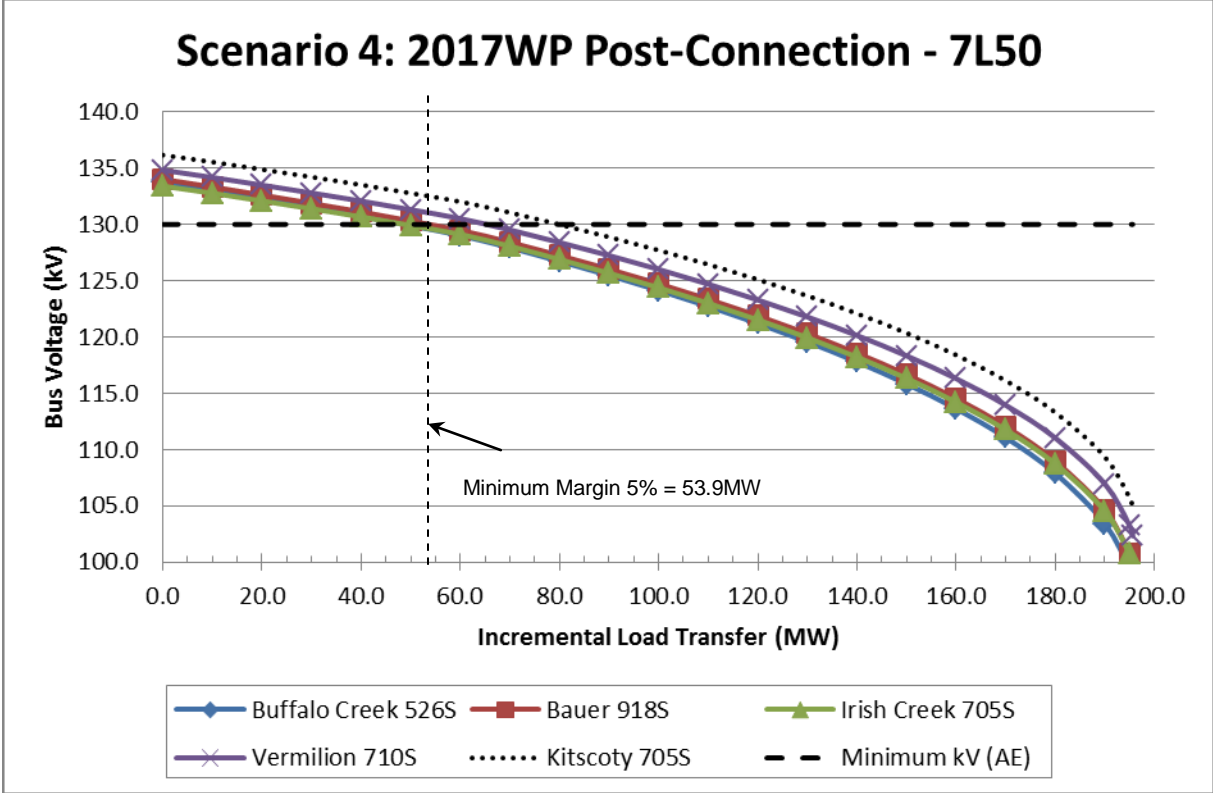


(b) 7L95 Contingency

### Scenario 4: 2017WP Post-Connection - 7L117



(c) 7L117 Contingency



(d) 7L50 Contingency

## B-2 Post-Connection System Load Flow Results

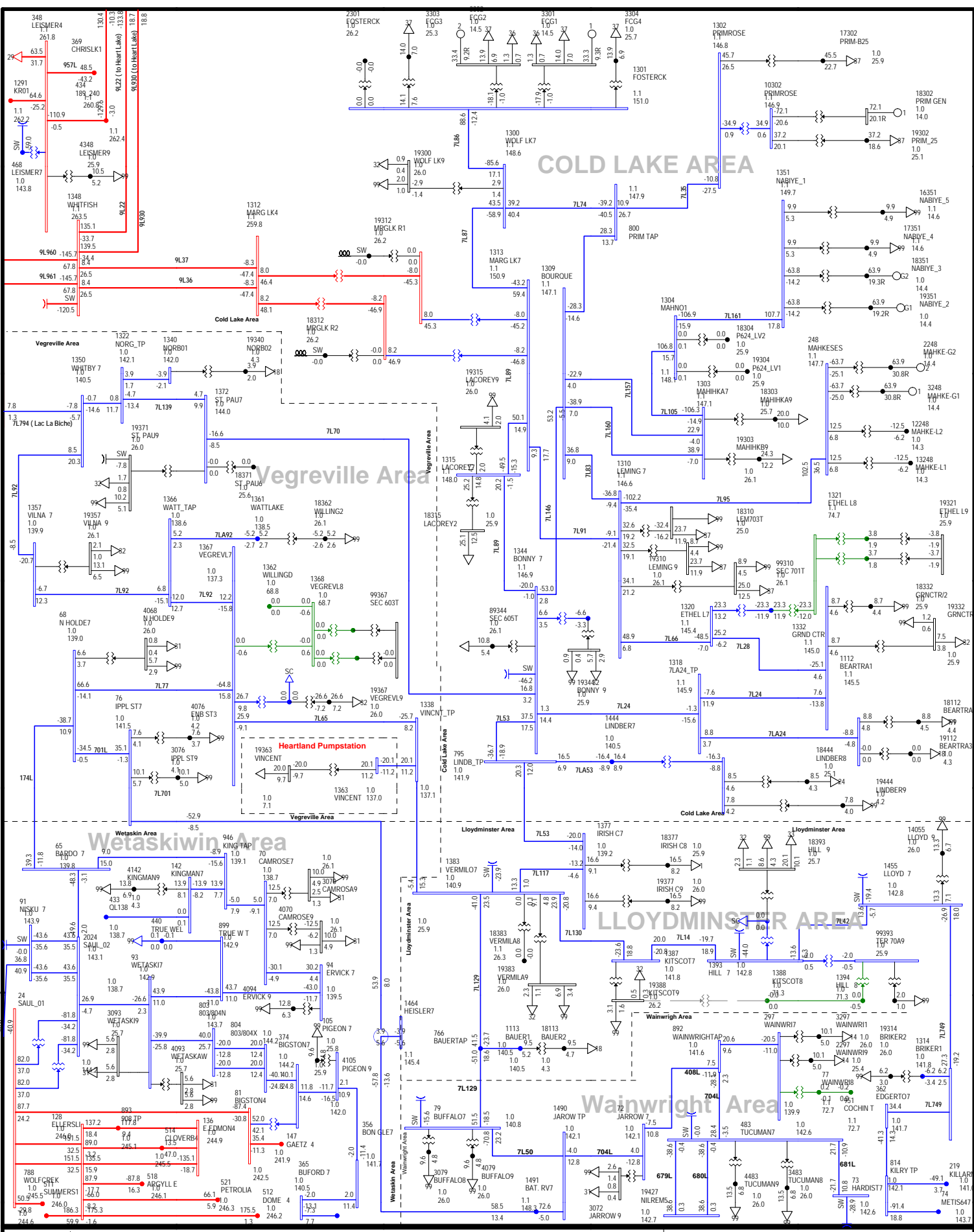
### Load Flow Diagrams

The post-connection load flow diagrams for Category A and selected Category B contingencies are provided in this section as listed in Table B-1.

**Table B-1: List of Post-Connection Load Flow Diagrams**

Scenario	Load flow diagram	Page number
Scenario 3 2017SP	N-G, System Normal Condition	B-6
	N-G-1, Loss 7L53	B-7
	N-G-1, Loss 7L117	B-8
	N-G-1, Loss of 749L	B-9
	N-G-1, Loss of 7L50	B-10
	N-G-1, Loss of 7L65 segment to Vermilion 710S	B-11
	N-G-1, Loss of 7L65 segment to Vegreville 709S	B-12
Scenario 4 2017WP	N-G, System Normal Condition	B-13
	N-G-1, Loss 7L53	B-14
	N-G-1, Loss 7L117	B-15
	N-G-1, Loss of 749L	B-16
	N-G-1, Loss of 7L50	B-17
	N-G-1, Loss of 7L65 segment to Vermilion 710S	B-18
	N-G-1, Loss of 7L65 segment to Vegreville 709S	B-19





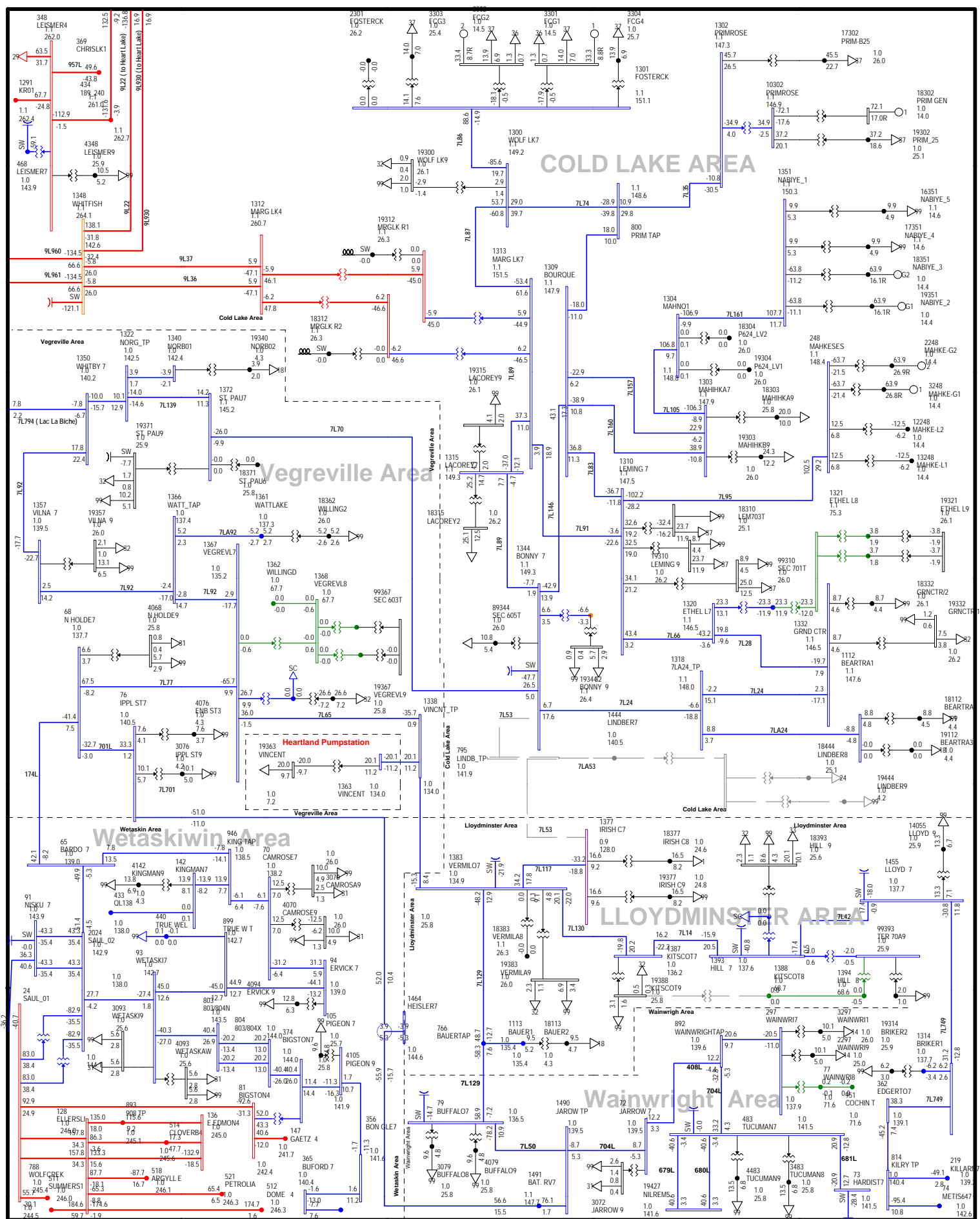
**P1410 - Heartland Pumpstation**  
**2017SP Post-Connection**  
**N-G, System Normal Condition**

**B-6**

Bus - Voltage (kV/pu)  
 Branch - MW/Mvar  
 Equipment - MW/Mvar

100.0%Rate A  
 1.100OV 0.942LV

kV: <=25.000<=72.000<=144.000<=240.000<=500.000



## P1410 - Heartland Pumpstation

2017SP Post-Connection

N-G-1, Loss of 7L53 from Bonnyville 700S to Irish Creek 706S

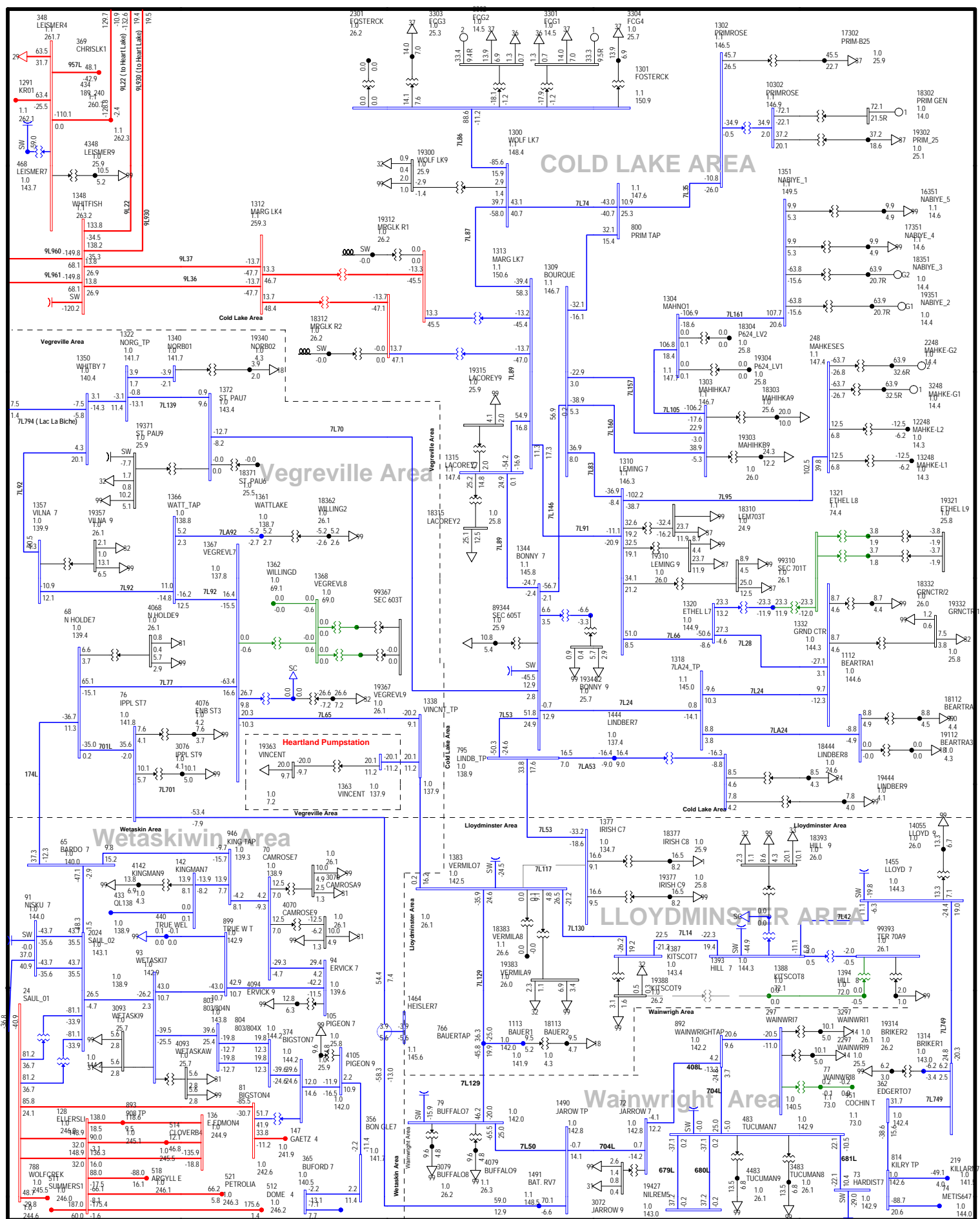
B-7

Bus - Voltage (kV/pu)  
Branch - MW/Mvar  
Equipment - MW/Mvar

100.0%Rate A

1.100OV 0.942LUV

kV: <=25.000<=72.000<=144.000<=240.000<=500.000



# P1410 - Heartland Pumpstation

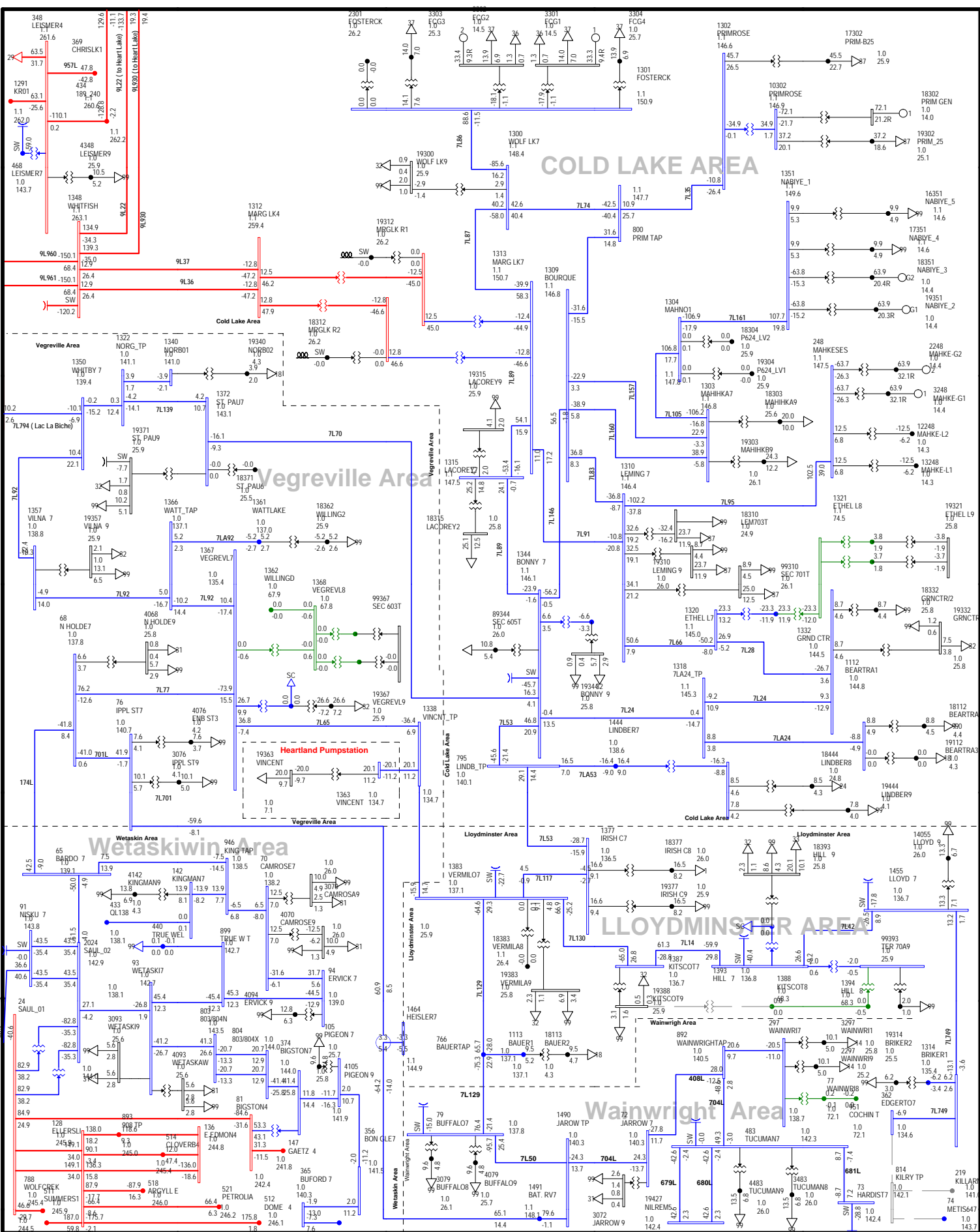
B-8

2017SP Post-Connection

N-G-1, Loss of 7L117 from Vermilion 710S to Irish Creek 706S

Bus - Voltage (kV/pu)  
 Branch - MW/Mvar  
 Equipment - MW/Mvar

100.0%Rate A  
 1.100OV 0.942LV  
 kV: <=25.000<=72.000 <=144.000 <=240.000 <=500.000



## P1410 - Heartland Pumpstation

2017SP Post-Connection

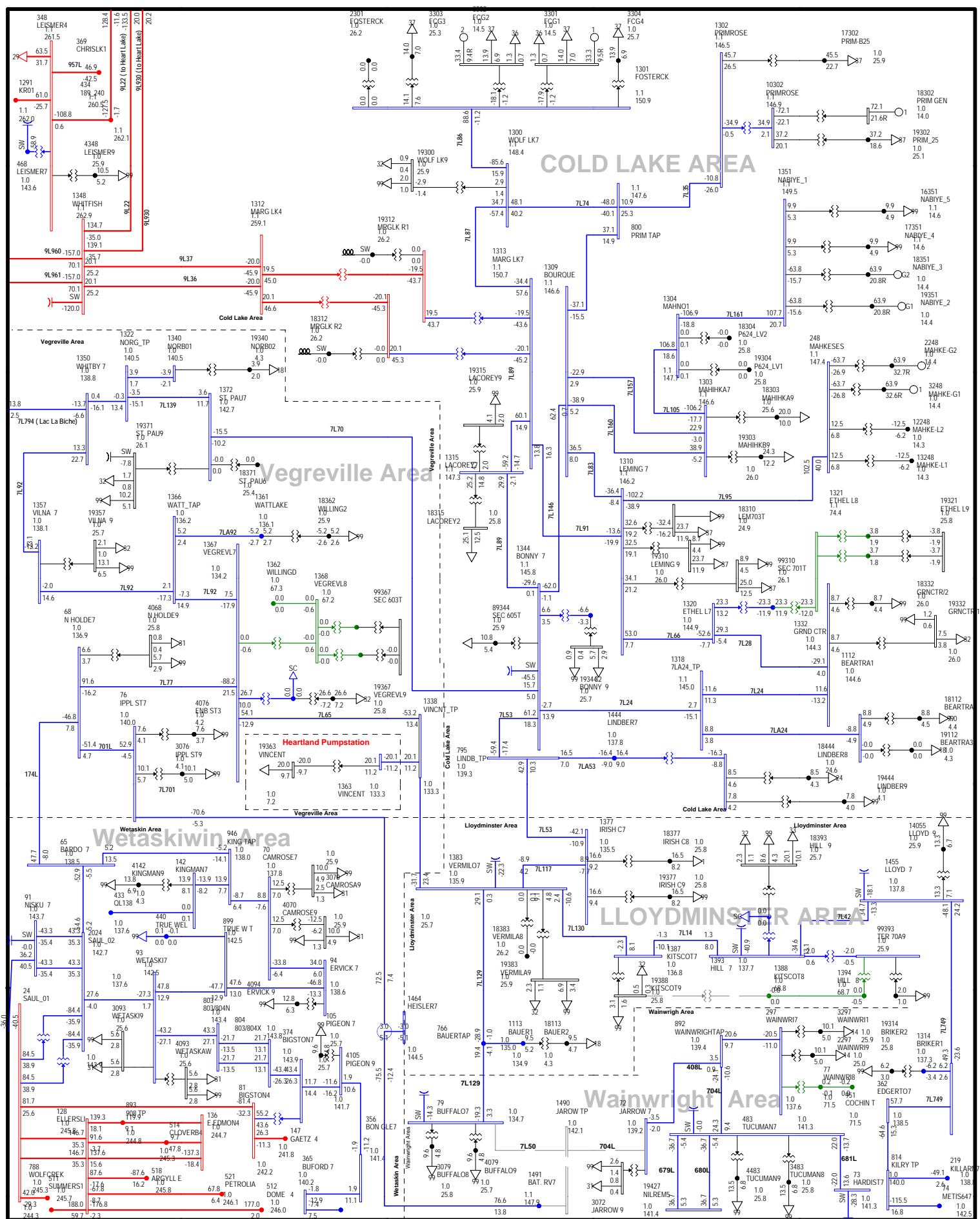
N-G-1, Loss of 749L from Metiskow 648S to Edgerton 899S

B-9

Bus - Voltage (kV/pu)  
 Branch - MW/Mvar  
 Equipment - MW/Mvar

100.0%Rate A  
 1.100OV 0.942LV

kV: <=25.000<=72.000<=144.000<=240.000<=500.000



## P1410 - Heartland Pumpstation

2017SP Post-Connection

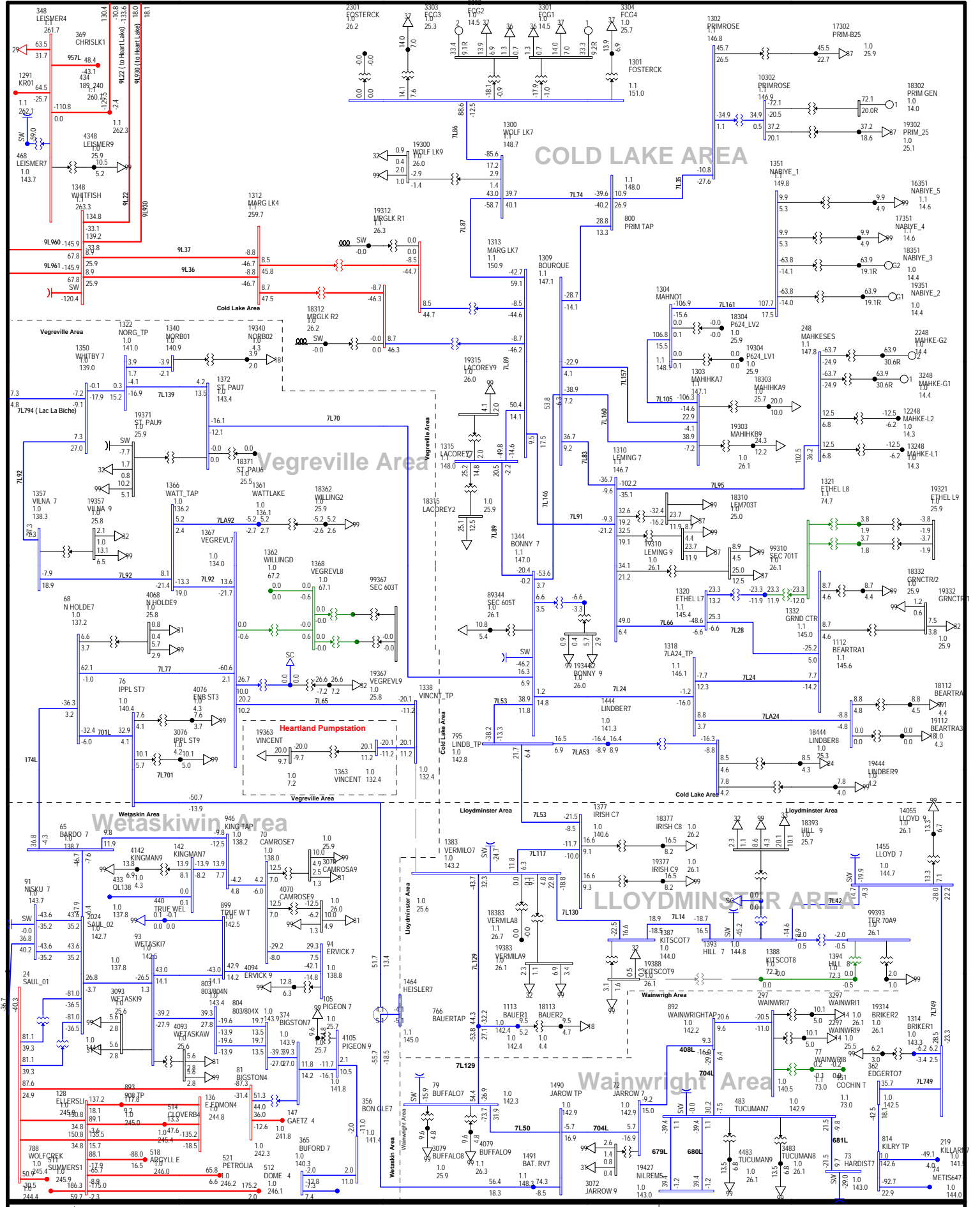
N-G-1, Loss of 7L50 from Battle River 757S to Buffalo Creek 526S

B-10

Bus - Voltage (kV/pu)  
Branch - MW/Mvar  
Equipment - MW/Mvar

100.0%Rate A  
1.100OV 0.942LV

kV: <=25.000<=72.000<=144.000<=240.000<=500.000



# P1410 - Heartland Pumpstation

2017SP Post-Connection

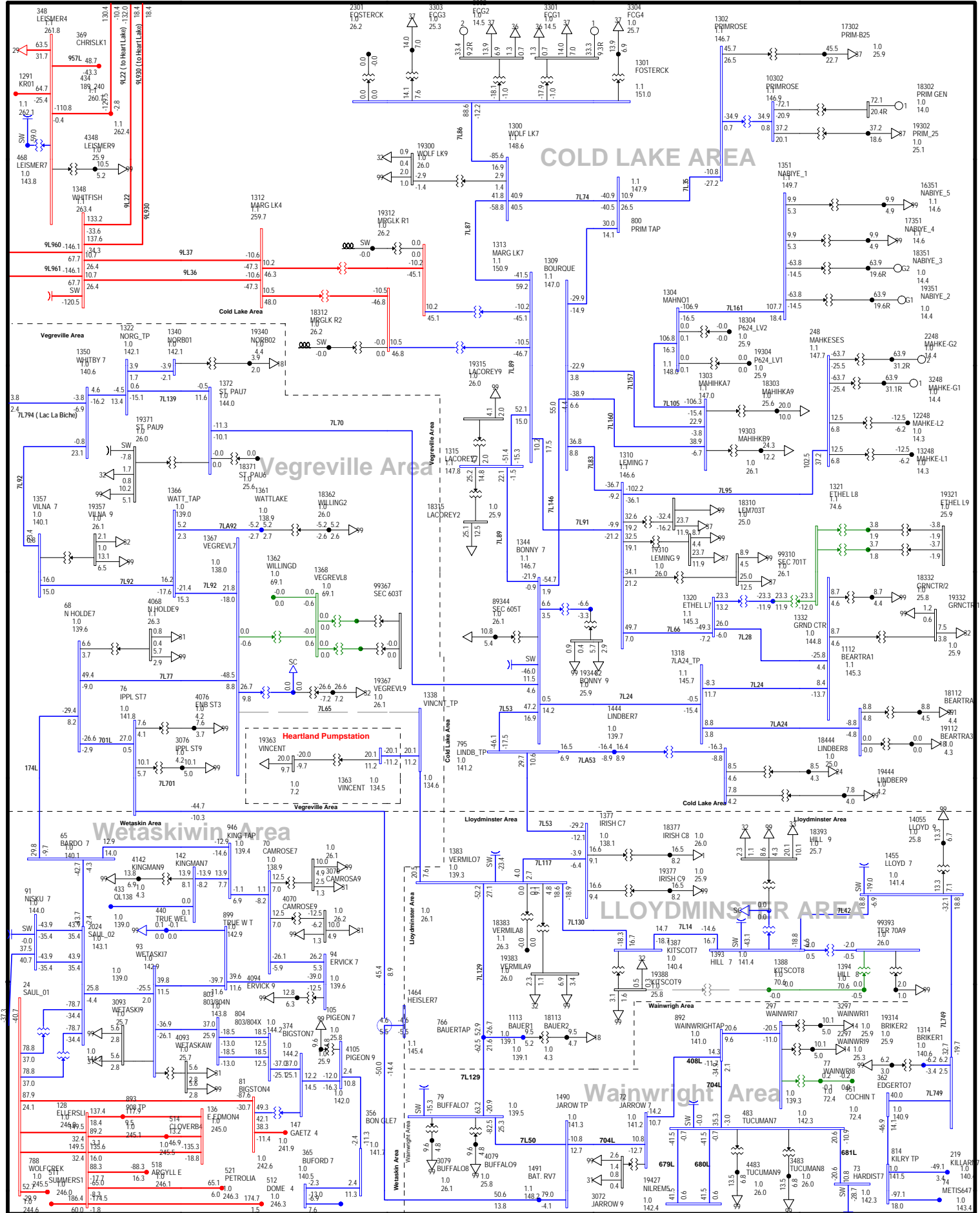
N-G-1, Loss of 7L65 segment from Vermilion 710S to Vincent 2019S

Bus - Voltage (kV/pu)  
 Branch - MW/Mvar  
 Equipment - MW/Mvar

100.0%Rate A  
 1.100OV 0.942LUV

kV: <math>\leq 25.000</math> <math>= 72.000</math> <math>\leq 144.000</math> <math>\leq 240.000</math> <math>= 500.000</math>

B-11



# P1410 - Heartland Pumpstation

2017SP Post-Connection

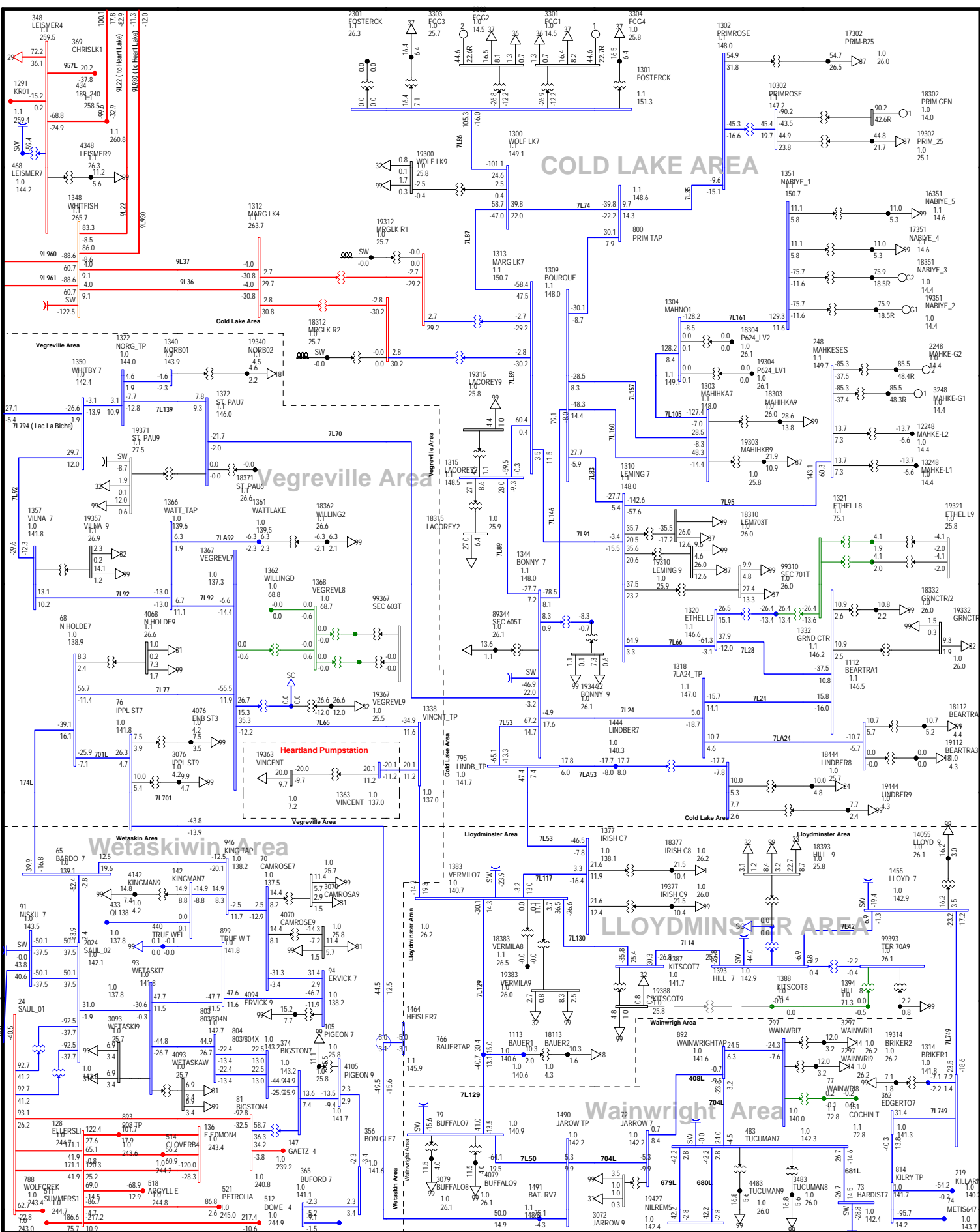
N-G-1, Loss of 7L65 segment from Vegreville 709S to Vincent 2019S

Bus - Voltage (kV/pu)  
 Branch - MW/Mvar  
 Equipment - MW/Mvar

100.0%Rate A  
 1.100OV 0.942LV

kV: <=25.000<=72.000<=144.000<=240.000<=500.000

B-12



# P1410 - Heartland Pumpstation

2017WP Post-Connection  
N-G, System Normal Condition

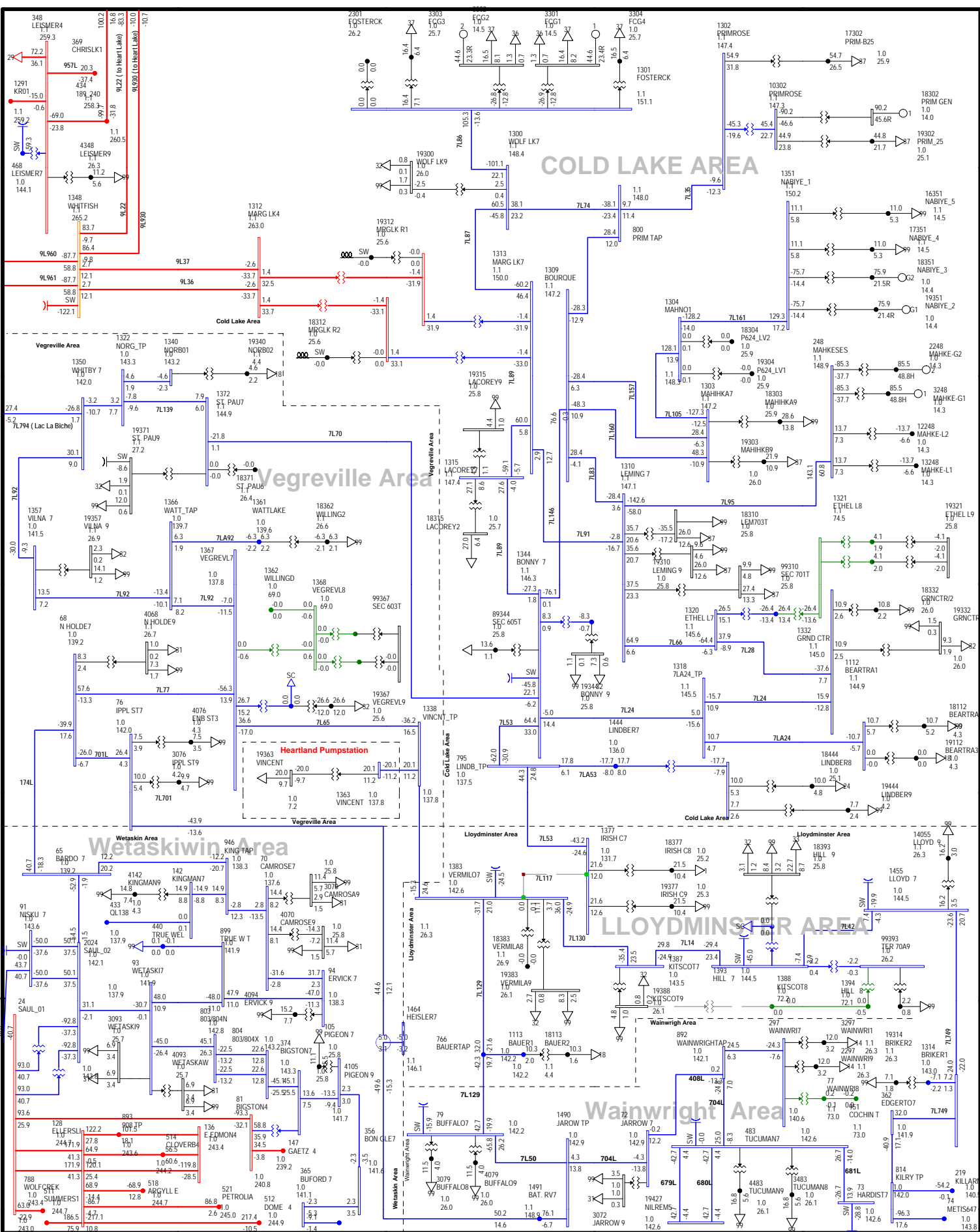
Bus - Voltage (kV/pu)  
Branch - MW/Mvar  
Equipment - MW/Mvar

100.0%Rate B  
1.100OV 0.942UV

kV: <=25.000 <=72.000 <=144.000 <=240.000 <=500.000







# P1410 - Heartland Pumpstation

2017WP Post-Connection

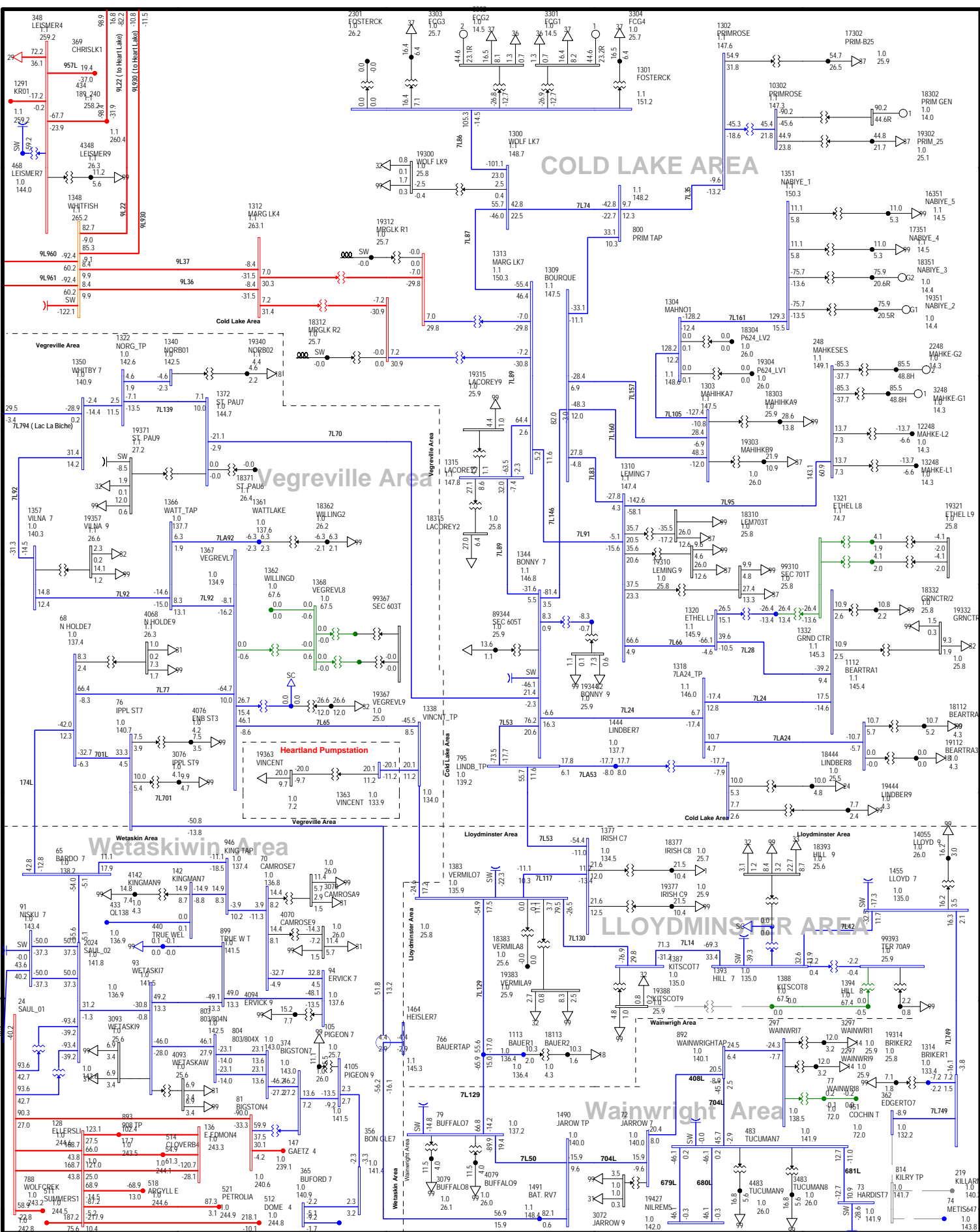
N-G-1, Loss of 7L117 from Vermilion 710S to Irish Creek 706S

Bus - Voltage (kV/pu)  
 Branch - MW/Mvar  
 Equipment - MW/Mvar

100.0%Rate B  
 1.100OV 0.942UV

kV: <=25.000 <=72.000 <=144.000 <=240.000 <=500.000

B-15



## P1410 - Heartland Pumpstation

2017WP Post-Connection

N-G-1, Loss of 749L from Metiskow 648S to Edgerton 899S

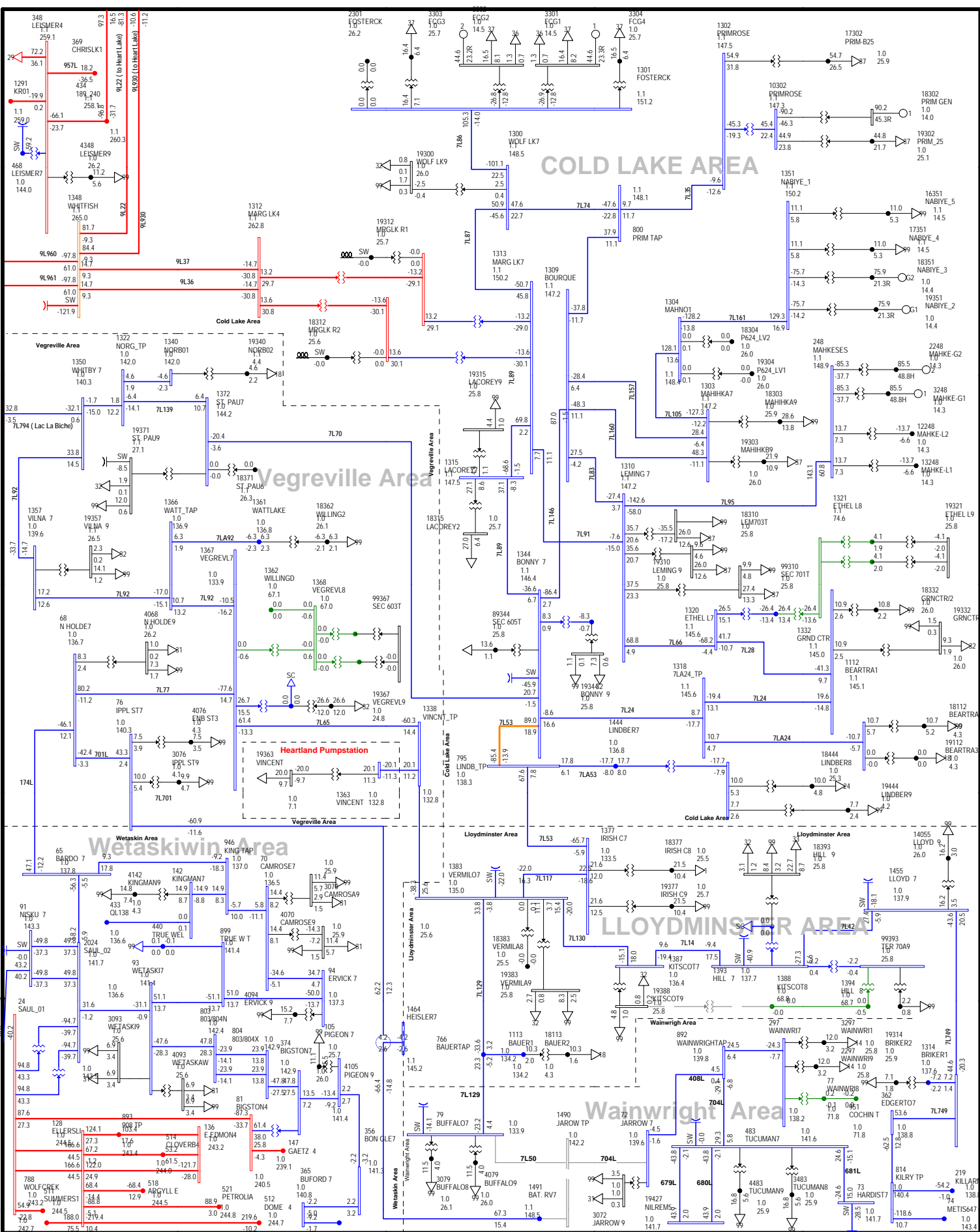
Bus - Voltage (kV/pu)  
 Branch - MW/Mvar  
 Equipment - MW/Mvar

100.0%Rate B

1.100OV 0.942UV

kV: <=25.000 <=72.000 <=144.000 <=240.000 <=500.000

B-16



## P1410 - Heartland Pumpstation

2017WP Post-Connection

N-G-1, Loss of 7L50 from Battle River 757S to Buffalo Creek 526S

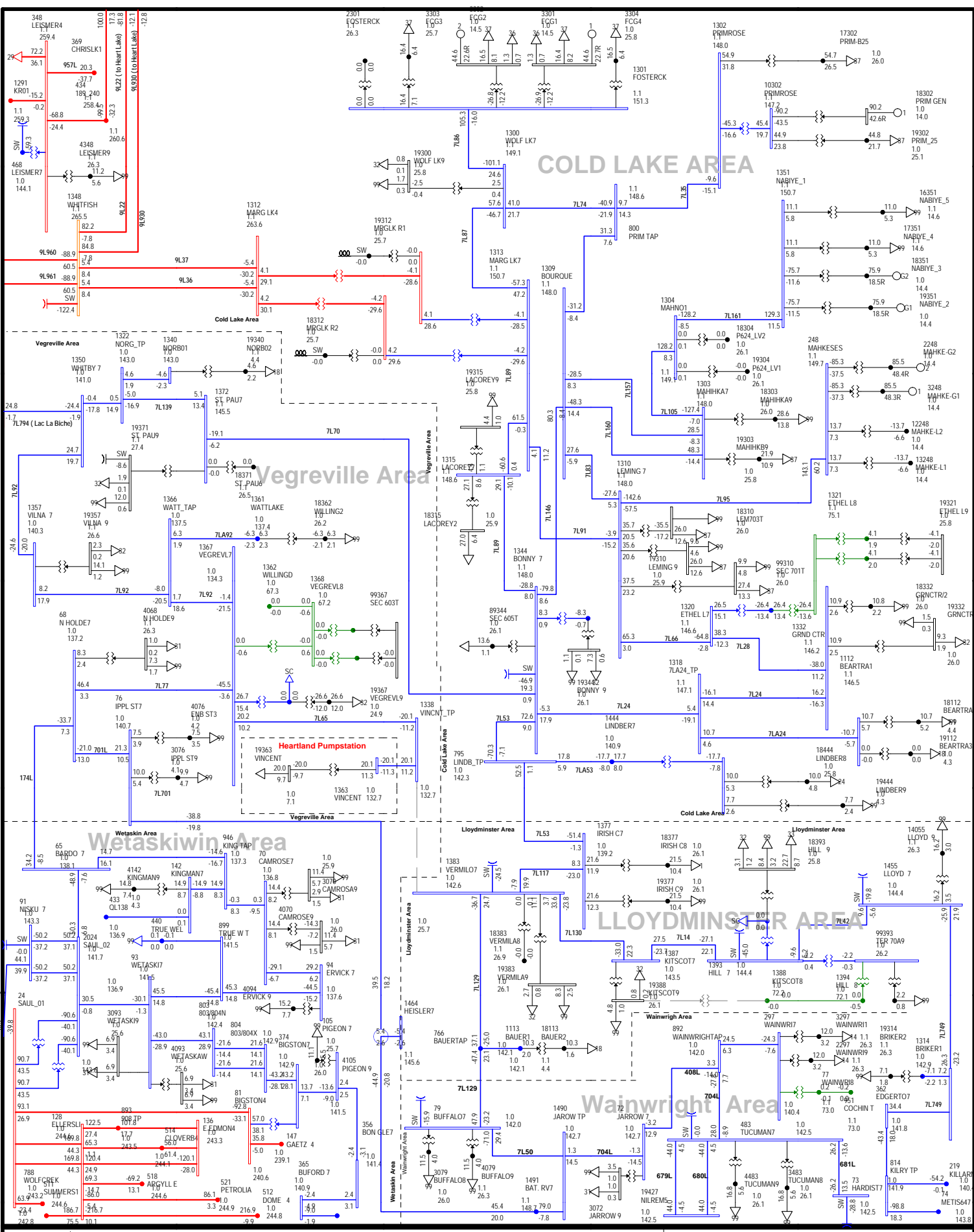
B-17

Bus - Voltage (kV/pu)  
 Branch - MW/Mvar  
 Equipment - MW/Mvar

100.0%Rate B

1.100OV 0.942UV

kV: <=25.000 <=72.000 <=144.000 <=240.000 <=500.000



# P1410 - Heartland Pumpstation

2017WP Post-Connection

N-G-1, Loss of 7L65 segment from Vermilion 710S to Vincent 2019S

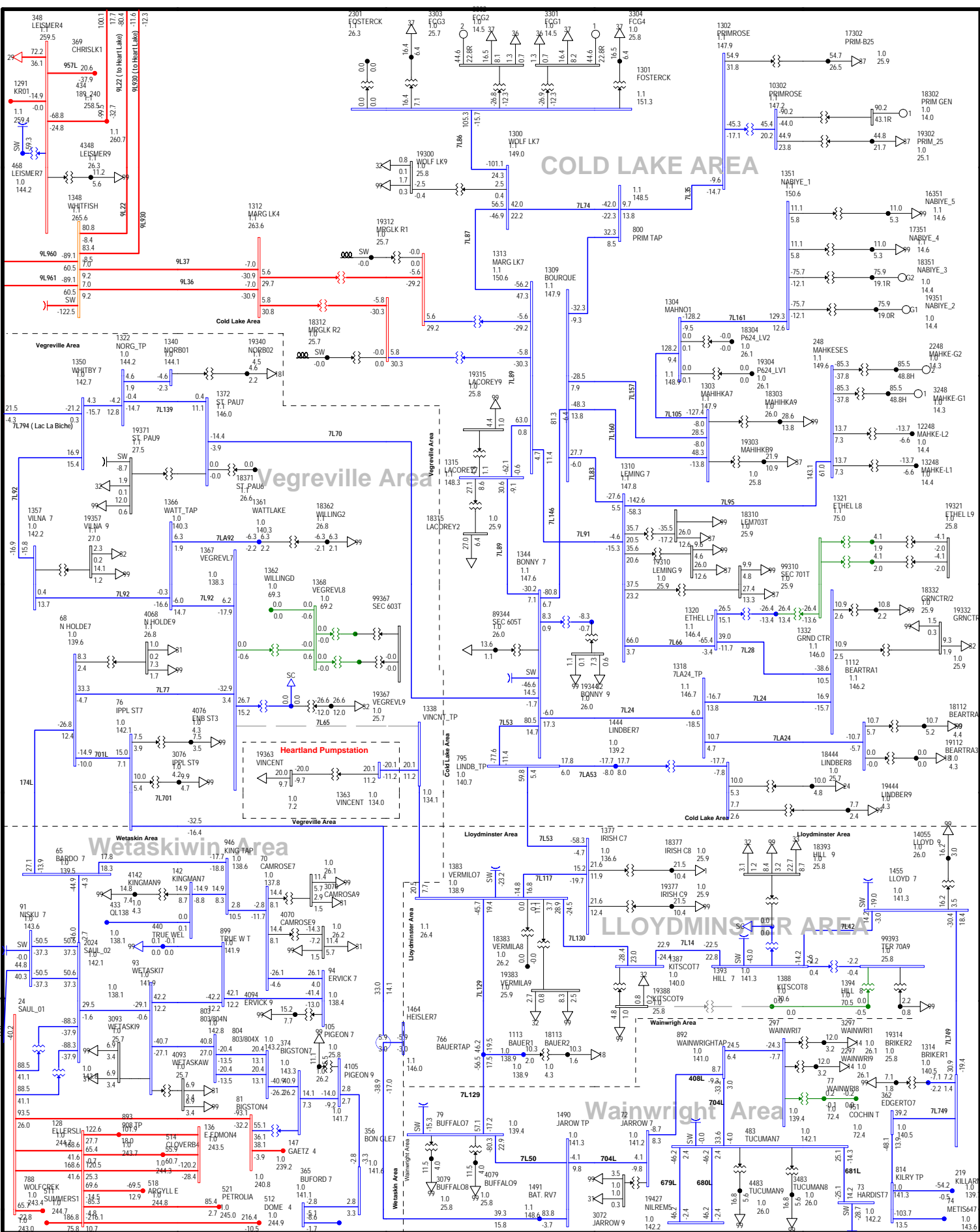
Bus - Voltage (kV/pu)  
 Branch - MW/Mvar  
 Equipment - MW/Mvar

100.0%Rate B

1.100OV 0.942UV

kV: <=25.000 <=72.000 <=144.000 <=240.000 <=500.000

B-18



**P1410 - Heartland Pumpstation  
2017WP Post-Connection**

**N-G-1, Loss of 7L65 segment from Vegreville 709S to Vincent 2019S**

Bus - Voltage (kV/pu)  
Branch - MW/Mvar  
Equipment - MW/Mvar

100.0%Rate B  
1.100OV 0.942UV  
kV: <=25.000 <=72.000 <=144.000 <=240.000 <=500.000

**B-19**

**ATTACHMENT C**  
**Sensitivity Analysis:**  
**Post-Connection Load Flow Plots**  
**With the Irish Creek 706S Capacitor**

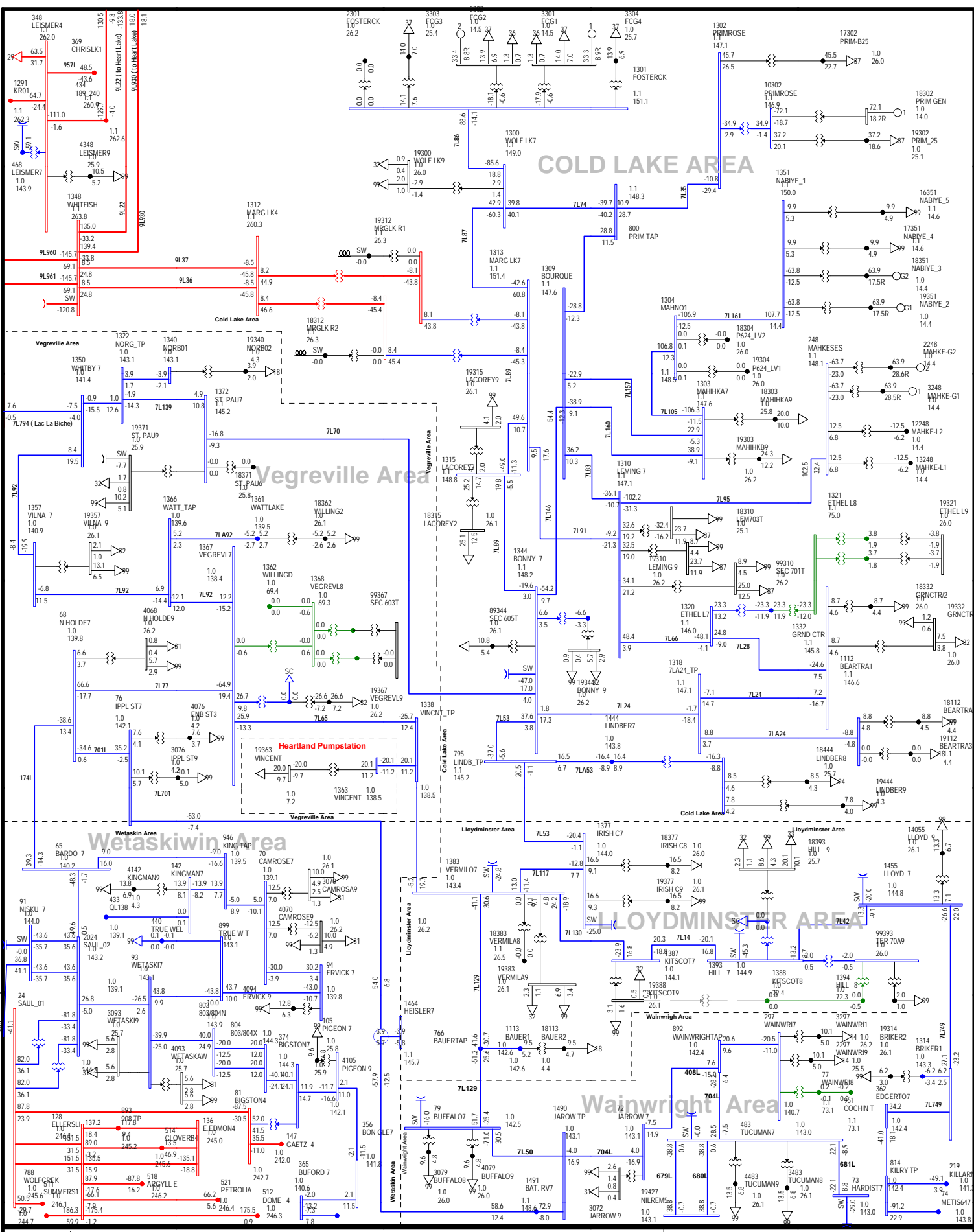
## Post-Connection System Load Flow Plots with the Irish Creek Capacitor

The post-connection load flow diagrams for Category A and selected Category B contingencies are provided in this section which include a 25 MVAR 144 kV capacitor at Irish Creek 706S as listed in Table C-1.

**Table C-1: List of Post-Connection Load Flow Diagrams which include a 25 MVAR capacitor at 706S**

Scenario	Load flow diagram	Page number
Scenario 3 2017SP	N-G, System Normal Condition	C-3
	N-G-1, Loss 7L53	C-4
	N-G-1, Loss 7L117	C-5
	N-G-1, Loss of 749L	C-6
	N-G-1, Loss of 7L50	C-7
	N-G-1, Loss of 7L65 segment to Vermilion 710S	C-8
	N-G-1, Loss of 7L65 segment to Vegreville 709S	C-9
Scenario 4 2017WP	N-G, System Normal Condition	C-10
	N-G-1, Loss 7L53	C-11
	N-G-1, Loss 7L117	C-12
	N-G-1, Loss of 749L	C-13
	N-G-1, Loss of 7L50	C-14
	N-G-1, Loss of 7L65 segment to Vermilion 710S	C-15
	N-G-1, Loss of 7L65 segment to Vegreville 709S	C-16





# P1410 - Heartland Pumpstation

2017SP Post-Connection

N-G, System Normal Condition

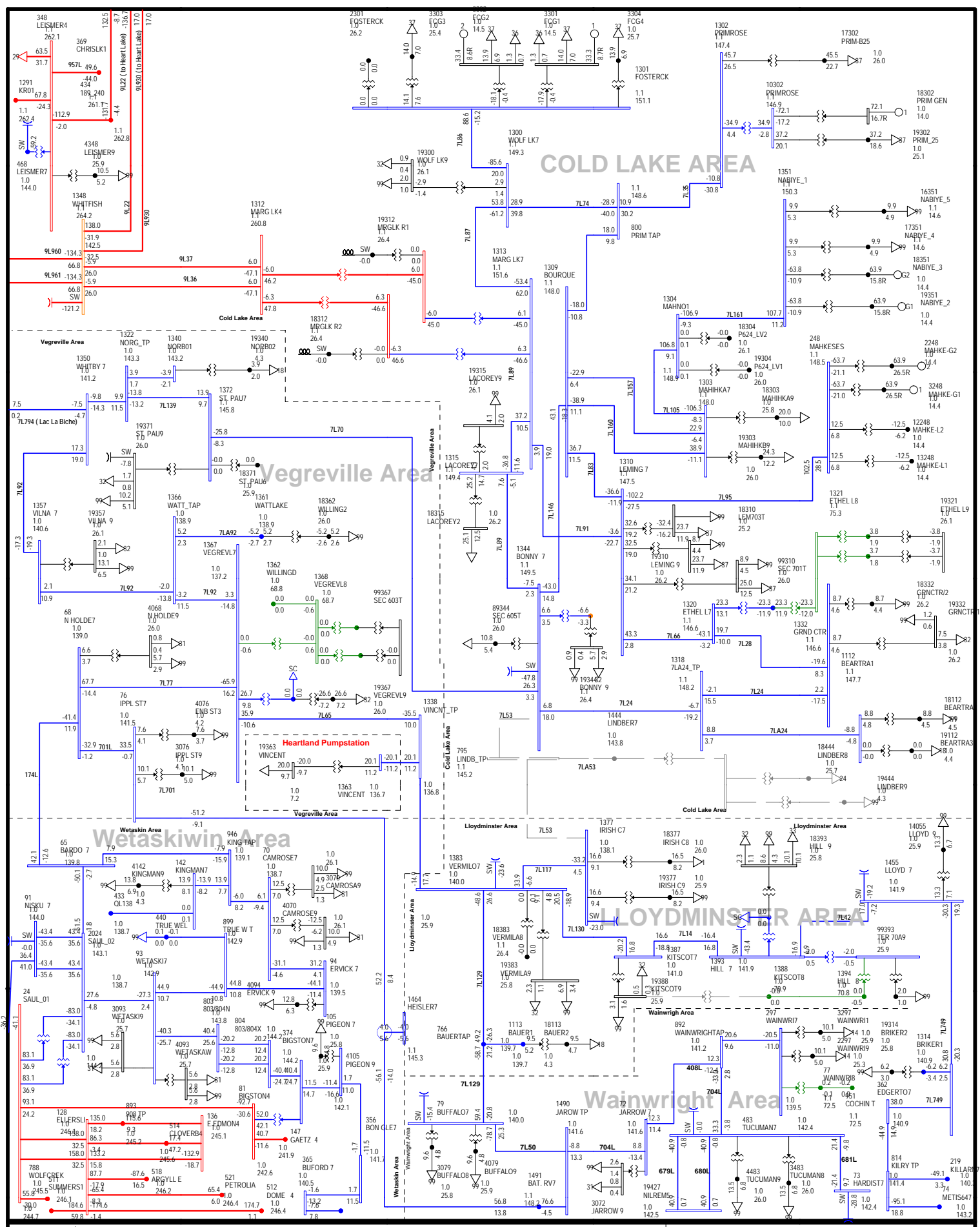
Bus - Voltage (kV/pu)  
 Branch - MW/Mvar  
 Equipment - MW/Mvar

100.0%Rate A

1.100OV 0.942LV

kV: <=25.000<=72.000<=144.000<=240.000<=500.000

C-3



## P1410 - Heartland Pumpstation

2017SP Post-Connection

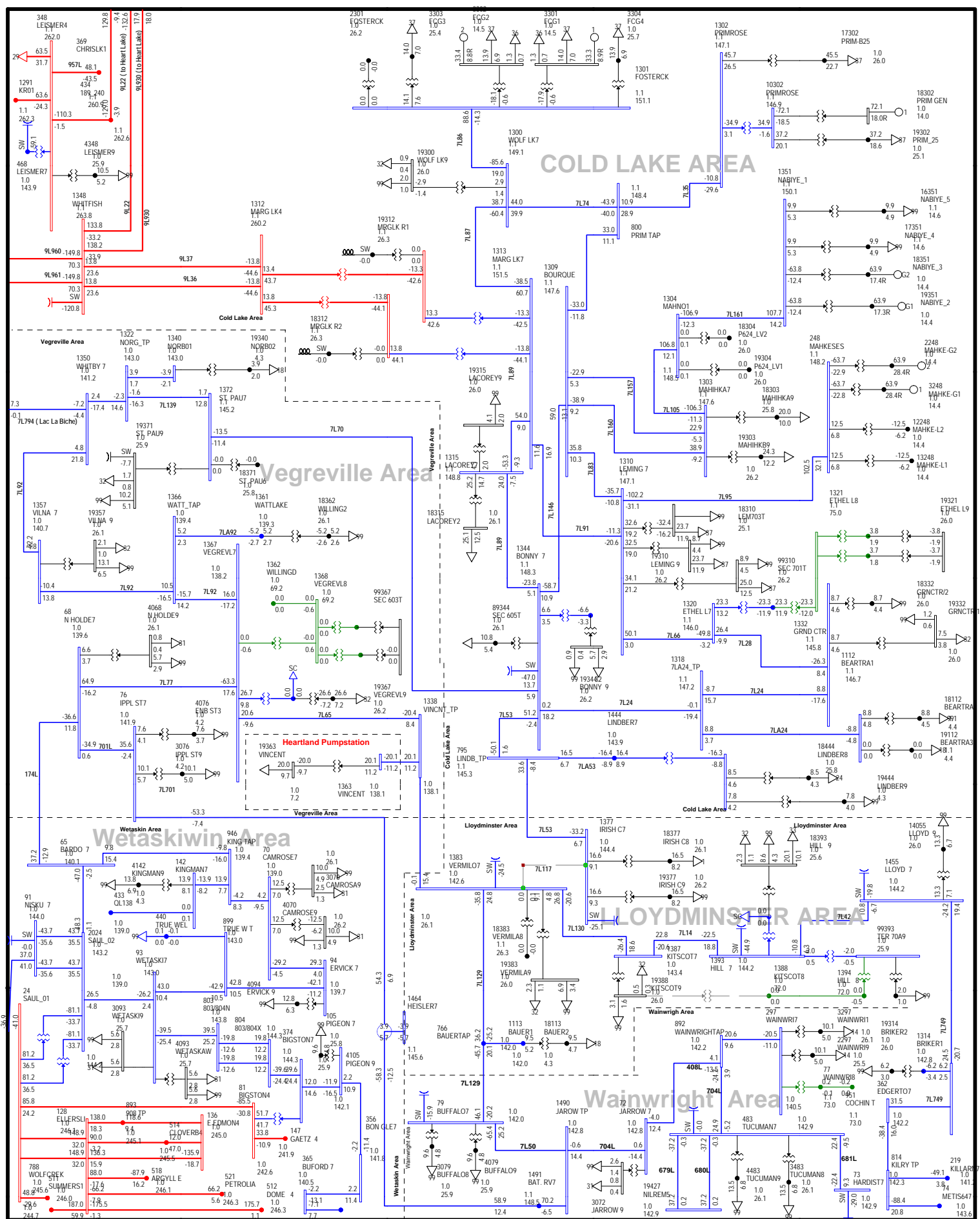
N-G-1, Loss of 7L53 from Bonnyville 700S to Irish Creek 706S

Bus - Voltage (kV/pu)  
 Branch - MW/Mvar  
 Equipment - MW/Mvar

100.0%Rate A  
 1.100OV 0.942LV

kV: <=25.000<=72.000<=144.000<=240.000<=500.000

C-4



## P1410 - Heartland Pumpstation

2017SP Post-Connection

N-G-1, Loss of 7L117 from Vermilion 710S to Irish Creek 706S

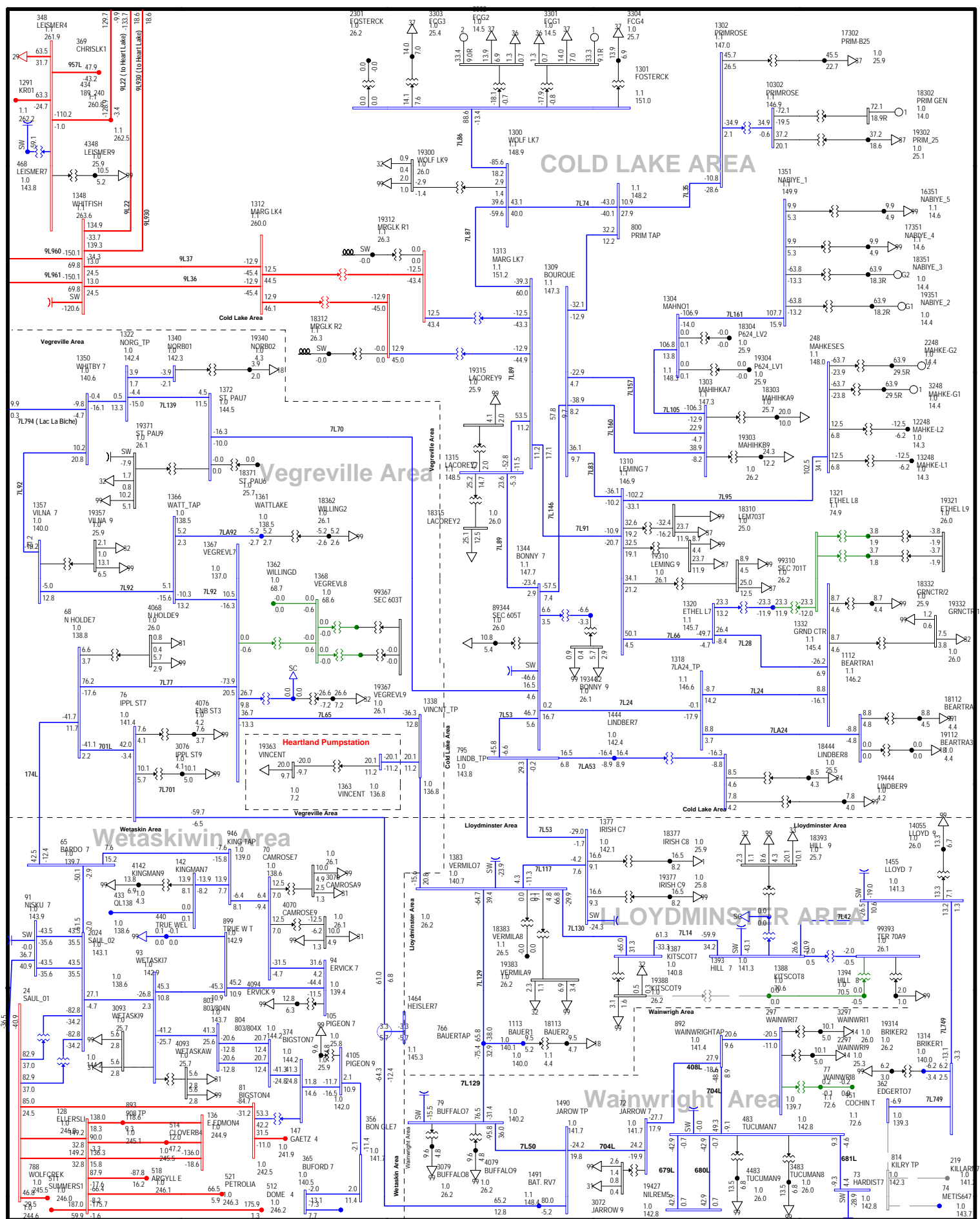
Bus - Voltage (kV/pu)  
 Branch - MW/Mvar  
 Equipment - MW/Mvar

100.0%Rate A

1.100OV 0.942LUV

kV: <=25.000<=72.000<=144.000<=240.000<=500.000

C-5



## P1410 - Heartland Pumpstation

2017SP Post-Connection

N-G-1, Loss of 749L from Metiskow 648S to Edgerton 899S

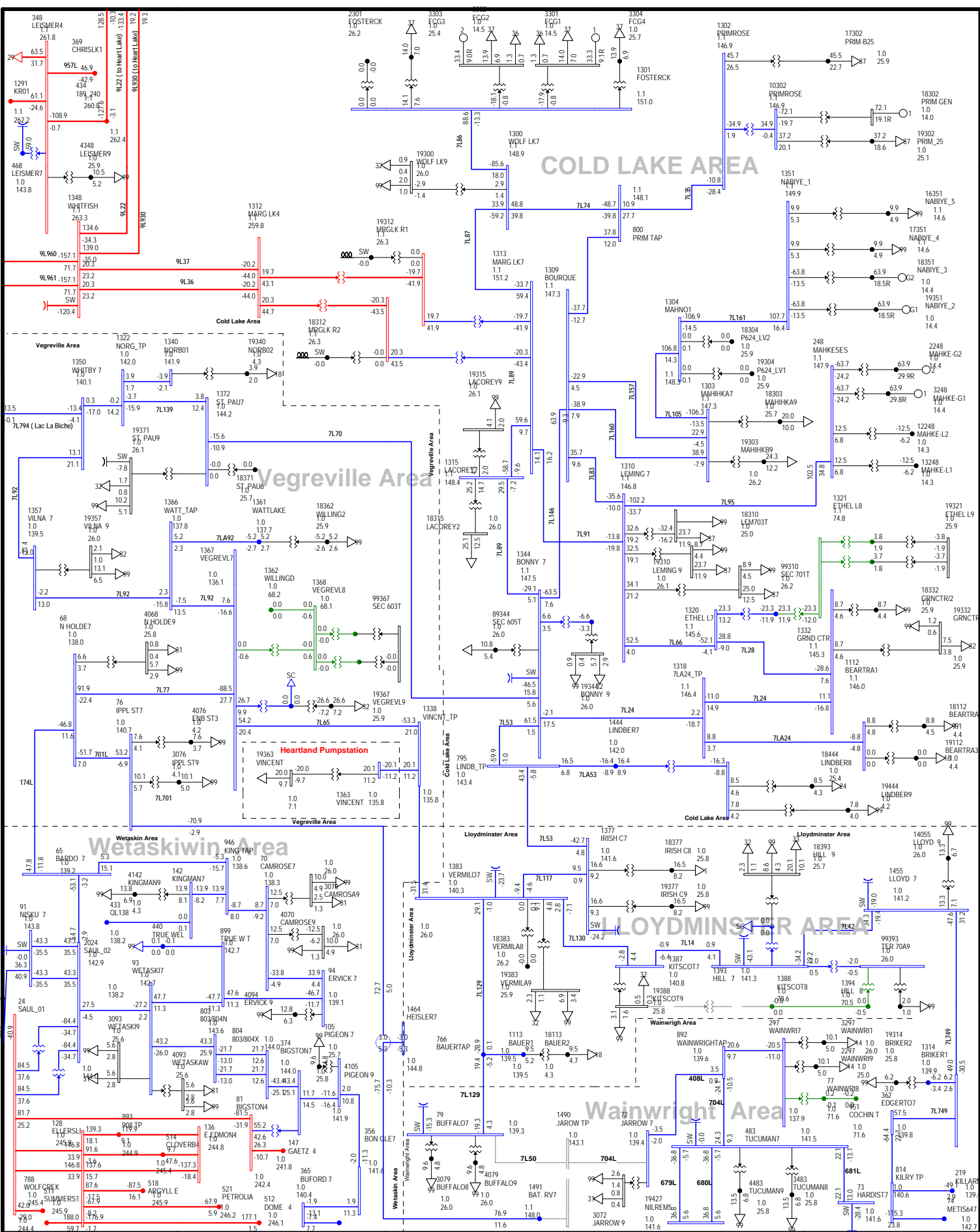
Bus - Voltage (kV/pu)  
Branch - MW/Mvar  
Equipment - MW/Mvar

100.0%Rate A

1.100OV 0.942LV

kV: <=25.000<=72.000<=144.000<=240.000<=500.000

C-6



# P1410 - Heartland Pumpstation

2017SP Post-Connection

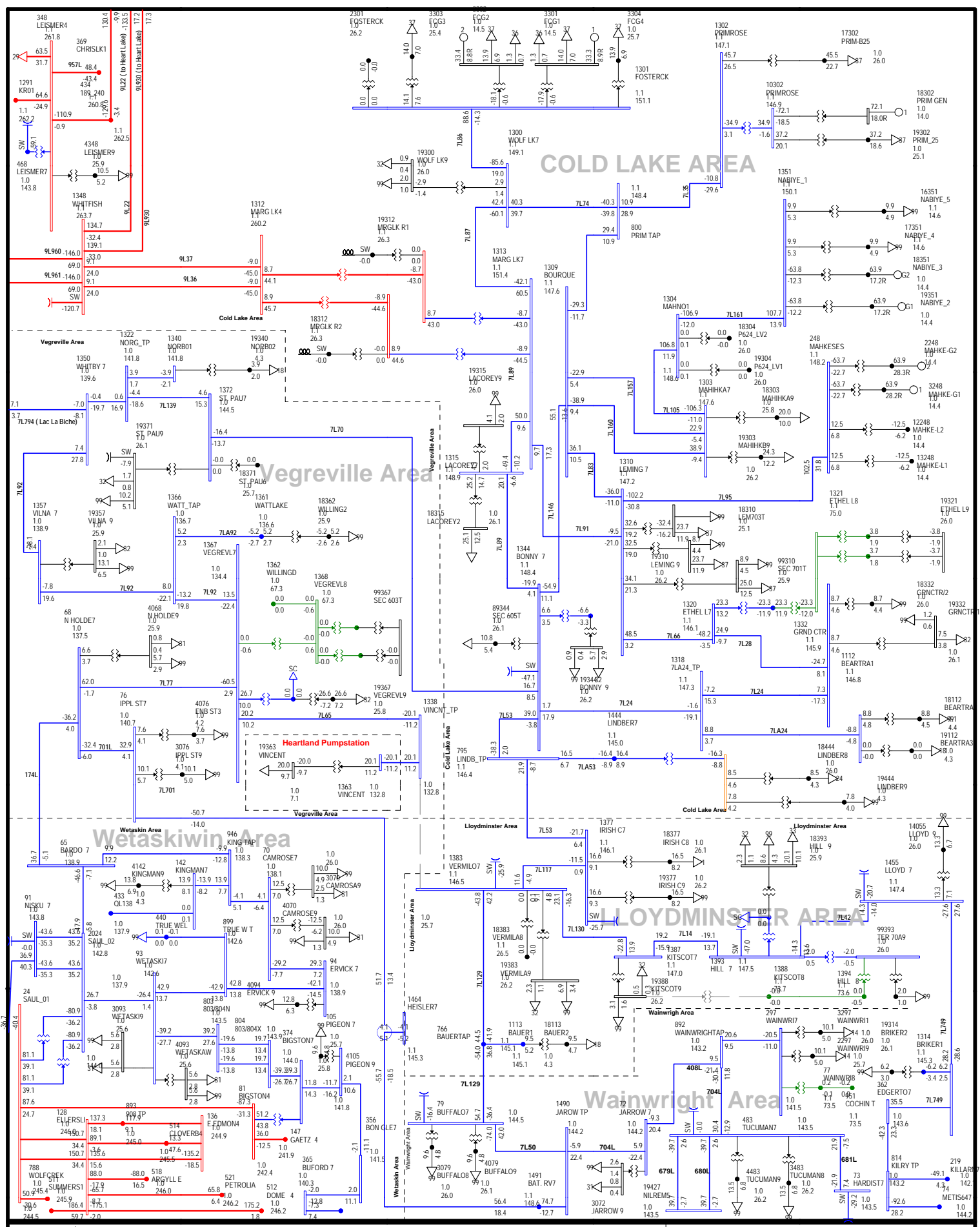
N-G-1, Loss of 7L50 from Battle River 75S to Buffalo Creek 526S

Bus - Voltage (kV/pu)  
 Branch - MW/Mvar  
 Equipment - MW/Mvar

100.0%Rate A  
 1.100OV 0.942LUV

kV: <=25.000<=72.000 <=144.000 <=240.000<=500.000

C-7



# P1410 - Heartland Pumpstation

2017SP Post-Connection

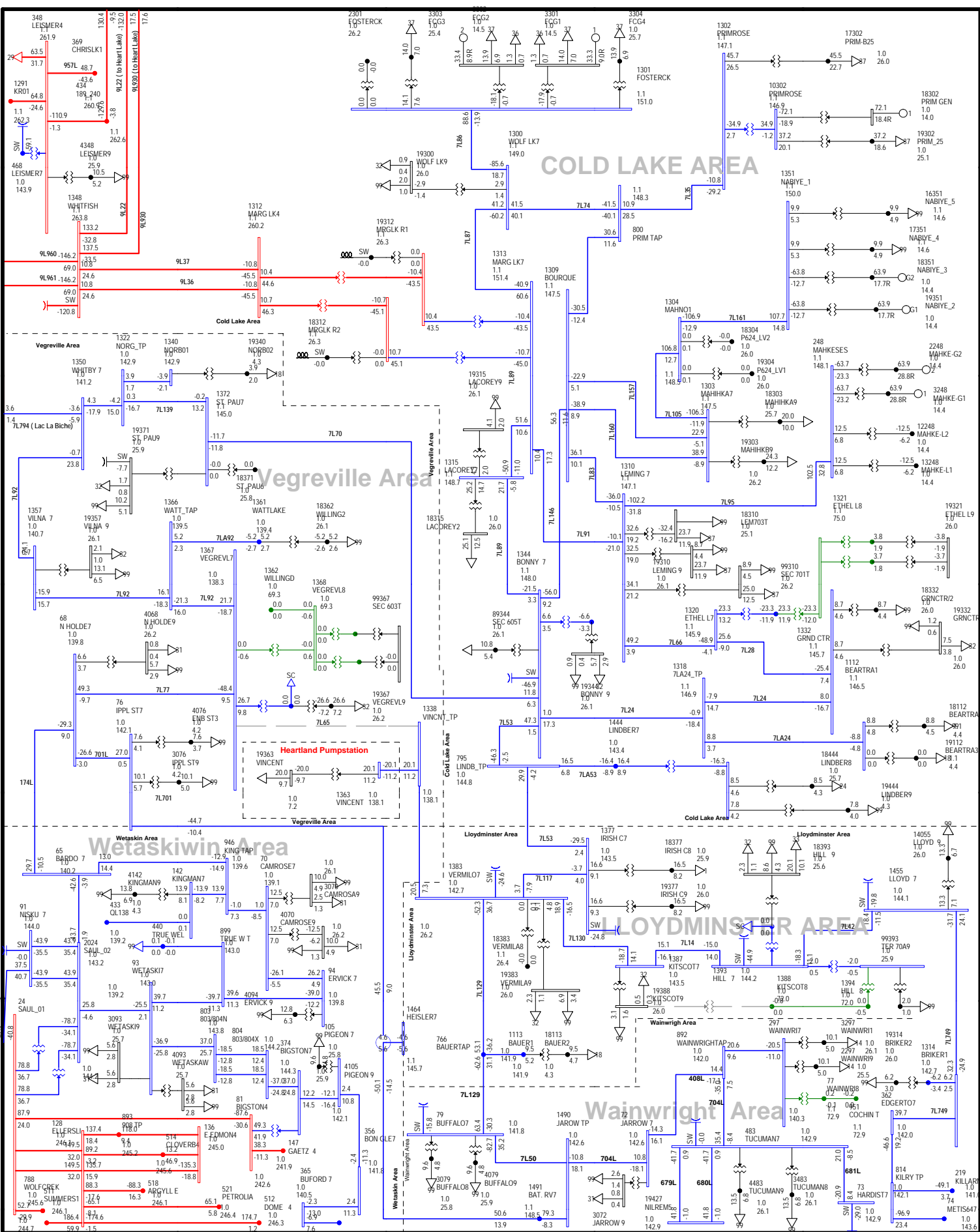
C-8

N-G-1, Loss of 7L65 segment from Vermilion 710S to Vincent 2019S

Bus - Voltage (kV/pu)  
 Branch - MW/Mvar  
 Equipment - MW/Mvar

100.0%Rate A  
 1.100OV 0.942LV

kV: <=25.000<=72.000<=144.000<=240.000<=500.000



# P1410 - Heartland Pumpstation

2017SP Post-Connection

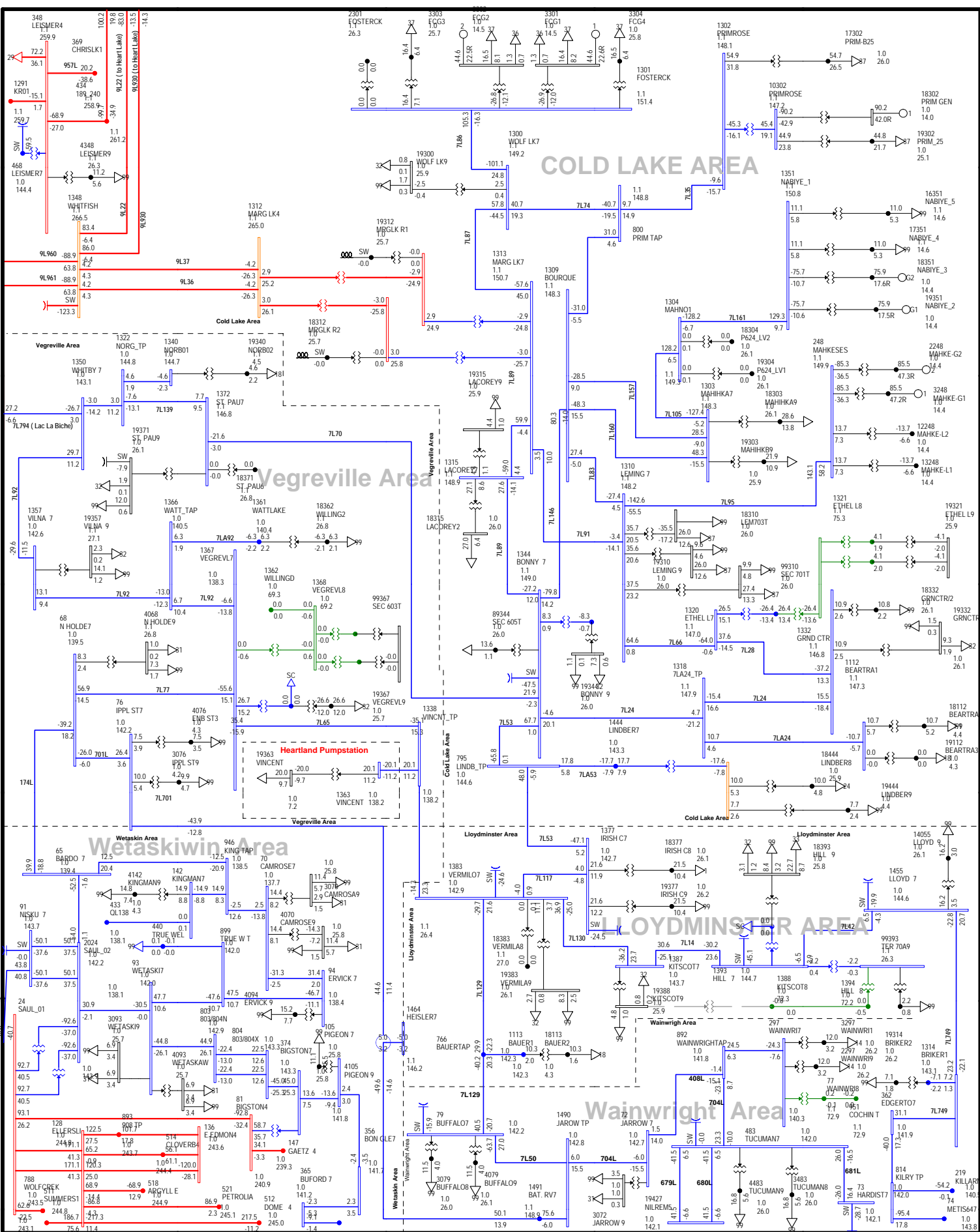
N-G-1, Loss of 7L65 segment from Vegreville 709S to Vincent 2019S

Bus - Voltage (kV/pu)  
 Branch - MW/Mvar  
 Equipment - MW/Mvar

100.0%Rate A  
 1.100OV 0.942LV

kV: <=25.000<=72.000<=144.000<=240.000<=500.000

C-9



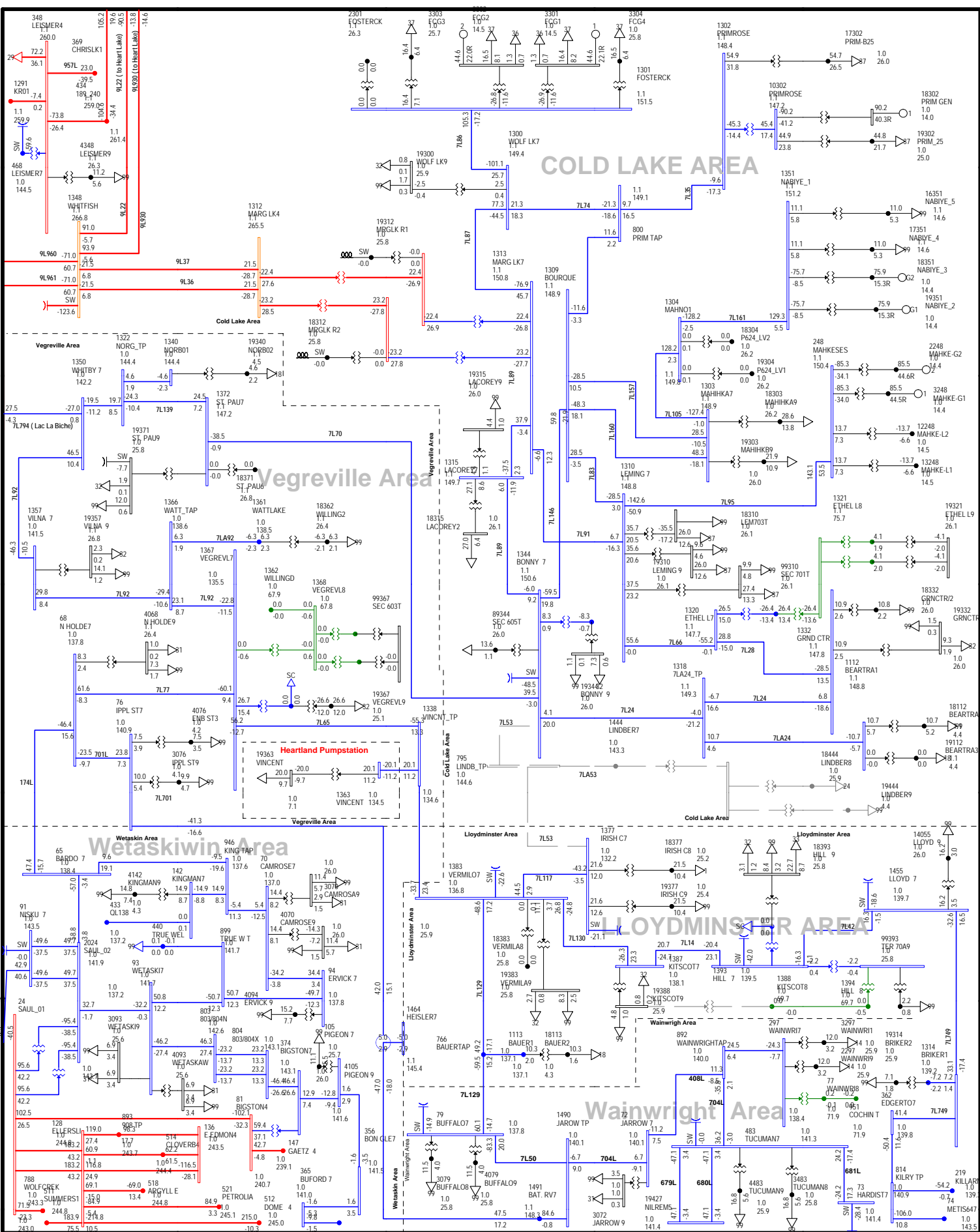
**P1410 - Heartland Pumpstation**  
**2017WP Post-Connection**  
**N-G, System Normal Condition**

Bus - Voltage (kV/pu)  
 Branch - MW/Mvar  
 Equipment - MW/Mvar

100.0%Rate B  
 1.100OV 0.942UV

kV: <=25.000 <=72.000 <=144.000 <=240.000 <=500.000





## P1410 - Heartland Pumpstation

### 2017WP Post-Connection

#### N-G-1, Loss of 7L53 from Bonnyville 700S to Irish Creek 706S

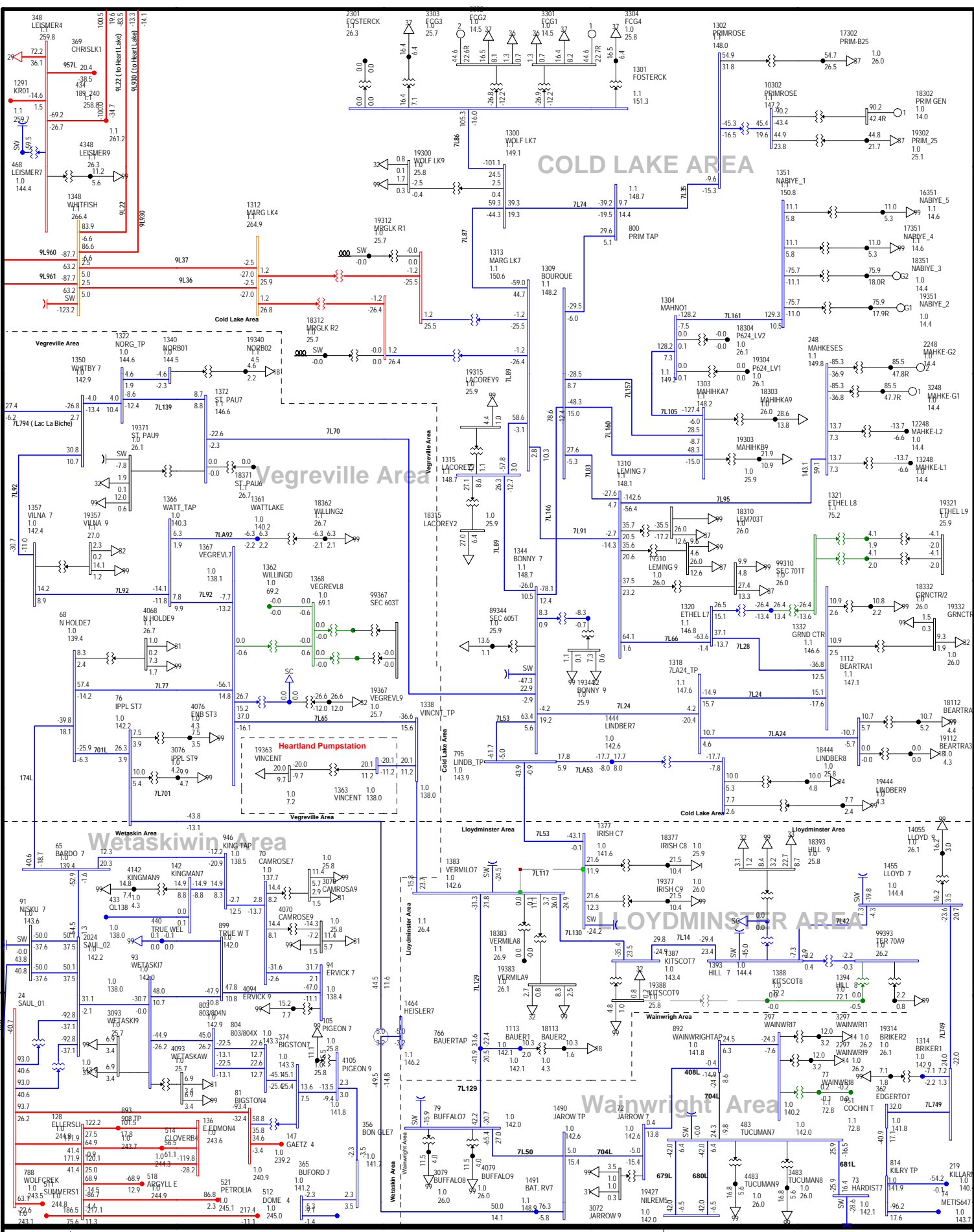
Bus - Voltage (kV/pu)  
 Branch - MW/Mvar  
 Equipment - MW/Mvar

100.0%Rate B

1.100OV 0.942UV

kV: <=25.000 <=72.000 <=144.000 <=240.000 <=500.000

C-11



## P1410 - Heartland Pumpstation

2017WP Post-Connection

N-G-1, Loss of 7L117 from Vermilion 710S to Irish Creek 706S

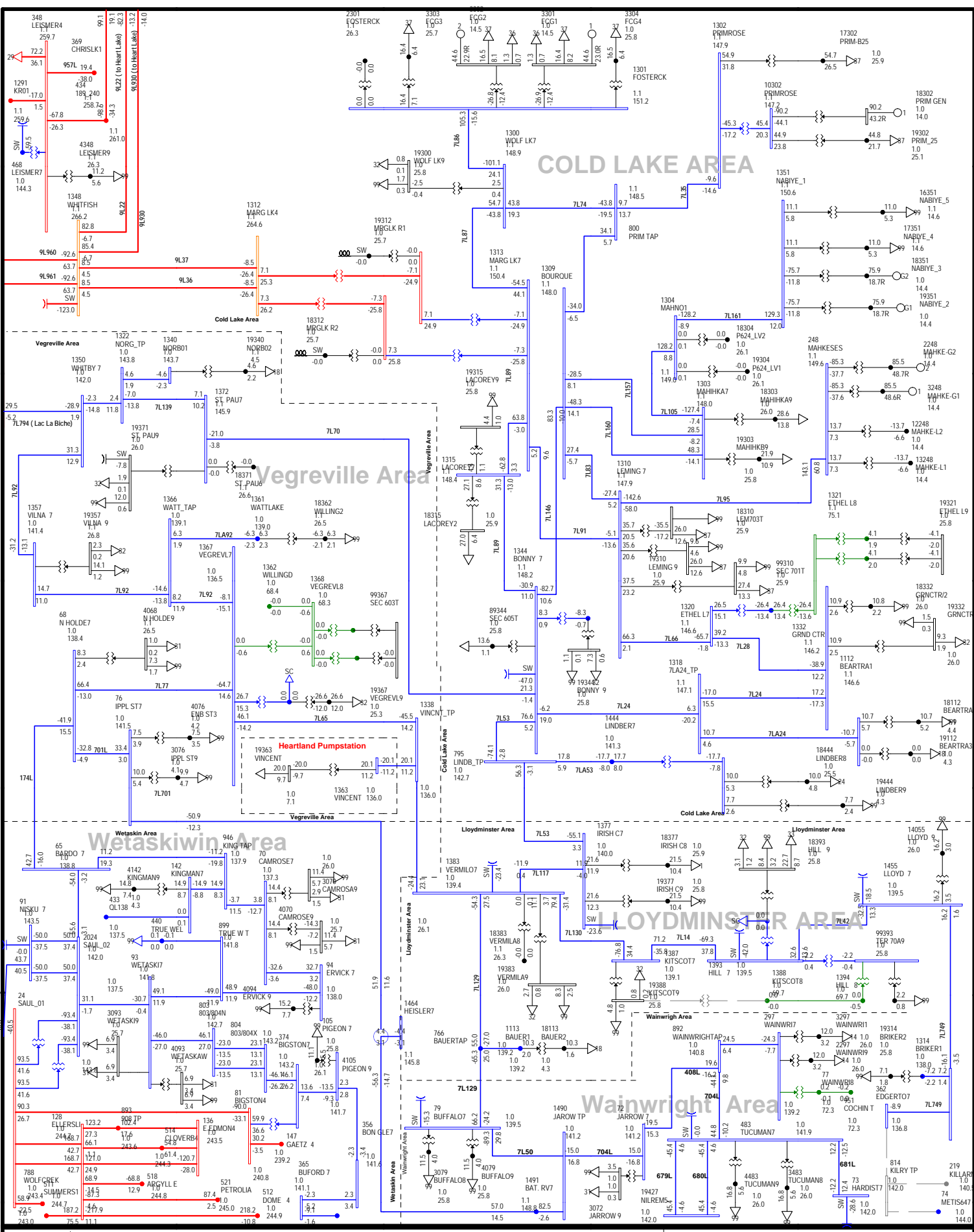
Bus - Voltage (kV/pu)  
Branch - MW/Mvar  
Equipment - MW/Mvar

100.0%Rate B

1.100OV 0.942UV

kV: <=25.000 <=72.000 <=144.000 <=240.000 <=500.000

C-12



# P1410 - Heartland Pumpstation

## 2017WP Post-Connection

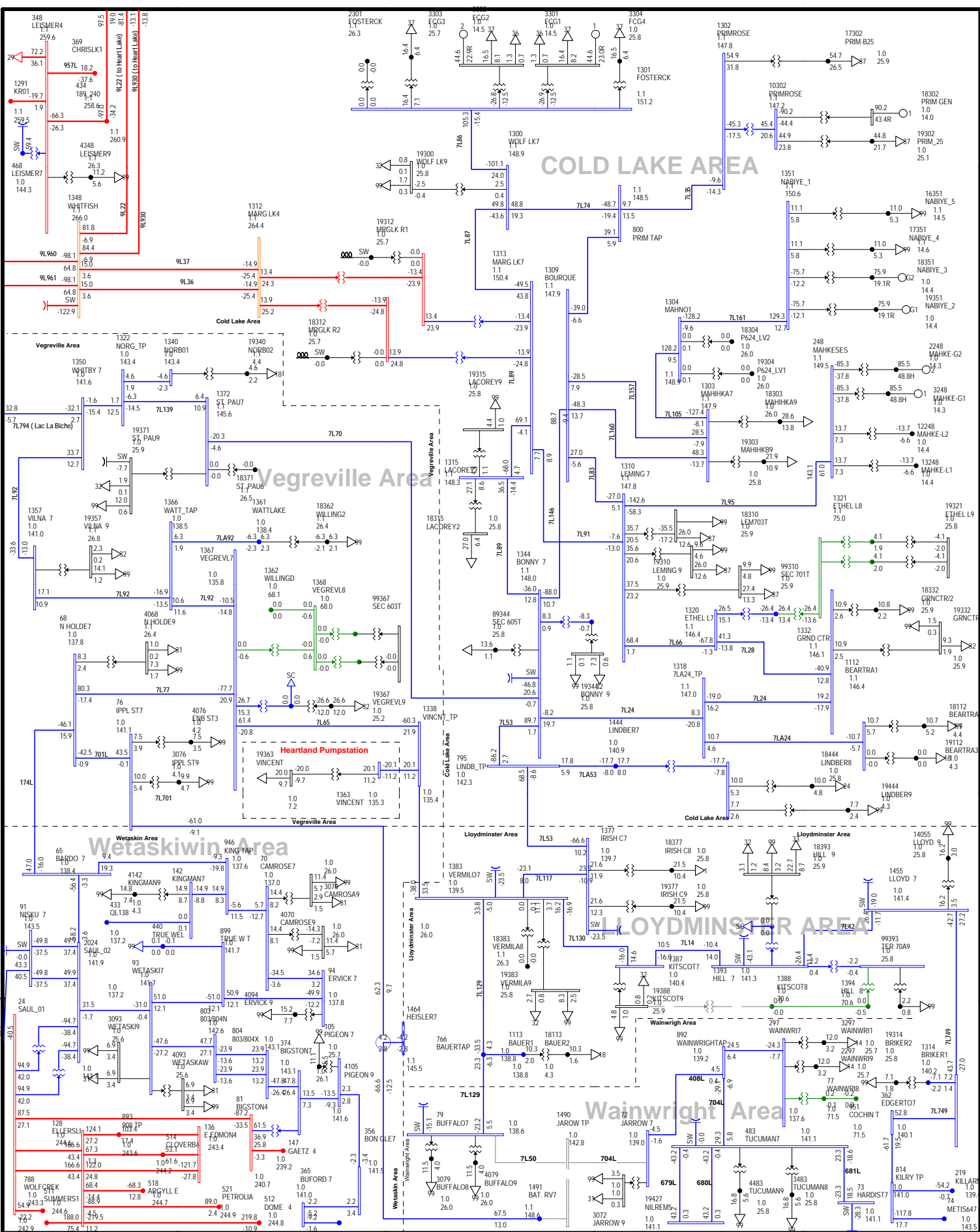
**N-G-1, Loss of 749L from Metiskow 648S to Edgerton 899S**

Bus - Voltage (kV/pu)  
Branch - MW/Mvar  
Equipment - MW/Mvar

100.0%Rate B

1.100OV 0.942UV

kV: <=25.000 <=72.000 <=144.000 <=240.000 <=500.000



## P1410 - Heartland Pumpstation

2017WP Post-Connection

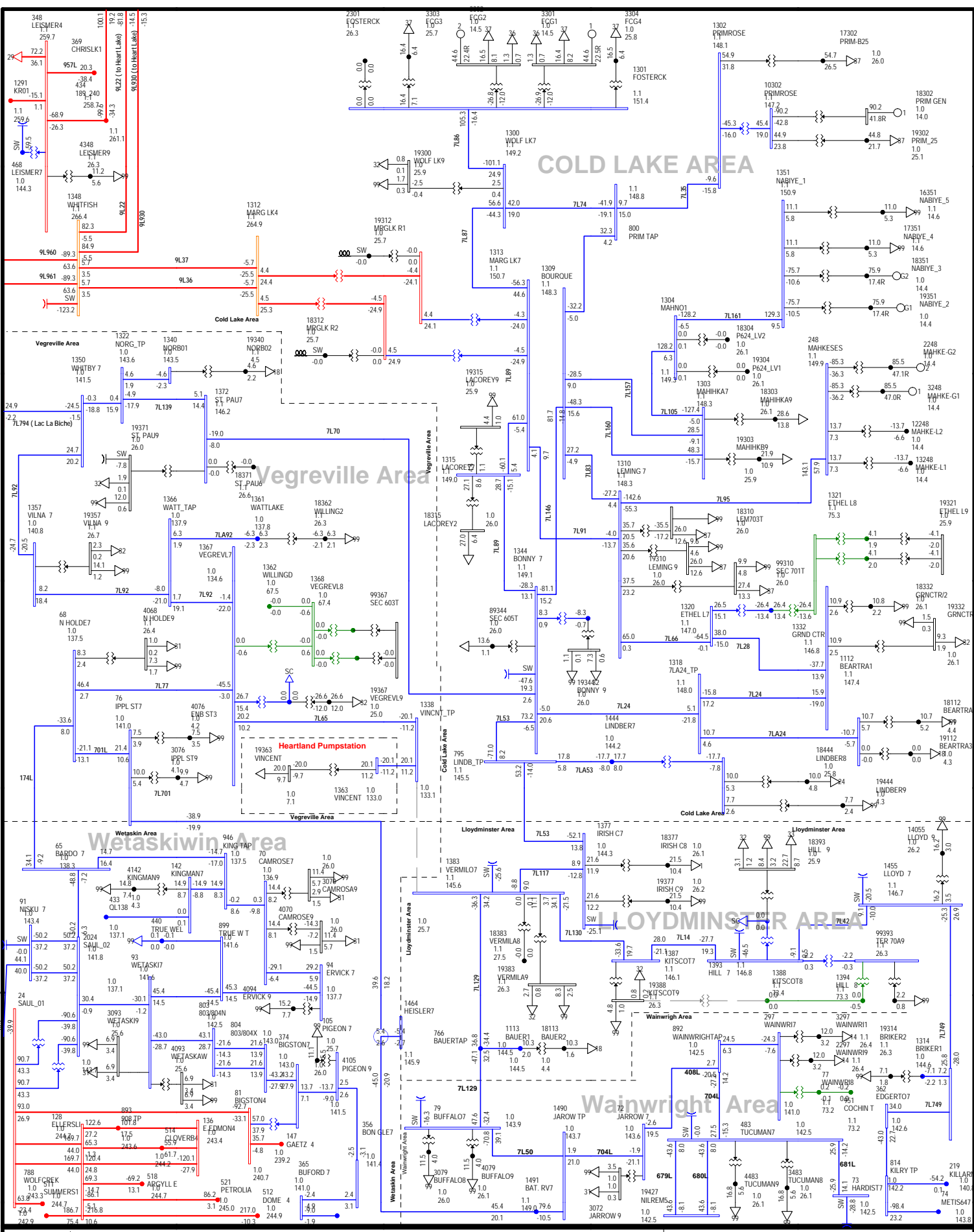
**N-G-1, Loss of Bus 75L50 from Battle River 75S to Buffalo Creek 526S**

Bus - Voltage (kV/pu)  
 Branch - MW/Mvar  
 Equipment - MW/Mvar

100.0%Rate B

1.100OV 0.942UV

kV: <=25.000 <=72.000 <=144.000 <=240.000 <=500.000



# P1410 - Heartland Pumpstation

## 2017WP Post-Connection

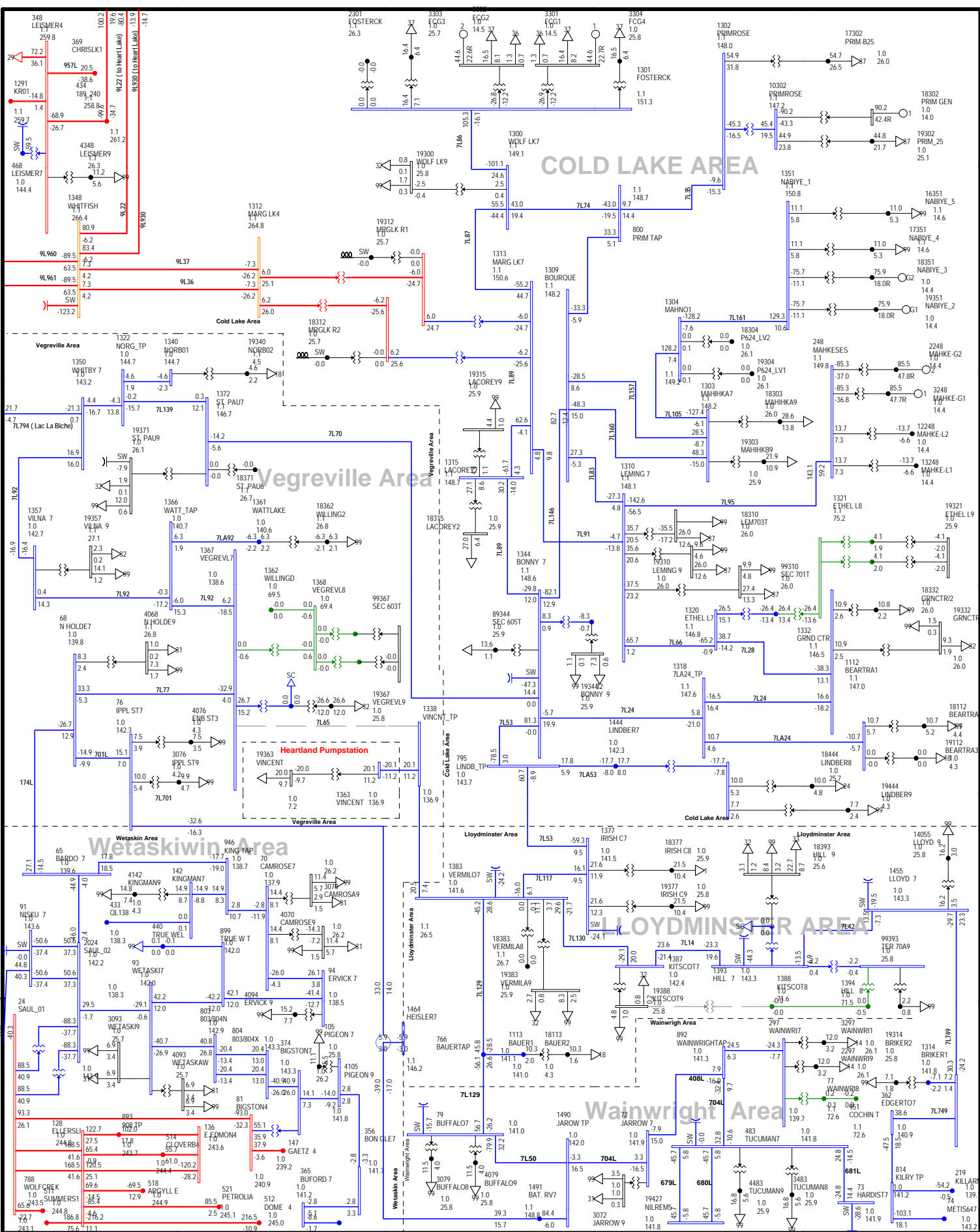
**N-G-1, Loss of 7L65 segment from Vermilion 710S to Vincent 2019S**

Bus - Voltage (kV/pu)  
 Branch - MW/Mvar  
 Equipment - MW/Mvar

100.0%Rate B  
 1.100OV 0.942UV

kV: <=25.000 <=72.000 <=144.000 <=240.000 <=500.000

C-15



## P1410 - Heartland Pumpstation

2017WP Post-Connection

N-G-1, Loss of 7L65 segment from Vegreville 709S to Vincent 2019S

Bus - Voltage (kV/pu)  
 Branch - MWM/Mvar  
 Equipment - MWM/Mvar

100.0%Rate B

1.100OV 0.942UV

kV: <=25.000 <=72.000 <=144.000 <=240.000 <=500.000

C-16