Appendix B9

EPS Transmission Reports

12-19-REP_EPS Watana Transmission Study Pre-Watana Analysis

11-17-REP_EPS Watana Hydro Transmission Corridor Report

Electric Power Systems inc.
Consulting Engineers

MWH
Watana Transmission Study
Pre – Watana Analysis

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Summary of Changes

Revision	Revision Date	Revision Description
0	July 19, 2012	Initial Report Draft

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Executive Summary

EPS has completed the Northern System Analysis to define the expected Railbelt transmission system prior to the completion of the proposed Watana project. This project analyzed the northern system between Anchorage and Fairbanks to determine the required transmission upgrades. The results of this study will be utilized with the preliminary results of other Railbelt studies to determine the most probable pre-Watana transmission configuration. This "probable" transmission configuration will be used in system studies to determine the impact of the proposed Watana project on the transmission grid.

The transmission configurations analyzed included single or double circuit 230 kV lines from Lorraine to Douglas, a new 138 kV line (new line constructed at 230 kV but operated at 138 kV) from Douglas to Healy, upgrade the Healy-Wilson and Healy-North Pole lines to 230kV line and construct a new station at Gold Creek substation between Stevens and Cantwell was also analyzed.

The transmission configurations were analyzed for the summer valley, summer peak and winter peak conditions using three different Healy generation levels. The three Healy generation levels included Healy generation at full output (including Eva Creek), HCCP offline (Healy #1 and Eva Creek at full output), and Healy #1 at minimum output (no Eva Creek). The cases were created to show the sensitivity of the Healy import limits due to different Healy generation levels.

When the lines from Douglas – Healy are upgraded to 230 kV, significant reactive compensation is required on the Railbelt system, especially during periods of little or no energy transfer over the Intertie. Until the Watana or another large hydro project is constructed, the Anchorage-Fairbanks Intertie is recommended to consist of a second line between Healy and Douglas constructed at 230 kV but operated at 138 kV. The results also show that adding the Gold Creek substation between Stevens and Cantwell results in a significant reduction in the required reactive support for the 138 kV and 230 kV Healy to Douglas line configurations and also provides increased sectionalizing.

Stability analysis was used to quantify the maximum Healy import levels based on different transmission and generation configurations and that in most cases the amount of power transferred from Healy north is somewhat constant with decreased Healy/Eva Creek generation allowing increased imports from the south. The addition of the second 138 kV line between Healy and Douglas increases the Healy import limit by a small amount for the same cases but provides for the firm transfer of the same power. Reducing Healy generation (turning HCCP offline, running Healy #1 at minimum) increases the Healy import limit. Upgrading of the Healy – Gold Hill / Wilson lines to 230 kV would further increase the Healy import limits to beyond 155 MW for all dispatches.

Power flow results show that the GVEA system will require transmission improvements in order to handle increased transfer levels. These upgrades will include increased transmission capacity on the 69 kV system from the Gold Hill / Wilson areas and possible transmission line additions. These upgrades are under the purview of GVEA and are outside of the focus of this study.

This study defined the most probable pre-Watana Railbelt transmission system configuration. This configuration includes the equipment additions below.

- Add one 138 kV lines from Douglas to Healy (new line constructed to 230 kV)
- Gold Creek Substation between Stevens and Cantwell

- 30 MVAR's of reactors (switchable)

- Lorraine Substation
  - 2 – 230 kV lines from Lorraine to Douglas
  - 1 – 230 kV line from Lorraine to Teeland
  - 1 – 230 kV line from Lorraine to Plant 2
  - 2 – 230 kV lines from Lorraine to Pt. Mackenzie
  - 80 MVAR's of reactors (switchable or SVC)
- Fossil Creek 115 kV substation
- Raptor Sub – Fossil Creek 115 kV line
- Bernice Lake – Beluga HVDC Line
- New 115 kV Line Bradley – Soldotna
- Rebuild 230 kV line Dave's Creek - University

The Fossil Creek substation, Raptor – Fossil Creek, Beluga-Bernice HVDC, Bradley-Soldotna and Dave's Creek-University improvements have been identified from previous Railbelt studies.

The probable transmission configuration will allow for Healy import levels between 100 and 130 MW if HCCP is offline, and 65 MW with all of Healy generation online. Table 1 shows the Healy transfer limits for the different Healy generation levels and load seasons.

Table 1 Healy Transfer Limits

Case	Summer Valley		Summer Peak		Winter Peak	
	Import	Export*	Import	Export*	Import	Export*
g1	-	-	65	160	65	161
g2	65	106	110	150	100	142
g3	100	112	130	140	125	135

* includes Eva Creek generation

The reliability of the GVEA system is increased by removing a single contingency islanding that occurs on the Healy – Douglas – Teeland line sections. The additions will also easily meet the future transmission system needs with the addition of the Watana hydro station by allowing for the conversion of the 138 kV lines from Douglas to Healy to 230 kV operation.

1 Introduction

EPS has completed the Northern System Analysis for the MWH pre-Watana project. The purpose of the study is to evaluate the transmission improvements required in the Railbelt transmission system ("backbone") prior to the construction of Watana. For purposes of this study, the backbone transmission system is defined as the 230 and 138 kV transmission lines from Anchorage to Gold Hill and Wilson substations in GVEA. Transmission requirements beyond the backbone are considered outside the scope of this study and are under the responsibility of the local utility.

The study utilized three seasonal power flow cases, summer valley, summer peak, and winter peak, using the IOC approved 2020 PSS/E base cases as a starting point. The pre-2023 power flow cases were configured to analyze the northern system to identify facility alternatives and to recommend a northern system plan for the pre-2023 time frame for different levels of Healy generation output and different levels of GVEA imports. The transmission upgrades were determined by applying the criteria mentioned below to determine their cost effectiveness for possible future Railbelt generation additions. Following the completion of the transmission system upgrades, it is assumed that the GVEA BESS will be available for loadshed and spinning reserve contributions as opposed to being scheduled for transmission contingencies. EPS assumed Healy Clean Coal and Eva Creek wind project were available for dispatch in the study.

The Northern transmission system evaluation assumed the most probable transmission system exists in the Central and Kenai transmission systems. The major improvements included in the study are: Anchorage - Dave's Creek line upgraded to 230 kV, Beluga – Bernice HVDC line, new Bradley – Soldotna 115 kV line, new Lake Lorraine station, and additional SVC capability in the 230 kV system.

2 Generation Dispatches

Generation dispatches were created to determine the effects different generation configurations would have on the results. Generation dispatches were created for each of the three load seasons, winter peak, summer peak, and summer valley. The generation dispatches were also created based on three different dispatch configurations of Healy plant outputs. These dispatches are Healy generators at maximum output (Healy #1, HCCP, and Eva Creek at full output), HCCP offline (Healy #1 and Eva Creek at full output), and Healy at minimum output (HCCP offline, Eva Creek offline, Healy #1 at minimum output of 18 MW). The Healy generation configurations are shown below in Table 2.1.

Table 2.1 Seasonal Generation Dispatches

Gen. Dispatch	Generator Output (MW)			
	Healy #1	HCCP	Eva Creek	North Pole Generators
Healy Max	Full	Full	Full	adjusted based on GVEA import
HCCP offline	offline	Full	Full	adjusted based on GVEA import
Healy Min	offline	minimum	offline	adjusted based on GVEA import

Power flow cases were created for the three different generation dispatches with Healy import levels ranging from 75 MW to 155 MW in 5 MW increments by adjusting or reducing the generation at North Pole (North Pole #1, #2, CC1, and ST2). The North Pole plant output was reduced until a maximum of 155 MW of Healy import was achieved. It was assumed that 155 MW of Healy import would be beyond the maximum import reasonable without the addition of the Watana large hydro unit. Additional cases were created below the 75 MW Healy import level for some summer valley and summer peak cases in order to verify stable system response. Tables 2.2, 2.3, and 2.4 shows the different Healy import cases created for the three different generation dispatches.

Table 2.2 Generation Dispatch #1, Healy at Full Output

Healy Flows (MW)		Healy	Summer	Summer	Winter
Import	Export*	Gen	Valley	Peak	Peak
50	145	103	-	x	-
55	150	103	-	x	-
60	155	103	-	x	-
65	160	103	-	x	x
75	170	103	-	x	x
80	175	103	-	x	x
85	180	103	-	x	x
90	185	103	-	x	x
95	190	103	-	x	x
100	195	103	-	x	x
105	200	103	-	x	x
110	205	103	-	x	x
115	210	103	-	x	x
120	214	102	-	x	x
125	219	102	-	x	x
125	220	103	-	-	x
130	225	103	-	-	x
135	230	103	-	-	x
140	235	103	-	-	x
145	239	102	-	-	x
150	244	102	-	-	x
155	249	102	-	-	x

* includes Eva Creek output   x denotes power flow case use

Table 2.3 Generation Dispatch #2, HCCP offline

Healy Flows (MW) Import	Export*	Healy Gen	Summer Valley	Summer Peak	Winter Peak
30	71	47	x	-	-
35	76	47	x	-	-
40	81	47	x	-	-
45	86	47	x	-	-
50	91	47	x	-	-
55	96	47	x	-	-
60	101	47	x	-	-
65	106	47	x	-	-
75	115	48	-	x	x
80	120	48	-	x	x
85	125	48	-	x	x
90	130	48	-	x	x
95	135	48	-	x	x
100	140	48	-	x	x
105	144	47	-	x	x
110	150	48	-	x	x
115	155	48	-	x	x
120	159	47	-	x	x
125	165	48	-	x	x
130	169	47	-	x	x
135	175	48	-	x	x
140	179	47	-	x	x
145	184	47	-	x	x
150	189	47	-	x	x
155	195	48	-	x	x

* includes Eva Creek output   x denotes power flow case use

Table 2.4 Generation Dispatch #3, Healy #1 at Minimum

Healy Flows (MW) Import	Export*	Healy Gen	Summer Valley	Summer Peak	Winter Peak
60	72	18	x	-	-
65	77	18	x	-	-
70	82	18	x	-	-
75	85	18	x	x	x
80	90	18	x	x	x
85	95	18	x	x	x
90	100	18	x	x	x
95	105	18	x	x	x
100	110	18	x	x	x
105	115	18	-	x	x
110	120	18	-	x	x
115	125	18	-	x	x
120	130	18	-	x	x
125	135	18	-	x	x
130	140	18	-	x	x
135	145	18	-	x	x
140	150	18	-	x	x
145	155	18	-	x	x
150	160	18	-	x	x
155	165	18	-	x	x

* includes Eva Creek output   x denotes power flow case use

3 Transmission Configurations

Several transmission upgrades and configurations were studied to determine their impact on the transfer limits into and out of the Healy substation. The transmission configurations include a second 230 or 138 kV (constructed at 230 kV, operated at 138 kV) line from Healy to Douglas, one or two 230 kV lines from Lorraine to Douglas, and upgrading the 138 kV transmission lines from Healy north to Gold Hill (reconductored to 954 Rail) and Wilson to 230 kV.

A proposed Gold Creek substation was analyzed for cases with two transmission lines (138 kV or 230 kV) between Douglas and Healy. The Gold Creek substation will be located between the Cantwell and Stevens substations and will include breaker locations for both transmission lines between Healy and Douglas. The combinations of the different transmission configurations are shown below in Table 3.1. Single line drawings of the transmission configurations are included in Appendix D.

Table 3.1 Transmission Configurations

Config #	Healy - Douglas #1 (138 kV)	Healy - Douglas #2 (138 kV)	Healy - Douglas #1 (230 kV)	Healy - Douglas #2 (230 kV)	Lorraine - Douglas #1 (230 kV)	Lorraine - Douglas #2 (230 kV)	Gold Creek Substation 138 kV	Gold Creek Substation 230 kV	upgrade lines from Healy to: Wilson (230 kV)	upgrade lines from Healy to: Gold (230 kV)
0	x				x					
1	x				x	x				
2	x	x			x	x				
3	x	x			x	x	x			
4	x	x			x	x			x	x
5	x	x			x	x	x		x	x
6			x	x	x	x				
7			x	x	x	x		x		
8			x	x	x	x			x	x
9			x	x	x	x		x	x	x

4 Reactive Support Analysis

Reactive support analysis was used to determine the location and size of the reactors on the Northern System. The reactive support is required to keep voltages below their maximum limit during line closing and low load and power transfer system conditions. The analysis included sensitivities to determine the amount of reactive support in SVC's versus from fixed reactors. Possible locations for reactive support will include the Healy, Douglas, and Lorraine substations, as well as at Gold Creek. The combinations of reactive support locations to be studied are shown in Table 4.1.

Table 4.1 Reactive Support Locations and Configurations

Config #	Healy	Douglas	Gold Creek	Lorraine
a	x	x		x
b	x		x	x

The criteria to determine the amount of reactive support required for the Northern System includes maximum voltage limits allowed on the Railbelt system as well as operation limits of the generators and the SVC's. The criteria are listed below:

- Voltages at the 230 kV undersea cable must be below 1.02 pu
- Voltages at 230 kV, 138 kV, and 115 kV must be below 1.05 pu
- Generators operating at unity power factor
- SVC's operating with a minimum 5 MVAR of margin

Line closing analysis on the transmission lines were used to determine the amount of reactors required to meet the criteria. The worst case line closing events are on the Healy – Douglas line sections. These line sections were opened at each end for each transmission configuration listed above and the amount of reactive support required was recorded. The summer valley cases with minimal import / export power between utilities represents the worst case system configuration.

It should be noted that the results assume that the existing 138 kV and 230 kV line reactors in the Anchorage area are in service and are online. It was assumed that the Lorraine reactor would be primarily used to keep the voltage on the 230 kV undersea cable at or below its maximum voltage limit of 1.02 pu. The Douglas, Gold Creek, and Healy reactors would primarily be used to reduce the voltages on the Healy – Douglas transmission lines during line closing events or low power transfer conditions. It was assumed that no additional reactive support is required for the current single 138 kV line between Douglas and Healy configuration except to control the voltage of the undersea 230 kV cable. The results of the reactive support analysis are shown in Table 4.2 below. Detailed results are shown in Appendix C.

Table 4.2 Reactive Support Results

Config #	Healy - Douglas 138 kV		Healy - Douglas 230 kV		Lorraine - Douglas 230 kV		Gold Creek		upgrade 230 kV		No GVEA Import Reactor Size (MVAR)				Total Comp (MVAR)
	#1	#2	#1	#2	#1	#2	138 kV	230 kV	H - W	H - GH	Lorr	Doug	Gold Crk	Healy	
0	x				x						53	0	-	0	53
1	x				x	x					70	0	-	0	70
2	x	x			x	x					76	137	-	5	218
3	x	x			x	x	x				76	-	27	0	103
4	x	x			x	x			x	x	81	137	-	27	245
5	x	x			x	x	x		x	x	81	-	27	0	108
6			x	x	x	x					121	240	-	101	461
7			x	x	x	x		x			107	-	83	0	190
8			x	x	x	x			x	x	115	244	-	131	490
9			x	x	x	x		x	x	x	99	-	92	3	193

The results show that the Gold Creek location (configurations 5, 7, and 9) results in a decrease of greater than 50% of the reactive support compared to using Douglas (configurations 2, 4, 6, 8). The results also show significant reactive support requirements for cases with 2 – 230 kV lines from Douglas – Healy (configurations 6-8). Based on these results, it is not recommended to install and operate the lines from Douglas – Healy at 230 kV. If an additional line from Douglas to Healy is constructed, it is recommended that it be built to 230 kV but operated at 138 kV. Upgrading the line from Healy – Gold Hill and operating it at 230 kV in conjunction with operating the Healy – Wilson line at 230 kV results in increased reactive requirements at Healy due to the increased charging of the transmission lines.

The reactive analysis was also completed for the summer peak and winter peak cases with high transfers north to Healy. These simulations were used to determine the maximum amount of reactors that could be online before the voltage would be reduced below 1.0 pu. The difference between the reactive support during high transfer levels and the summer valley minimal transfer cases were used to determine if switched reactors can be used and / or if part of the reactive support should be in the form of SVC's. The amount of reactive support in terms of fixed caps and SVC capability for the reduced set of cases are shown in Table 4.3

Table 4.3 Reactive Support Results

Config #	Healy - Douglas		Healy - Douglas		Lorraine - Douglas		Gold Creek		upgrade		Reactive Support (MVAR)					
									H - W	H - GH	Lorraine			Gold Crk		
	#1	#2	#1	#2	#1	#2	138 kV	230 kV	230 kV		Fix	SVC	Tot	Fix	SVC	Tot
	138 kV		230 kV		230 kV											
0	x				x						50	0	50		-	
1	x				x	x					80	0	80		-	
3	x	x			x	x	x				80	0	80	30	0	30
5	x	x			x	x	x		x	x	60	20	80	10	20	30
5a	x	x			x	x	x		x	x	80	0	80	30	0	30

The results for the reduced set of cases shows that the reactive support requirements increases from 50 to 80 MVAR's with the addition of the second 230 kV line from Lorraine to Douglas (configuration 1). The addition of the second 138 kV line from Healy – Douglas (configuration 3) requires an additional 30 MVAR of reactors at the proposed Gold Creek substation. Upgrading and operating the lines from Healy to Gold Hill and Healy to Wilson (configuration 5) require 20 MVAR of the reactive compensation at Lorraine and Gold Creek to be from SVC's. A sensitivity cases (configuration 5a) was created to determine if replacing the SVC capability with switchable reactors would impact the transfer capability of the system.

5 Transient Stability Analysis

Transient stability simulations were run to assess the impact of the proposed system improvements. Simulations of unit trip events and line fault and trip events were conducted to include the major transmission system lines as well as the large Railbelt generation units. These disturbances are shown in Table 5.2. All new transmission additions will have communications assisted protection schemes that result in clearing times of 5 cycles for the near and far end of the transmission lines. These values were also used for current transmission line contingencies.

Table 5.2 Dynamic Analysis Disturbances

Contingency		Volt (kV)	Fault Location	Clearing Time (Cycles)	
Name	Line			Local	Remote
a0	Wilson-Ft_WW	138	Wilson	5	5
a1	North_Pole-Ft_WW	138	North_Pole	5	5
a2	Douglas-Healy	138	Douglas	5	5
a3	Douglas-Healy	138	Healy	5	5
a4	Lorraine-West_Term	230	Lorraine	5	5
a5	Lorraine-Douglas	230	Lorraine	5	5
a6	Lorraine-Douglas	230	Douglas	5	5
b0	Eva_Creek-Healy	138	Healy	5	5
b1	Eva_Creek-Healy	138	Eva	5	5
b2	Eva_Creek-Wilson	138	Eva	5	5
b3	Gold_Hill-Healy	138	Healy	5	5
u0	Eva_Creek-Healy	230	Healy	5	5
u1	Eva_Creek-Healy	230	Eva	5	5
u2	Eva_Creek-Wilson	230	Eva	5	5
u3	Gold_Hill-Healy	230	Healy	5	5
g0	NPCC1		n/a - trip only		
g3	Healy		n/a - trip only		
g4	HCCP		n/a - trip only		

The transient stability criteria include limits on the system frequency, voltage levels, and system response, and unit response. The transient criteria listed below will be used for N-1 contingency analysis and will be applied to the backbone of the northern transmission system.

- Sustained voltages on the 138 kV and 230 kV buses must not be below 0.85 pu
- Frequency must stay between 57 Hz and 62 Hz
- System response must not exhibit large or increasing amplitude oscillations in frequency or voltage
- Units must not exhibit out of step or loss of synchronism response
- Single contingency cannot cause uncontrolled load shedding

The contingencies were run for the transmission configurations and generation dispatches listed above. The output files were analyzed along with plots of the simulations to determine the the stability limit of power flows into the Healy substation. The simulation plots are included in an electronic appendix due to its large size.

5.1 Summer Valley Results

The summer valley results show that the Healy import level for cases with HCCP offline (dispatch 2) are quite small at 35 MW even following the addition of the Lake Lorraine – Douglas transmission line in comparison to the assumed 75 MW GVEA import limit of the existing system. The addition of the second 230 kV line from Lorraine – Douglas does not increase the stability limit The addition of the second 138 kV line from Douglas to Healy increases the stability limit to 100 MW while keeping Eva Creek and Healy #1 online at their maximum. With Healy at its minimum and HCCP and Eva Creek offline (dispatch 3) the stability limit increases from 35 to 65 MW for cases with a single 138 kV line from Douglas to Healy (configurations 0 and 1). The addition of the second 138 kV line from Douglas to Healy (configurations 3 and 5) increases the stability limit to its maximum allowed while keeping Healy #1 online at its minimum output. Table 5.3 shows the stability results for the summer valley cases.

Table 5.3 Healy Import Stability Limits – Summer Valley

Case	Healy Limits (MW)							
	0		1		3		5	
	Import	Export*	Import	Export*	Import	Export*	Import	Export*
g2	35	76	35	76	65	106	65	106
g3	65	77	65	77	100	112	100	112

(red)	limiting contingency: Lorraine - Douglas
(blue)	limiting contingnecy: Douglas - Healy
(green)	limited due to generation dispatch

* includes Eva Creek Generation

5.2 Summer Peak Results

The summer peak case results show that the stability limit does not increase materially with the addition of a second 230 kV line from Douglas to Lorraine and the second 138 kV line from Douglas to Healy when Healy generation is at full output (dispatch 1), however, the second line does prevent the loss of load in the GVEA system for the loss of a Anchorage – Fairbanks line. The conversion of the Healy to Gold Hill and Healy to Wilson 138 kV lines to 230 kV operation along with the addition of the second line from Douglas to Healy allow for stable Healy import capability to at least 155 MW. Turning off HCCP (dispatch 2 and 3) increases the stability limit compared to cases with HCCP online. Dispatches 2 and 3 also show an increase in the stability limits due to the addition of the second 138 kV line from Douglas to Healy. Upgrading the 138 kV lines from Healy north to Gold Hill and Wilson allow for a Healy import level of 155 MW without stability problems. Table 5.4 shows the stability results for the summer peak cases.

Table 5.4 Healy Import Stability Limits – Summer Peak

Case	Healy Limits (MW)							
	0		1		3		5	
	Import	Export*	Import	Export*	Import	Export*	Import	Export*
g1	55	150	55	150	70	165	125	219
g2	80	120	85	125	110	150	155	195
g3	80	90	85	95	130	140	155	165

(red)	limiting contingency: Lorraine - Douglas
(purple)	limiting contingnecy: Healy - Gold Hill or Healy - Wilson
(green)	limited due to generation dispatch

* includes Eva Creek Generation

5.3 Winter Peak Results

The winter peak results are similar to the summer peak results. Dispatching all Healy generation online at full output (dispatch 1) results in stability limits between 75 and 85 MW for

Electric Power Systems Inc. Consulting Engineers the different transmission configurations (0, 1, and 3) until the 138 kV lines from Healy north are upgraded to 230 kV (configuration 5). The addition of the second 138 kV line from Healy to Douglas allows for a large increase in Healy import levels for dispatch cases 2 and 3. The addition of all transmission upgrades (configuration 5) results in maximum Healy import levels of above 155 MW. Table 5.5 shows the stability results for the winter peak cases.

Table 5.5 Healy Import Stability Limits – Winter Peak

Case	Healy Limits (MW)							
	0		1		3		5	
	Import	Export*	Import	Export*	Import	Export*	Import	Export*
g1	75	171	75	171	85	181	155	249
g2	75	117	80	122	115	157	155	195
g3	80	85	85	95	130	140	155	165

(pink) limiting contingency: Lorraine - Douglas
(purple) limiting contingnecy: Healy - Gold Hill or Healy - Wilson
(green) limited due to generation dispatch
* includes Eva Creek Generation

Sensitivity analysis of configuration 5a with all reactive compensation in the form of switched shunts instead of 20 MVAR SVC's at Lorraine and Gold Creek (configuration 5) show minimal impact on the system response due to contingencies for all generation dispatches and seasonal cases. It is recommended that the reactive support be designed using switched reactors instead of SVC's. Detailed switching studies should be completed to ensure there are no adverse transmission system impacts due to energizing the reactors.

The upgrade / operation of the 138 kV lines from Healy north to Gold Hill / Wilson along with two 230 kV transmission lines from Lorraine – Douglas and two 138 kV lines from Douglas to Healy result in the ability to import high amounts of energy into the Healy substation (155 MW) with unconstrained operation of the Healy generation units. Due to the significant costs of these upgrades and the unlikeliness that GVEA would import these levels of energy transmission, configuration 5 is not deemed a probable upgrade path without Watana being built. The addition of the second 138 kV line from Healy to Douglas increases the import levels into Healy and also increases the reliability. The second line eliminates GVEA islanding due to single contingencies and allows the import of energy into the GVEA system to become firm. Table 5.6 shows the Healy transfer limits for the different generation dispatches for transmission configuration 3.

Table 5.6 Healy Stability Limits, Transmission Configuration 3

Case	Summer Valley		Summer Peak		Winter Peak	
	Import	Export*	Import	Export*	Import	Export*
g1	-	-	70	165	85	181
g2	65	106	110	150	115	157
g3	100	112	130	140	130	140

* includes Eva Creek generation

6 Power Flow Contingency Analysis

Power flow single contingency (N-1) analysis was used to determine the steady state impact of the upgrading the northern system with the addition of 2 – 230 kV lines from Lorraine to Douglas and the addition of a second 138 kV line from Douglas to Healy. The power flow contingencies to be used are 230 kV and 138 kV branches and transformers on the backbone system and are listed in Table 6.1. Since this study is focusing on upgrades required on the backbone system, overloads on other parts of the GVEA system will be mentioned only. Upgrades required outside the backbone system will be the responsibility of the individual utility.

Table 6.1 Power Flow Contingencies

From Bus	To Bus	ID	Voltage (kV)
Healy	Eva Creek	1	138
Eva Creek	Wilson	1	138
Healy	Nenana	1	138
Nenena	Ester	1	138
Ester	Gold Hill	1	138
Gold Hill	Wilson	1	138
Wilson	Ft. WW	1	138
Ft. WW	N. Pole Ind	1	138
N. Pole Ind	N. Pole Sub	1	138
N. Pole Ind	Carney	1	138
Lorraine	Douglas	1	230
Gold Hill 3 Winding Transformer			
FT WW 3 Winding Transformer			
Carney 3 Winding Transformer			

6.1 Power Flow Contingency - Criteria

The power flow criteria will include limits on voltage levels as well as branch flow levels. The power flow criteria are listed below and will be used for normal (all equipment in service) and N-1 contingency analysis.

- Voltages on the transmission system between 0.95 pu and 1.05 pu
- Branch flows on the transmission system below their rating (winter or summer)

6.2 Summer Valley Results

The summer valley cases (dispatches 2 and 3) exhibit overloads on Ft. Wainwright Sub – Ft. Wainwright Tap – Badger Tap 69 kV line sections due to a loss of the Ft. Wainwright – North Pole 138 kV line. The overloads are 105% of the 46 MVA summer rating of the lines. No other power flow violations occur. These overloads are outside the "backbone" system and should be eliminated by the utility.

6.3 Summer Peak Results

The summer peak cases have similar results for the three different generation dispatches. All three dispatches show overloads in the base cases without any contingencies. The base case overloads are the Hamilton – Ft. Wainwright 69 kV line, which overloads 105-107% of its 46 MVA summer rating. Generation dispatches 1 and 2 show low voltages at Nenana (0.93 pu) for an outage of the Eva Creek – Wilson line section. It is possible to eliminate this low voltage condition by increasing the reactive power output of the generators and SVC's at Healy, Gold Hill, and Wilson.

Outages of the Wilson – Ft. Wainwright 138 kV line result in heavy overloads (120 – 130%) on the Gold Hill – Aurora – Zehnder 69 kV line sections. An outage of one of the 3 winding transformers at Gold Hill or Ft. Wainwright will cause an overload on the remaining transformer. These overloads are outside the "backbone" system and should be eliminated by the utility.

6.4 Winter Peak Results

The winter peak cases with generation dispatches #1 and #2 would not converge for outages of the Eva Creek – Wilson 138 kV line section. The dispatch #1 case required the Healy import to be reduced by 20 MW before the power flow would solve with the contingency. The dispatch #2 case required the Healy import to be reduced by 15 MW. The power flow analysis was completed with these new reduced Healy import cases for generation dispatches #1 and #2.

All cases show low voltages at Nenana (0.93 pu) for an outage of the Eva Creek – Wilson line section. It is possible to eliminate this low voltage condition by increasing the reactive power output of the generators and SVC's at Healy, Gold Hill, and Wilson for dispatches #1 and #2. Dispatch #3 (Healy at minimum output) requires a reduction in Healy import levels of 5 MW in addition to the reactive support of the existing voltage support equipment.

All three dispatches show overloads in the base cases without any contingencies. The base case overloads are the Ft. Wainwright 3 winding transformer, which overloads 101-103% of its 100 MVA summer rating. An outage of one of the 3 winding transformers at Gold Hill or Ft. Wainwright will cause an overload on the remaining transformer. An outage of the Gold Hill transformer will also overload the Hamilton – Ft. Wainwright 69 kV line section by 167% of its 66 MVA rating. These overloads are outside the "backbone" system and should be eliminated by the utility.

7 Healy Import Limits Analysis

The power flow results were combined with the stability limits and are shown in Table 6.2. Note that the power flow import limits for the winter peak cases were reduced for all generation dispatch cases from their stability limits due to low voltages at Nenana for an outage of the Eva Creek – Wilson 138 kV line section.

Table 6.2 Healy Stability Limits (MW), Transmission Configuration 3

Case	Summer Valley				Summer Peak				Winter Peak			
	Stability		Power Flow		Stability		Power Flow		Stability		Power Flow	
	Import	Export*	Import	Export*	Import	Export*	Import	Export*	Import	Export*	Import	Export*
g1	-	-	-	-	65	160	65	160	85	181	65	161
g2	65	106	65	106	110	150	110	150	115	157	100	142
g3	100	112	100	112	130	140	130	140	130	140	125	135

8 Conclusions

This project analyzed the northern system between Anchorage and Fairbanks to determine the impact of transmission upgrades and to determine the most probable pre-Watana transmission configuration.

The transmission configurations analyzed included multiple 230 kV lines from Lorraine to Douglas, multiple lines (138 kV and 230 kV) from Douglas to Healy, and upgrading and converting the lines north of Healy to 230 kV. The transmission configurations were analyzed for different load levels and different Healy generation dispatches. The three Healy generation levels were Healy generation at full output (to include Eva Creek), HCCP offline (Healy #1 and Eva Creek at full output), and Healy #1 at minimum output. The cases were created to show the sensitivity of the Healy import limits due to different Healy generation levels.

The addition of a new line and operating the existing transmission line from Douglas to Healy at 230 kV result in significant reactive support requirements. Creating a new Gold Creek substation between Stevens and Cantwell can reduce the reactive support requirement by more than 50% and also improve the stability and sectionalizing by dividing the outage line by approximately 50% of it existing length. Based on the expected Healy import levels, it is recommended that if a second line is built between Healy and Douglas that it is constructed to 230 kV but operated at 138 kV to reduce the added reactor expense.

The Healy import stability limit is reduced when all generation at Healy is online and at full output. Reducing Healy generation will increase the Healy import limit. The addition of the second 138 kV line between Healy and Douglas increases the Healy import limit by a small amount when Healy generation is at full output. The Healy import limit increases by a larger amount when Healy generation is reduced. Upgrading and operating the lines from Healy north to 230 kV increase the Healy import limit to a high level, though GVEA may not be able to utilize the additional transfer level capability.

The GVEA system will require system improvements in order to handle increased transfer levels evaluated in this study. These upgrades might include possible transmission line additions and / or conversions of 69 kV lines to 138 kV. These upgrades are under the purview of GVEA and are outside the focus of this study.

The most probable transmission configuration for the Railbelt system for the pre – Watana time period includes the addition of a second 138 kV line from Douglas to Healy (constructed to 230 kV) along with constructing the Gold Creek substation with 30 MVAR of reactors.

Additions to the Anchorage area of the transmission system include building the Lorraine 230 kV substation with transmission line interconnections to Plant 2, Teeland, Douglas (2), and Pt. Mackenzie (2). 80 MVAR's of reactors will be placed at the Lorraine substation to keep the voltage of the undersea 230 kV cable below 1.02 pu. The Anchorage area system upgrades include that addition of the Fossil Creek 115 kV substation and the Raptor – Fossil Creek 115 kV transmission line. The Kenai system upgrades include the Bernice-Beluga HVDC line, new Bradley-Soldotna 115 kV line and the rebuild of the University-Dave's Creek line to 230 kV.