DEZÉ ENERGY CORPORATION

TALTSON TRANSMISSION EXPANSION PROJECT
TRANSMISSION ALTERNATIVES STUDY

FINAL REPORT

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EXECUTIVE SUMMARY

The existing Taltson Hydroelectric Project generates 18 MW of power at Taltson Twin Gorges facility and supplies the power to Fort Fitzgerald, Alberta and Hay River, Northwest Territories. This facility was built in 1964-65 by Northern Canadian Power Commission (NCPC) to supply power to the Pine Point mine and associated community. After closure of these facilities in 1986, the power supply was transferred to Northwest Territories Power Corporation (NTPC). However, because of significantly lower requirements the full potential of Taltson Twin Gorges facility has not yet been utilized.

In 2003 studies were carried out to investigate the opportunity of increasing the capacity of the existing plant and supplying power to four diamond mines located north of Great Slave Lake, in the vicinity of Snap Lake, Gahcho Kué, Ekati and Diavik mines. Between 2004 and 2006 further feasibility and environmental work was carried out. A proposal was made to increase power transfer to 54 MW by expanding generating facilities on Taltson River and Nonacho Lake and adding 161 kV and 69 kV transmission lines.

In June 2008 Teshmont Consultants LP was contracted to further study the Taltson transmission system. The goal of the study was to present the optimum technically and economically feasible route to stakeholders and concerned parties. Teshmont was asked to assess four alternative transmission routes based on technical and financial viability, as well as environmental and social impact.

Teshmont subcontracted Valard Construction for construction methodology, construction schedule and cost estimate support. AD Gould and Associates provided geotechnical expertise and foundation recommendations.

The first of the routes, named Baseline Alternative, has previously been studied. This route starts from Twin Gorges and spans along the east side of Great Slave Lake to Gahcho Kué, Snap Lake, Ekati and Diavik mines. Three different Baseline Alternative options were considered to supply power to Snap Lake.

The second alternative, named Trans-Island Option, starts from Twin Gorges and spans north over Great Slave Lake via the Simpson Islands to Snap Lake, Gahcho Kué, Ekati and Diavik mines. This option requires two relatively short submarine cable crossings, along with several special crossing structures.

The third alternative, named Submarine Cable Option, starts from Twin Gorges and spans north through Great Slave Lake, west of Simpson Islands, to Snap Lake, Gahcho Kué, Ekati and Diavik mines. Cable crossing length for this option would be between 60 and 70 km.

The fourth alternative, named West Route, starts from Twin Gorges and spans along the west side of Great Slave Lake, passing through Fort Smith, Fort Providence, and Yellowknife to Snap Lake, Gahcho Kué, Ekati and Diavik mines. This route is the longest alternative considered.

Electrical system studies were carried out for all four alternatives, including the three Baseline options. It was concluded that all routes are technically feasible. Due to line length, shunt reactor and series compensation stations are required along the route, as well as SVCs for reactive power and voltage support at the loads side. Single line diagrams of the substations were developed for the Baseline and Trans-Island options, based on the required equipment.

Desktop routing studies were performed for the Trans-Island, Submarine Cable and West Route options. The study was based on NAD 83 datum topographic maps, with a scale of 1:50,000. As a result of these studies, preliminary routes were selected for the above three options.

For the alternatives that include submarine cables, preliminary cable parameters and types were determined. Supply, transportation to site, installation methodology, and environmental impact were discussed.

For overhead transmission portions, electromagnetic field effects such as audible noise, radio interference, and electric and magnetic field magnitudes within right of way were calculated for use in the environmental impact assessment. A specification for the final route, LiDAR survey, was prepared.

Two aerial field studies were conducted for the Baseline and Trans-Island routes. During these studies the constructability of the line was assessed, and the possibility of locating special structures was investigated, especially over large bodies of water and lakes. At several environmentally and socially sensitive areas, the preliminary established routes were diverted and optimized.

During the second field survey, a geotechnical survey of the area was carried out. Based on this survey and aerial photo interpretation, four types of soil were identified. For these soil conditions, preliminary foundation designs were developed.

Following the desktop and system studies, and field survey, the construction methodology and project schedule were developed. The construction methodology addresses utilizing existing and constructing new winter roads, building temporary access trails, stage camps and marshalling yards, and labour camps. The objective was also to locate appropriate areas for barging and hauling material along the line route. Portions of the route which are not easily accessible by land were identified, and helicopter erection and stringing was proposed.

Stretches of the route with vegetation were identified, and the need to clear the right of way was assessed.

High level cost estimates were developed for all four alternatives based on budgets obtained from equipment and material suppliers, current market conditions and recent bids. These cost estimates are presented in Table 0-1. Following the alternatives assessment and cost estimate carried out in this study, the Baseline Option is the most favourable and is recommended for construction.

Table 0-1
Summary of Cost Estimates

Option	Length (km)	Estimated Cost in 2008 CAD
Baseline	693	[redacted] Ø
Trans-Island	731	[redacted] +40M
Submarine Cable	726	[redacted] +50M
West Route	1244	[redacted] +220M

The Trans-Island Option is the second most feasible alternative, with line length comparable to the Baseline Option. Crossing Great Slave Lake over a series of islands with an overhead line creates significant environmental impact in this environmentally sensitive region. Two submarine cable crossings would also be required to cross Hearne Channel and the channel between Blanchet and Eaton Islands. Due to the depth of Great Slave Lake, these would be some of the deepest cable crossings in the world. Combined with the uncertainty of the configuration of the lake bottom and difficulties in transporting, installing and maintaining the cables in remote and extreme climate areas, this option is less attractive than the Baseline Option.

The Submarine Cable Option assumes crossing Great Slave Lake with a 60 – 70 km long cable, and is more expensive than the Trans-Island alternative. Comments made for cable crossings of the Trans-Island Option also apply for this option. Additionally, in case of cable failure, the repair time in these extreme weather conditions will be approximately six months to a year, resulting in low reliability of the scheme. This alternative is not recommended.

The West Route Option is the longest alternative, with line length at the limit of technical feasibility. Intermediate series and shunt compensation would be required to maintain operating parameters stable and within limits. These intermediate stations will need to be accessible for maintenance and during forced outages. As this is the longest alternative, it would be most expensive for construction, operation and maintenance, and is therefore not recommended.

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TALTSON TRANSMISSION EXPANSION PROJECT
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1 INTRODUCTION

The existing Taltson Hydroelectric project generates 18 MW power at Taltson Twin Gorges facility and supplies the power to Fort Fitzgerald, Alberta and Hay River, Northwest Territories. Taltson Twin Gorges was built in the years 1964/65 by NCPC (Northern Canadian Power Commission) to supply electricity to Pine Point mine and associated community until the mine site was closed in 1986. Subsequently the Twin Gorges facilities were transferred to NTPC along with a number of other generation assets in the territories. However, because of significantly lower requirements the full potential of Taltson Twin Gorges has not been utilized for over 20 years, since the closure of Pine Point mine.

In 2003 initial studies were carried out to investigate the opportunity of increasing the capacity of the existing plant and supplying power to four diamond mines located north of Great Slave Lake, in the vicinity of Snap Lake, Gahcho Kué, Ekati and Diavik mines. The objective was to provide power to these mines and thereby displace a significant portion of the current diesel generation at these sites, which is an environmental hazard in the area. Between 2004 and 2006 further feasibility and environmental work was carried out to optimize project design, develop cost estimates, consider alternatives, develop operational and financial models and establish baseline environmental settings for a preferred route and arrangements. A proposal was made to increase the power transfer to 54 MW by expanding generating facilities on Taltson River and Nonacho Lake and adding about 554 km of 161 kV and 136 km of 69 kV transmission lines.

In June 2008 Teshmont Consultants LP was contracted to undertake further studies of the Taltson transmission system. Teshmont was presented with four alternative transmission routes for assessment based on technical and financial viability, as well as environmental and social impact. This report summarizes the results of the studies and activities that were undertaken to achieve the above objectives.

The first of the routes, named Baseline Alternative, has previously been studied. This route starts from Twin Gorges and spans along the east side of Great Slave Lake, to Gahcho Kué, Snap Lake, Ekati and Diavik mines. Three different Baseline Alternative Options were considered for supply to Snap Lake.

The second alternative, named Trans-Island Option starts from Twin Gorges and spans north over Great Slave Lake via the Simpson Islands to Snap Lake, Gahcho Kué, Ekati and Diavik mines. This option requires two relatively short submarine cable crossings and several special crossing structures.

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The fourth alternative, named West Route starts from Twin Gorges and spans along the west side of the Great Slave Lake, passing through Fort Smith, Fort Providence and Yellowknife to Snap Lake, Gahcho Kué, Ekati and Diavik mines. This route is the longest alternative considered.

This document has two main sections.

Section 2 addresses Baseline Alternative Studies, and contains electrical system studies, field study report, geotechnical report, electromagnetic field study, route mapping, construction methodology and schedule, and cost estimate.

Section 3 addresses the three alternate options: Trans-Island, Submarine Cable and West Route, and contains desktop route studies, system studies, geotechnical study, submarine cable considerations, field study report, construction methodology and schedule, and cost estimate for the three alternatives, Trans-Island, Submarine Cable and West Route.

In Section 4 recommendations for future work are given. Most of this work is related to the electrical equipment design parameters; therefore it will have to be completed before the equipment is ordered.

Section 5 concludes the studies and presents comparative assessment of the routes based on selected criteria.

Supporting documents such as detailed route maps for all four options, substation layouts, foundations, and details of the electrical and EMF studies are located in the appendices.

2 BASELINE STUDIES

2.1 SYSTEM STUDIES

2.1.1 Introduction

The existing 18 MW Twin Gorges plant currently supplies power to communities in Forts Smith, Resolution, Fitzgerald, and Hay River. The Taltson Hydroelectric Expansion Project will add 36 MW of generation at the existing plant, and interlinks the expanded generation facilities through a new transmission network to operating diamond mines at Ekati, Diavik and Snap Lake sites, as well as the proposed Gahcho Kué mine. The proposed transmission network will consist of 161 kV and 69 kV transmission lines. The existing transmission network and mine locations are shown in Figure 2-1.

2.1.2 Scope and Objectives

The scope and methodology of the study is comprised of the following steps:

a) Establish steady state voltage criteria to enable evaluation of acceptable performance;
b) Estimate line losses;
c) Identify possible locations of line connected shunt reactors and their Mvar rating in such a manner that voltages across the system meet the criteria;
d) Identify possible location of Static Var Compensation (SVC) and their ratings;
e) Perform dynamic simulation for various disturbances to assess dynamic stability of the system.

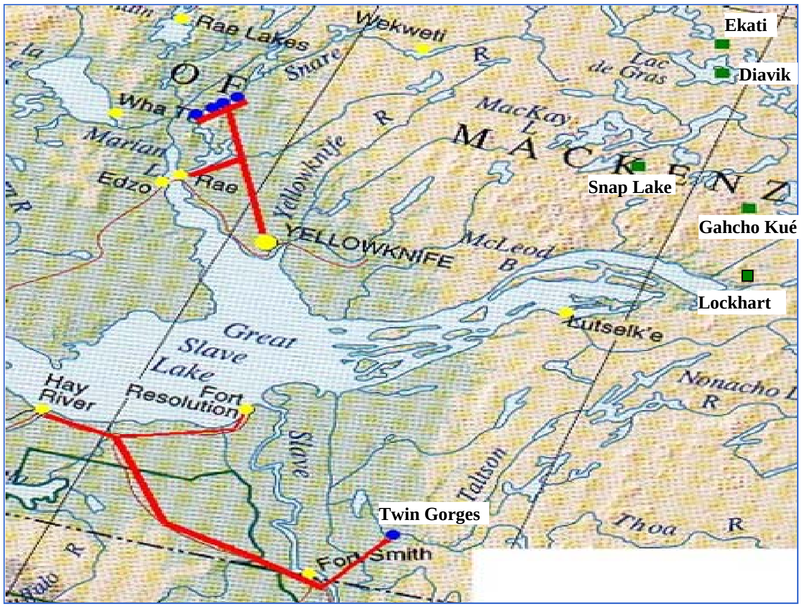
2.1.3 Criteria

The designated maximum system voltage is identified in ANSI C84.1-1995. Accordingly, the maximum and minimum continuous power frequency voltages for different system voltages are shown in the following table:

Table 2-1
Voltage Range

Nominal System Voltage	Maximum Voltage	Minimum Voltage
4.16 kV	4.37 kV	4.05 kV
69 kV	72.5 kV	-
115 kV	121 kV	-
161 kV	169 kV	-

Maximum voltage for the existing 72 kV system is not specified in the standard. Hence, it is assumed to be 75.6 kV.



Existing Generation and Transmission System in Great Slave Lake Area
Figure 2-1

2.1.4 Assumptions

The assumptions made in the power-flow and dynamic studies are:

a) The existing transmission lines are modelled using typical configurations and parameters for given line voltages;
b) Transmission line lengths are preliminary. Modest length deviations made in the routing desktop and field studies will not affect the results of this study;
c) During power-flow analysis it is assumed that the existing transmission lines are already energized successfully and the entire existing load is connected. The new (mine) load is connected to the system after successful energization of the complete system;
d) Dynamic parameters of new generators are assumed to be the same as that for the existing generator;
e) Turbine-governor details presented in the report have been published in the past by Monenco. Since there is no compatible PSS/E model to that described in the report, the Hydro Turbine-Governor is modelled using PSS/E model HYGOV and sample data presented in [2];
f) Excitation systems for the new generators are assumed to be IEEE AC1 type; and parameter values selected based on sample data presented in [3];

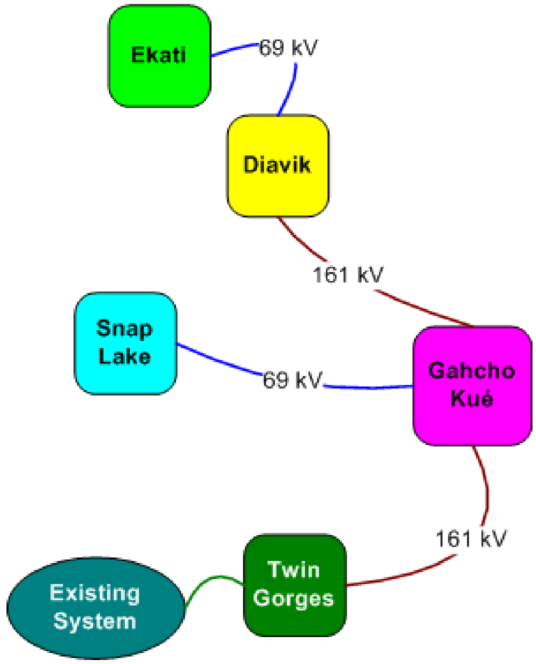
g) For all transformers, the taps are assumed to be fixed and set to nominal tap. Additionally, typical values for transformer impedance are assumed based on their voltage and MVA ratings;
h) The load is assumed to be connected to 4.2 kV bus at the mine site;
i) The power factor for all the loads is assumed to be 0.9 lagging;
j) During dynamic simulations the loads are assumed to be of constant impedance type.

2.1.5 Description of Baseline Options

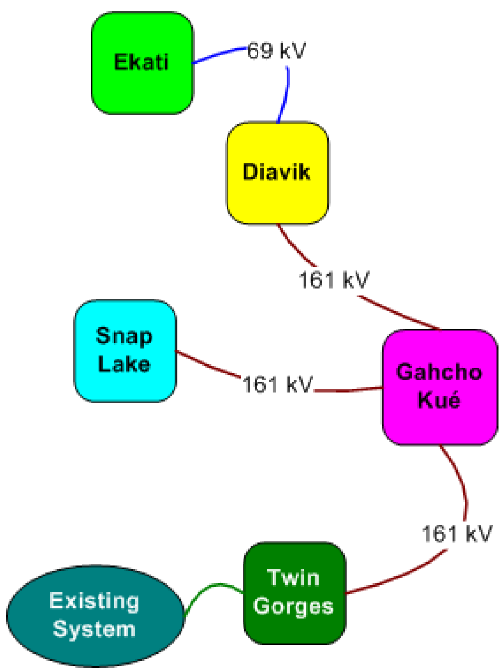
The new transmission network inter-connects Twin Gorges, Gahcho Kué Mine, Snap Lake Mine, Diavik Mine and Ekati Mine. Figure 2-1 shows the geographic locations of the sites. Three transmission network options were considered to connect mine loads. The three line route options studied are shown in Figure 2-2, Figure 2-3 and Figure 2-4; and line voltages and length under different options are shown in Table 2-2. Transmission line lengths are preliminary. Modest length deviations made in the routing desktop and field studies will not affect the results of this study. Three single line diagrams of system options, including the existing system, are shown in Figure 2-5, Figure 2-6, and Figure 2-7.

Table 2-2
New Transmission System Baseline Case Options

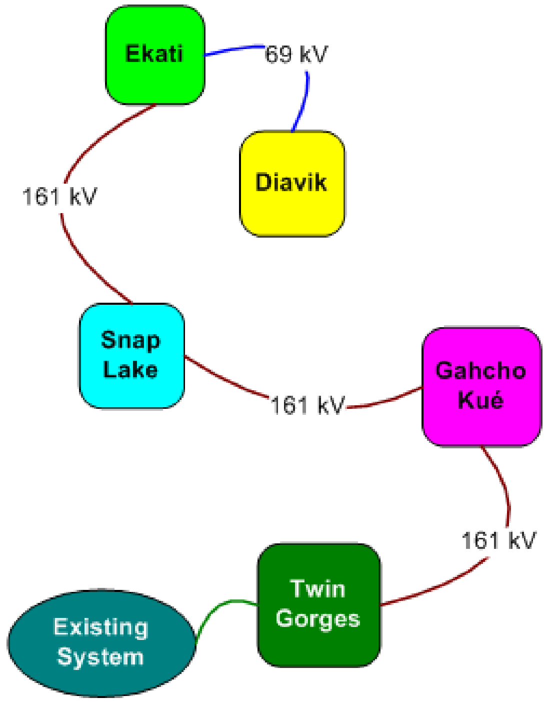
Transmission Line	Line Length	Line Voltages		
		Option 1	Option 2	Option 3
Twin Gorges - Gahcho Kué	383 km	161 kV	161 kV	161 kV
Gahcho Kué - Snap Lake	96 km	69 kV	161 kV	161 kV
Gahcho Kué - Diavik	171 km	161 kV	161 kV	--
Snap Lake – Ekati	149 km		--	161 kV
Ekati - Diavik	40 km	69 kV	69 kV	69 kV
		Line Length (km)		
161 kV		554	650	628
69 kV		136	40	40
Total line length (161 kV and 69 kV), (km)		690	690	668
Note: Line lengths are according to the Ian Hayward report.				



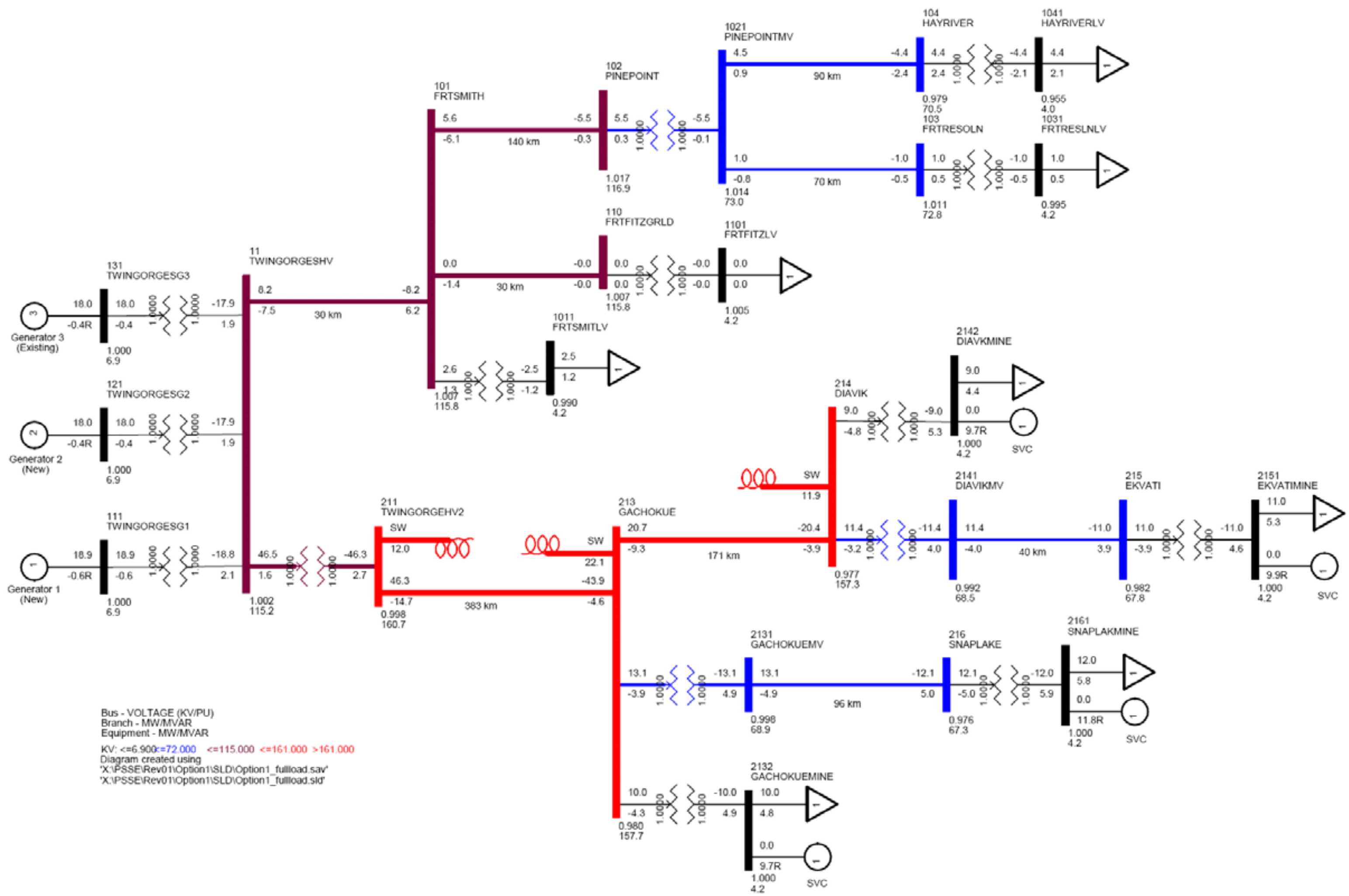
Conceptual Diagram of Baseline Option 1 for Taltson Transmission System
Figure 2-2



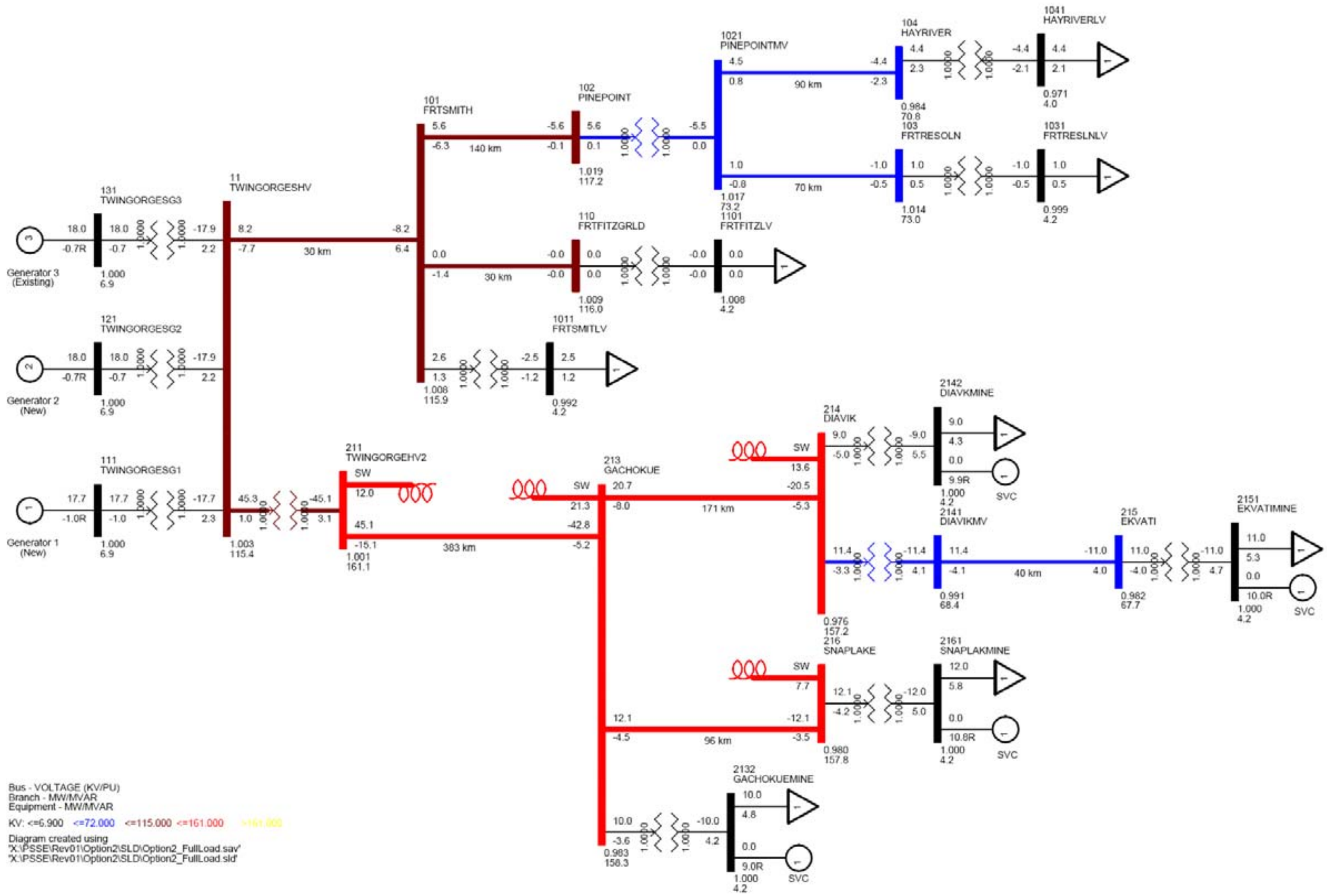
Conceptual Diagram of Baseline Option 2 for Taltson Transmission System
Figure 2-3



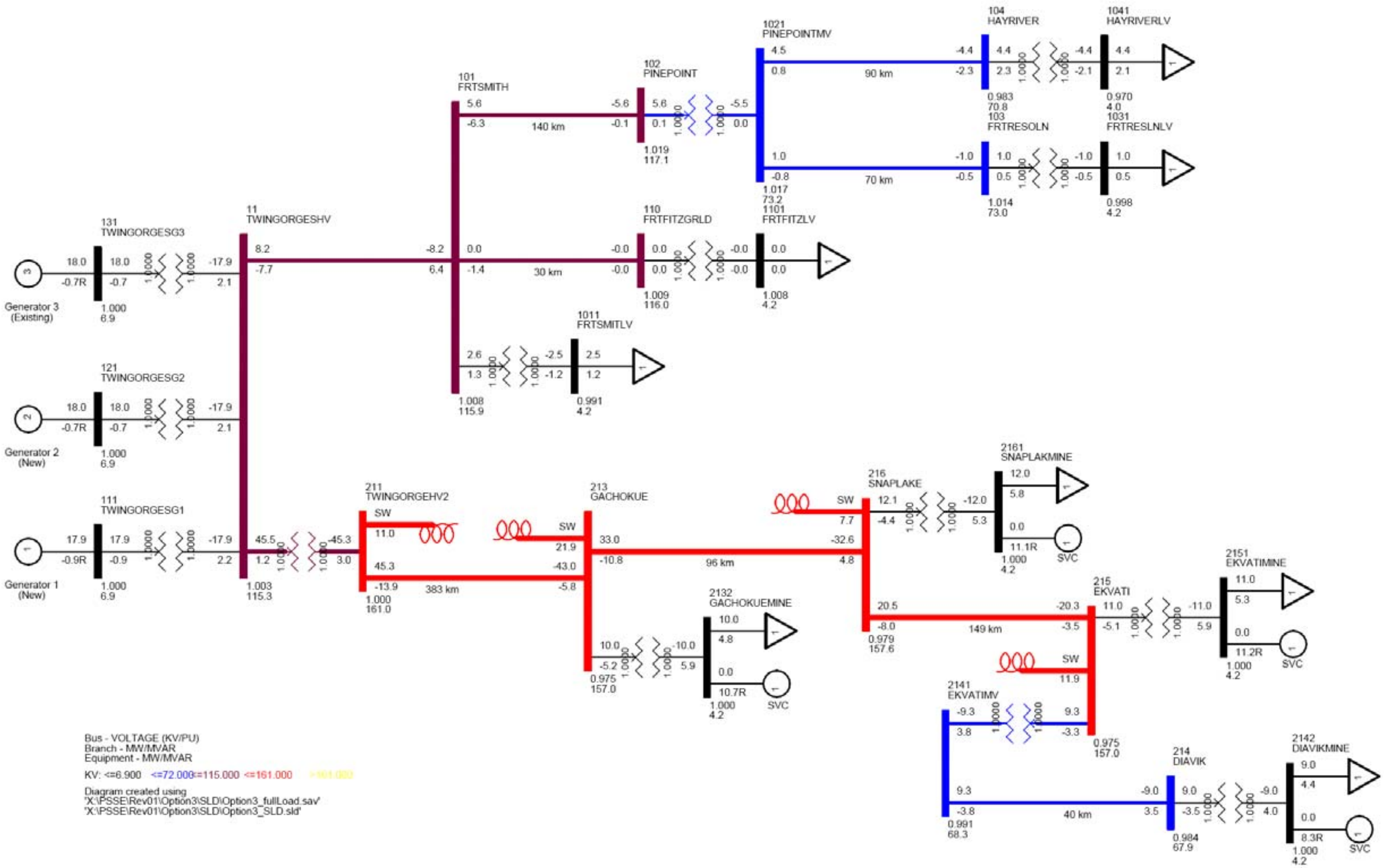
Conceptual Diagram of Baseline Option 3 for Taltson Transmission System
Figure 2-4



Option 1: Single Line Diagram
Figure 2-5



Option 2: Single Line Diagram
Figure 2-6



Option 3: Single Line Diagram
Figure 2-7

2.1.6 Data

In order to assess the options, the system was modelled in detail using data presented in the following reports, prepared by various consultants:

a) Feasibility Study – 161 kV Transmission Line Pine Point to Frank Channel – Volume 1, Monenco Consultants Ltd. AB, August 1989.
b) Taltson Expansion Project Feasibility Study: 161 kV Transmission System & Associated Substations, Ian Hayward International Ltd. BC, January 2005.
c) Taltson Hydroelectric Expansion Project: Project Description, Revision 1, Dezé Energy Corporation NT, May 2007.

Subsequently herein the above listed reports are referred to as the Monenco report, Ian Hayward report, and Dezé Energy report respectively.

2.1.6.1 Existing Transmission Network

Twin Gorges currently supplies power to communities in Forts Smith, Resolution, Fitzgerald, and Hay River. **Figure 2-1** shows the geographic locations of these communities. Details of the transmission network presented in the Dezé Energy report have been used to model the existing system. Details of the transmission network and calculated line parameters are presented in Table 2-3 in APPENDIX A, The tower head configurations for 115 kV and 72 kV lines are shown in Figure 6-1. It is assumed that Fort Fitzgerald is connected to Fort Smith via a single 115 kV transmission line. This assumption is not critical from power-flow or dynamic stability study points of view, as the line is very short (~25 km), the assumed load is relatively small (~45 kVA), and it is relatively close to generation.

2.1.6.2 New Transmission Lines

Three different options were considered for the transmission network to connect mine loads to the Twin Gorges plant.Conceptual diagrams for the three options are shown in Figure 2-2, Figure 2-3, and Figure 2-4. Towerhead configurations for the lines are shown in Figure 6-1, and line parameters are shown in Table 6-2, in the APPENDIX A.

2.1.6.3 Generators

The existing generator is 18 MW, and the expansion project will add 36 MW of generation. It is assumed that additional generation will be provided by two 18 MW generators.

For power-flow analysis the reactive power capability of the existing generator was determined using the generator capability curve presented in the Monenco report. Accordingly the rated power factor of the existing generator is unity, i.e. the generator cannot deliver reactive power when delivering an 18 MW load.

Modern generators are usually capable of delivering rated MVA at a power factor from 0.8 lag to 0.95 lead. Data for the new generators have been selected accordingly. Power-flow data for the generators is shown in Table 6-4.

For the dynamic study, generator models and parameter values presented in the Monenco report were used for all three generators. Dynamic data of the generators is shown in Table 6-5.

2.1.6.4 Excitation System

In the Monenco report the existing Twin Gorges generator excitation system is described as IEEE Type 1. This excitation system model represents DC exciters and continuously acting voltage regulators, such as amplidyne-based excitation systems. For the dynamic study, the existing generator's excitation system was modeled using PSS/E model IEEX1, with the parameters presented in the Monenco report. The value of 400.0 for exciter gain Ka presented therein is very high and needs further verification. With this Ka the exciter exhibits negatively damped oscillations for a step change in Vref under isolated generator conditions. In the study the value of Ka is set to 200.0. The exciter block diagram and parameters are shown in Figure 6-2 and Table 6-6 respectively.

Modern exciters are usually AC exciters. The excitation system for the new generator was modeled using IEEE AC1 excitation system, and parameter values selected were based on sample values in [3]. The exciter block diagram and parameter values are shown in Figure 6-3 and Table 2-7 respectively.

2.1.6.5 Governor

No governor model is available that is compatible with one described in the Monenco report. Hence, a turbine-governor system was modelled using PSS/E model HYGOV. Permanent and temporary droop settings were selected according to the Monenco report; and values for the rest of the parameters were selected based on sample values given in [2]. Block diagram representations of model and parameter values are shown in Figure 6-4 and Table 6-8 respectively.

2.1.6.6 SVC

The power-flow analysis reveals large voltage excursion for a small change in load. Hence, for stable and safe operation Static Var Compensators (SVC) are necessary at mine sites. For dynamic study the SVC are described using PSS/E model CSVGN1 with parameter values selected based on sample value in [2]. The block diagram of the model and parameters used is shown in Figure 6-5 and Table 6-9 respectively.

2.1.6.7 Load

Existing and future load data presented in Table 11-5 of the Dezé Energy report is reproduced in following Table 2-3.

Table 2-3
Existing and Future Load According to the Dezé Energy report

Load	**Peak Load (MW)**
Forts Smith, Resolution, Fitzgerald, Hay River	8-13(1)
Ekati Mine	11(2)
Diavik Mine	9(2)
Snap Lake Mine	12-14(2)
Gahcho Kué Mine	10(2)
Total	50-57

Note: (1) Existing load with transmission line losses
(2) New load without transmission line losses

After expansion, the maximum generation capacity will be 54 MW. In order to limit the total load to within generation capacity, the minimum load of 50 MW from the above table is considered in the study, leaving up to 4 MW allowance for transmission line losses. The exact load distribution for Forts Smith, Resolution, Fitzgerald, and Hay River cannot be ascertained from previous reports. For study purposes the load was distributed in proportion to population of the community. Accordingly, loads assumed in the study at various sites are shown in the following table.

Table 2-4
Loads Assumed in the Study

Customer	**P (MW)**	**Q (Mvar)**
Fort Smith	2.55	1.23
Fort Resolution	1.01	0.49
Fort Fitzgerald	0.03	0.02
Hay River	4.41	2.13
Ekati Mine	11.00	5.33
Diavik Mine	9.00	4.36
Snap Lake Mine	12.00	5.81
Gahcho Kué Mine	10.00	4.84
Total	50.00	24.22

2.1.7 Results and Analysis

2.1.7.1 Single Line Diagrams of the Substations

Single line diagrams were developed for Baseline Options 1, 2 and 3 substations. They are presented in the Appendix E, Appendix F and Appendix G, respectively. The main equipment required for these substations is listed in section 2.1.7.2.

2.1.7.2 Required Equipment

The continuous power frequency voltage range is described in Section 2.1.3. Accordingly, system voltages should remain within the specified range when the transmission line is energized; as well as when different mine loads are connected to the system. In order to achieve this objective, line connected shunt reactors and Static Var Compensators (SVC) are necessary. The ratings of shunt reactors, SVC, and transformers and length of 161 kV and 69 kV line are shown in Table 2-5, Table 2-6 and Table 2-7 for the three line route options. The number of reactors, transformers and SVC shown in the table are the minimum required. Additional equipment will be needed if spares are to be provided to increase reliability.

Line connected shunts are necessary to absorb capacitive var generated by long high voltage lines and thereby keep the voltage within limits at no load. Being a long radial transmission system, large excursion of voltages will be experienced for a small change in load at mine sites. Hence, SVC will be necessary to provide required var support over a continuous range.

During power-flow analysis it is assumed that the load at any mine is connected to the system only after connecting SVC at the corresponding mine.

Table 2-5
Required Equipment for Option 1

Description	Voltage Rating	Rating	Quantity	Location
Line connected reactors	161 kV	12.0 Mvar	1	At Twin Gorges on line Twin Gorges – Gahcho Kué
		23.0 Mvar	1	At Gahcho Kué on line Twin Gorges – Gahcho Kué
		15.0	1	At Diavik on line Gahcho Kué – Diavik
SVC	4.3 kV	±15 Mvar	4	One at each mine

Table 2-5
Required Equipment for Option 1

Description	Voltage Rating	Rating	Quantity	Location
Transformer	6.9 kV/ 115 kV	25 MVA	2	Twin Gorges, one for each of the new generators
	161kV/ 115 kV	50 MVA	1	Twin Gorges
	161 kV/ 69 kV	15.0 MVA	2	One each at Gahcho Kué and Diavik Mine
	161 kV/ 4.3kV	15.0 MVA	2	One each at Diavik and Gahcho Kué mines
	69 kV / 4.3 kV	15 MVA	1	Ekati Mine
	69 kV/ 4.3 kV	17.5 MVA	1	Snap Lake Mine
Transmission line	161 kV	-	554 km	See Table 2-2 for details.
	69 kV	-	136 km	

Table 2-6
Required Equipment for Option 2

Description	Voltage Rating	Rating	Quantity	Location
Line connected reactors	161 kV	12.0 Mvar	1	At Twin Gorges on line Twin Gorges – Gahcho Kué
		22.0 Mvar	1	At Gahcho Kué on line Twin Gorges – Gahcho Kué
		14.25 Mvar	1	At Diavik on line Gahcho Kué – Diavik
		8 Mvar	1	At Snap Lake on line Gahcho Kué – Snap Lake
SVC	4.3 kV	±15 Mvar	4	One at each mine
Transformer	6.9 kV/ 115 kV	25 MVA	2	Twin Gorges, one for each of the new generators
	161kV/ 115 kV	50 MVA	1	Twin Gorges
	161 kV/ 69 kV	15.0 MVA	1	Diavik Mine
	161 kV/ 4.3kV	15.0 MVA	2	One each at Diavik and Gahcho Kué mines
	161 kV/ 4.3 kV	17.5 MVA	1	Snap Lake mine
	69 kV / 4.3 kV	15 MVA	1	Ekati Mine
Transmission line	161 kV	-	650 km	See Table 2-2 for details.
	69 kV	-	40 km	

Table 2-7
Required Equipment for Option 3

Description	Voltage Rating	Rating	Quantity	Location
Line connected reactors	161 kV	11.0 Mvar	1	At Twin Gorges on line Twin Gorges – Gahcho Kué
		23.0 Mvar	1	At Gahcho Kué on line Twin Gorges – Gahcho Kué
		8 Mvar	1	At Snap Lake on line Gahcho Kué – Snap Lake
		12.5 Mvar	1	At Ekati Mine on line Snap Lake – Ekati Mine
SVC	4.3 kV	±15 Mvar	4	One at each mine
Transformer	6.9 kV/ 115 kV	25 MVA	2	Twin Gorges, one for each of the new generators
	161kV/ 115 kV	50 MVA	1	Twin Gorges
	161 kV/ 69 kV	15.0 MVA	1	Ekati Mine
	161 kV/ 4.3kV	15.0 MVA	2	One each at Ekati and Gahcho Kué Mines
	161 kV/ 4.3 kV	17.5 MVA	1	Snap Lake Mine
	69 kV / 4.3 kV	15 MVA	1	Diavik Mine
Transmission line	161 kV	Various	628 km	See Table 2-2 for details.
	69 kV	Various	40 km	

2.1.7.3 Transmission Line Losses

Line losses for three different options in the new system are shown in Table 2-8. Annual energy loss is estimated by assuming 2% annual outage and 90% reliability factor.

Table 2-8
Line Losses for Different Options

	Option 1	Option 2	Option 3
Line Losses (MW)	4.4	3.2	3.4
Losses % of 42 MW load	10.5 %	7.6 %	8.1 %
Losses Normalized to Minimum Loss	1.38	1.00	1.06
Annual Energy Loss (GWh)	34	25	26

2.1.7.4 Dynamic Simulation

The system was simulated for various contingencies in PSS/E. Contingencies simulated are shown in the following table. Modelling details of dynamic devices are described in Section 2.1.6. Single line diagrams of the system are shown in Figure 2-5, Figure 2-6 and Figure 2-7.

Table 2-9
Descriptions of Contingencies

Contingency Number	Pre-Disturbance Condition	Disturbance
1	Full load	3-ph fault at 161 kV bus at Ekati Mine. Fault removed after 0.1 second
2	Full load	3-ph fault at 161 kV bus at Gahcho Kué. Fault removed after 0.1 second
3	Full load	3-ph fault at 161 kV bus at Twin Gorges. Fault removed after 0.1 second
4	Full load	11.0+j5.33 MVA load at Ekati Mine disconnected.
5	Ekati Mine load 9.9+j4.8 MVA (90% of maximum)	Load increase at Ekati Mine to 11.0+j5.33 MVA (full load).

For the entire set of contingencies, the system exhibits well damped stable operations. Plots of key variables for contingencies 1 and 4, simulated for all options, are presented in APPENDIX B, Figure 6-6 through Figure 6-19.

2.1.8 Conclusions

In this study three optional routes were investigated for the Baseline Option. All three options are viable from the electrical steady state and dynamic stability points of view.

The total number of line connected switched shunts and the total MVA rating required for Option 1 are lower than for other options. However, power losses and the requirement of additional 161 kV/ 69 kV transformers may outweigh this advantage. For Option 3, the line connected shunt requirement is lower than that for Option 2 and is shorter by 22 km, but has marginally higher losses.

In conclusion, Option 2 and Option 3 routes for the East Arm option are equally viable and may be investigated further.

2.1.9 Recommendations

In the power-flow study the transformer taps were assumed to be fixed. It is recommended that a study be conducted to evaluate the benefits of installing Online Tap Changers (OLTC).

During dynamical study some of the key devices were modelled using generic models and typical data. It is very unlikely that change in models and/or their parameters will have significantly different outcomes, though it is recommended that dynamic performance be reviewed again once all equipment details are available.

2.1.10 References

[1] ANSI C84.1-1995, Electric Power System and Equipment—Voltage Ratings (60 Hz).
[2] PSS/E Program Application Guide Volume II: Power Technologies International, Siemens Power Transmission & Distribution, Inc.
[3] IEEE Std 421.5 - 2005 IEEE Recommended Practice for Excitation System Models for Power System Stability Studies.

2.2 FIELD STUDY

2.2.1 Introduction

This section covers the first of two field observation surveys that were conducted for the evaluation of route alternatives for the Taltson Transmission Expansion Project. This field study was performed July 14-18, 2008 on the Baseline Route, as defined in the project background documentation.

The field study started on Monday July 14 with team members traveling to Twin Gorges. On Tuesday July 15, the group examined the line route and staging areas from Twin Gorges to Snowdrift River. On Wednesday July 16, the team examined the line route and staging/barge areas from Snowdrift River to Gahcho Kué, then to Snap Lake. Staging/barging areas at Charlton Bay and just north of Fort Reliance on Great Slave Lake were also examined. On Thursday July 17, they examined the line route, winter road access and staging areas starting at Snap Lake and travelling to MacKay Lake, Ekati, Diavik, and finishing at Gahcho Kué. On Friday July 18, team members returned to the Lac de Gras/Lac du Savage Misery Point area and investigated an alternative route. Starting east of Misery Point, they headed in a southerly direction and several kilometers east of the eastern end of MacKay Lake to the intersection of the Lockhart River near the southern end of Zyena Lake. The team returned to Yellowknife at the end of the day on July 18.

Prior to the field study, existing studies and proposed line routes were reviewed. The following preliminary criteria were developed for consideration while investigating line routes and staging areas. These preferred criteria would produce a feasible, economical, and safe line while mitigating environmental impacts:

- Utilize existing or construct new winter road next to line route as much as possible.
- Set line route as close as possible to winter road.
- Build temporary access roads along line as much as possible, and to and from winter road as required.
- Access will be required for construction and maintenance.
- Stage small camps (< 35 workers) and marshalling yards (2 to 3 ha) every 120 to 150 km apart if ground construction with access along the line; otherwise stage camps and marshalling yards every 50 to 60 km apart for aerial construction.
- Haul materials and supplies as much as possible by winter road to line sections Twin Gorges to Nonacho Lake North, Ekati to Diavik to Gahcho Kué and as far south as possible from Gahcho Kué, and to Snap Lake, and distribute along winter road or line route as much as possible.
- Barge materials and supplies to Fort Reliance and other selected staging areas selected at the east arm of Great Slave Lake for aerial construction.
- Utilize guyed lattice steel towers for tangents (similar to those shown in January 2005 Feasibility Study: light, easy to assemble and climb for construction and maintenance)

and either the guyed triple mast structure (similar to those shown in the January 2005 Feasibility Study) or a self-supporting lattice steel tower for angles and dead ends.

- Utilize small diameter, drilled in, grouted foundations; anchors in rock and permafrost,; grillage type foundations, and anchors in unfrozen mineral soils.
- Perform tree clearing by machine and mostly in winter season (hand clearing very dangerous and slow; only to be done if lacking access for machines).
- May consider hand clearing by aerial access during warm weather.
- May consider installing rock foundations and anchors by aerial access during warm weather.
- May consider assembling towers, and transporting and setting towers by aerial access during warm weather.
- Install grillage type foundations and anchors during cold weather on frozen ground unless access is available during warm weather.
- Perform slack stringing during cold weather unless access is available during warm weather.
- Aerial tension string in rough terrain and at poor or no ground access areas.

The objective of the field study was to determine the feasibility of the line route and staging areas based on the above criteria and in terms of constructability and access by examining and evaluating the terrain, vegetation and clearing requirements, topographical features, geotechnical and foundation conditions, environmental issues, climate, sections of the line or line components that may be constructed during warm weather or cold weather, supply points, location of existing and proposed winter roads, temporary access to and along the line route, aerial vs. ground construction, and schedules.

The Taltson Hydroelectric Expansion Project Transmission Line Mapbook dated May 16, 2008 Rev 2, the Project Area Overview dated June 21, 2008 Rev 0, and the Project West Route Maps dated July 14, 2008 Rev 0, were used as references for the field study of proposed line routes.

The following observations were made during the field study. It was acknowledged that the proposed line route was preliminary, and refinement during design would be required to avoid large water and swamp crossings.

2.2.2 Twin Gorges to Snowdrift River (Tuesday, July 15, 2008)

The proposed line route was reasonable given the topography and proximity to the proposed winter road and staging areas. The proposed staging areas were also reasonably located and allowed for sufficient camp/storage/assembly working areas. The proposed line route was approximately 20 km at PI 5 from proposed winter road, 8 km at King Lake staging area, 14 km at the south end of Nonacho Lake, 7 km from PI 9 to Nonacho Lake south staging area, and 12 km from Nonacho Lake north staging area. Probably would like to move the line closer to the proposed winter road or vice versa in some sections.

The line route needs to be re-aligned between PI 1 and PI 2 to exit from the generating station to the spillway.

The terrain was variable with some sections rolling with knolls of rock and basins filled with water or swamp, and other sections rising and falling with steeper rock hills and cliffs and rivers or lakes or swamps in the valleys. Near N6716000 steep rock cliffs with raptor nest. From approximately N6735000 to N6745000 rough terrain with steep rock cliffs. After approximately N6760000 to N6790000 gentler rock knolls and swamp, lightly treed. Need to re-align line route at large water crossings at N6804000, N6831000 to N6834000, N6840000, N6854000, and at N6857000 Walker Lake. There is a large swamp at N6887000. The terrain becomes rockier starting at N6895000 and extending northwards.

Vegetation included evergreen and deciduous trees, mostly spruce and pine trees, some shrubs and grasses, lichen covered rock and sand, moss and peat covered muskeg.

Clearing of the right of way will be required, and is variable with denser, taller trees and vegetation near the south end and sparser shorter trees and vegetation near the north end. There are some sections with little tree clearing due to large burn areas.

There are no constructed features along the line route except for the generating station and spillway at the south end, and the Nonacho Lake water control dyke approximately 8 km east of the line.

The geotechnical conditions along the line route were primarily exposed sound rock with some fractures and joints, some boulders and cobbles on the surface, some sand, and water and swamp in the low lying areas. Foundations and anchors will mostly be drilled in grouted rock anchors.

Some raptor nests and wildlife, musk ox and moose were encountered along the line route.

A small section of the line near the south end may be cleared and constructed with access roads along the line during the warm weather season or cold weather season.

Sections of the line may have temporary access roads constructed from the proposed winter road and along the line during the cold weather season.

The section of the line from approximately N6700000 to N675000 may require aerial construction due to difficult terrain and N6895000 and beyond will require aerial construction due to difficult terrain and lack of access from winter road.

2.2.3 Snowdrift River to Snap Lake (Wednesday, July 16, 2008)

The proposed line route was reasonable given the topography and proximity to the selected barge landings and staging areas near the east end of Great Slave Lake at the outlet of the Lockhart River and the existing winter roads near Gahcho Kué and Snap Lake.

Barge landings and staging areas were selected in Charlton Bay at approximately N6945000 and E590000 and north of Fort Reliance at approximately N6966000 and E600000. The Charlton Bay barge landing and staging area is approximately 14 km perpendicular from the line and approximately 30 km from the Snowdrift River crossing and approximately 33 km from PI 13[1]. The rock cliffs along the south shore of Great Slave Lake rise some 250 m above the water level. The Fort Reliance north barge landing and staging area is approximately 8 km perpendicular from the line and approximately 18 km from PI 13[1] and approximately 44 km from the location where the proposed winter road south of Gahcho Kué may end. It was suggested that it may be possible to extend the winter road south of Gahcho Kué to approximately the tree line at approximately N7010000 and E600000. Therefore the Fort Reliance barge/staging area could service the line for up to 22 km north between PI 17[2] and PI 18[3]. A staging area could be located at the end of the proposed winter road at the tree line, and service the line for up to 22 km south.

It may be desirable to select another barge landing/staging area in Charlton Bay near Glacier Creek or move the line closer to Great Slave Lake from Snowdrift River in a northerly direction, and then northwest to PI 13[1].

From the tree line to Gahcho Kué and to Snap Lake it was deemed possible to construct a winter road along the line for access. In case a winter road along the line is not allowed, staging areas were selected at the south ends of Margaret Lake at approximately N7047000 and E557000, Munn Lake at approximately N7049000 and E549000, and Lac Capot Blanc near PI 54. An extension of the existing winter road from Snap Lake to Lac Capot Blanc would be required. The existing winter road is on Margaret and Munn Lakes. The Munn Lake staging area was preferred rather than the Margaret Lake option.

At Gahcho Kué it was suggested to extend the 161 kV line from PI 19 to PI 41[4] with an in-line substation in between and run a 69 kV line from the substation to the mine site.

The terrain was variable with the section from approximately the Snowdrift River to the Lockhart River to the tree line, rising and falling with steeper rock hills and rivers and lakes in deep valleys. The section of the line 10 to 15 km south and north of the Lockhart River was

[1] PI 13 is referring to coordinates N6957600 and E616200 based on [1]. The coordinates of this point were revised as per Table 2-20.
[2] PI 17 is referring to coordinates N7019000 and E600000 based on [1]. The coordinates of this point were revised as per Table 2-20.
[3] PI 18 is referring to coordinates N6991500 and E598800 based on [1]. The coordinates of this point were revised as per Table 2-20.
[4] PI 41 was renamed to PI 20 after the field studies, as per Table 2-20.

deemed very difficult for ground access, and aerial construction would be necessary. Many long spans would be required to cross the large rivers and valleys and go from rock peak to peak. Beyond the tree line to Gahcho Kué and on to Snap Lake the terrain is rolling with knolls of sound and broken rock and basins filled with water or swamp.

Vegetation included evergreen and deciduous trees, mostly spruce and pine trees, some shrubs and grasses, lichen covered rock and sand, moss and peat covered muskeg.

Clearing of the right of way will be required and is variable. Above the tree line no clearing is required. There are some sections within the treed area that require little tree clearing due to large burn areas.

There are no constructed features along the line route except for the mine sites.

The geotechnical conditions varied along the line route, with exposed sound rock with some fractures and joints from the Snowdrift River to north of the Lockhart River, and then changing to broken rock to Gahcho Kué and on to Snap Lake. Also there were some boulders and cobbles on the surface, some sand, water and swamp in the low lying areas. Ice wedges and boulder fields were present. Foundations and anchors will be mostly drilled in grouted rock anchors.

Some raptor nests and wildlife, musk ox and moose were encountered along the line route generally between Snowdrift River and the tree line.

Winter construction would be done along the sections of line that would have access roads. Aerial construction would most likely be done during the warm weather season.

2.2.4 Snap Lake to Ekati to Diavik to Gahcho Kué (Thursday, July 17, 2008)

The proposed line route was reasonable, given the topography and proximity to the existing winter road and staging areas.

However due to major caribou movements near Misery Point and the east end of MacKay Lake, and also the presence of a hunting camp on the east side of Lac du Gras, it was suggested the line route be moved east. An alternative line route was selected and examined on Friday July 18.

A revised line route is required exiting Snap Lake. Near King Lake the line route will have to be diverted to the east to avoid a large water crossing.

At MacKay Lake, a number of islands will have to be utilized to cross the lake with long spans of 715 m from south shore to the second island, 667 m, 507 m, 775 m in between the islands, and 320 m from the most northern island to the north shore. The MacKay Lake crossing is feasible however with very long spans and the islands will have to be built up and armoured with large rock rip rap to protect the towers from ice damage. Apparently the thickness of the ice can reach 1.8 m.

The existing winter road travels to all of the four mine sites and goes by the MacKay Lake Lodge.

A staging area was proposed at the west end of Lac du Gras at approximately N7136000 and E507000. The line route is approximately 9 km away at this point. At PI 88 there is a large water body crossing which will require hopping across the island.

It may be desirable to move PI 90 closer to the north shore of Lac du Gras and provide a more direct route to Ekati, shortening the line length.

From Ekati to Diavik it may be more desirable to follow the existing roads more closely.

The terrain was fairly consistent along the line route, being tundra with gentler rolling hills with some exposed rock and broken rock (boulder fields in some areas) and shallow valleys, lakes and swamps. Near the west arm and north of Lac du Gras it appeared that the hills were more pronounced, and more broken rock was visible on the surface. It was still deemed passable for an access road.

The vegetation was consistent with tundra with small plants and shrubs. No trees. No clearing is required along this section of the line route as all of it is above the tree line and in the tundra.

The geotechnical conditions varied along the line route with exposed broken rock sometimes boulder fields, boulders and cobbles on the tundra surface, ice wedges, swampy areas and many water bodies. A shallow test pit was dug and silty sand was found beneath the tundra vegetation.

Some wildlife was encountered along this section of the line, one moose near King Lake, a great horned owl north of MacKay Lake, and a wolf at MacKay Lake Lodge.

An access road along the entire line route in this section was deemed possible during cold weather. Winter construction along this line section is most likely.

2.2.5 Alternative Route Ekati to Lac du Gras Crossing to Zyena Lake (Friday, July 18, 2008)

An alternative line route was selected to avoid the major caribou movements near Misery Point and the east end of MacKay Lake, and be further away from the hunting camp on the east side of Lac du Gras. The alternative line route varied from approximately 5 to 10 km east of the previously proposed route [1]. Waypoints #84[1] to #100[2] for the alternative route were marked.

[1] Waypoint #84 has become a PI 39, as per Table 2-20.
[2] Waypoint #100 has become a PI 25, as per Table 2-20.

The revised line route would head in an eastern direction for approximately 25 km from Ekati and then south-east to PI 84. The line would cross Lac du Gras at approximately N7165000 and E550000. The revised line route then heads in a southern direction to intersect with the original alignment near the south end of Zyena Lake at waypoint #100[2].

Two alternative crossings of Thonokeid Lake were investigated and deemed feasible with waypoints at #91[1] and #93[2]. All features i.e. terrain, topographical, vegetation, geotechnical, etc. are similar to the original alignment. The disadvantage of the alternative line route is that it is further away from the existing winter roads, and longer access roads to the line will be necessary, but this will become a non-issue if an access road is built directly along the line.

Also on Friday July 18th the MacKay Lake crossing was revisited and additional waypoints #102 to #109 were marked. These points are given in Table 2-10.

Table 2-10
Waypoints Selected for MacKay Lake Crossing

Waypoint	Northing	Easting	Description
102	7082179	516679	north shore
103	7081900	516521	northern most island
104	7081220	516145	intermediate island
105	7080777	515897	intermediate island
106	7080149	515644	southern most island
108	7079881	515777	south shore south of 106
109	7080117	516177	south shore south of 105

2.2.6 General Comments

The eastern route from Gahcho Kué to Ekati at 161 kV along the original alignment is estimated at 179 km. The tap-off to Diavik at 69 kV is estimated at 12.8 km. The Gahcho Kué to Snap Lake leg at 69 kV is estimated at 97 km. Therefore the east route has 179 km of 161 kV and 110 km of 69 kV.

The west route from Gahcho Kué to Snap Lake at 69 kV is estimated at 97 km. The Snap Lake to Ekati leg at 161 kV is estimated at 150 km. The line length from Ekati to the Diavik tap off at 69 kV is estimated at 19.4 km and the tap off to Diavik at 69 kV is estimated at 12.8 km. Therefore the west route has 247 km of 161 kV and 32.2 km of 69 kV. The western route is advantageous from an environmental perspective over the eastern route as it avoids the major caribou movements along the eastern route. The disadvantage is that it has 68 km of additional

[1] N7129696 and E556301
[2] N7128585 and E560863

161 kV. However, it has 77.8 km less of 69 kV. Another disadvantage is the major crossing of MacKay Lake by island hopping and the risk with ice and flooding.

The eastern route would cost less.

The line route from the Lockhart River running along the northern shore of Great Slave Lake to Snap Lake was discarded. The opinion was that the terrain would be difficult and there would be added clearing costs. The Gahcho Kué to Snap Lake route is above the tree line and is accessible with a road along the line.

For the next field study an alternative route from Snowdrift River to Lockhart River closer to Great Slave Lake should be examined.

A geotechnical assessment of the line routes should also be conducted in the next field study.

An updated map book with the current winter roads is required.

In conclusion, all the proposed line routes are feasible from a construction point view. It is our opinion that the practical, economical, and safer method to construct the lines is with the use of winter access roads along the line. Certain sections of the line routes will have to be constructed using aerial construction. The selection of the best route will depend on access, electrical studies, environmental impacts, and costs.

2.2.7 References

[1] Taltson Hydroelectric Expansion Project - Transmission Line Mapbook, Revision 2, Dezé Energy Corporation.

2.3 GEOTECHNICAL CONSIDERATIONS

2.3.1 Terrain Typing

The terrain typing initially was conducted through examination of aerial photography available from satellite photography. A search was made for low-level photography, which proved unsuccessful in the time frame available. Based upon the photographic evidence and indicators shown on the appended sheets, each route was evaluated independently with bedrock outcrops, soil types, permafrost conditions identified broadly. The methodology employed in this report, followed the Dr. GD Mollard approach that had extensive experience in northern landscapes and in road, dikes and transmission line routing.

2.3.2 Field Reconnaissance

On August 11 through August 15,2008 an aerial field reconnaissance of the transmission line routes were made. The reconnaissance commenced at the Twin Gorges generation station and proceeded northward along Route B (Trans Island Route) through to Great Slave lake and then northward to Snap Lake and the Ekati diamond mines. From the diamond mines, Route A known as the Base Line Route was followed back to Twin Gorges. A small section of the route was missed due to low clouds and poor weather.

2.3.3 Topography

The topography of all three-line options varies from flat, low lying rock plateaus to sharp near vertical rock faces of over 200 meters in height. Most of the high relief areas border the shores of Great Slave Lake with more moderate topography north of Snap Lake and South of the Snowdrift River.

To establish the most economical and accessible route with tower locations will require detailed survey such as Lidar surveying that is used extensively with GPS horizontal control.

2.3.4 Basic Soil Types

The basic terrain of the area was found to be comprised of four types. These are:

a) Bedrock Outcrops
b) Heavily weathered and broken Rock Outcrops
c) Permafrost affected soil
d) Marsh and swamp areas

2.3.4.1 Bedrock Outcrops

The majority of the route passed over bedrock outcrops, the rock being granite gneiss with heavily weathered surfaces and lichen cover. The bedrock is massive, of high strength and occurs at elevation above surrounding lake level of over 300 meters. At lake shorelines, the rock has been shattered into large boulders through frost action. Boulder sizes range up to 2 meters in diameter. The rock surface has been modified by glacial action, which has created grooves or etchings. The direction of the glacial movement is primarily northeast, nearly perpendicular to the transmission line direction. While the etchings make construction of winter road difficult, it does allow longer swing spans when advantage is taken of higher rock topography.

Bedrock Outcrops
Figure 2-8

2.3.4.2 Heavily Weathered and broken Rock Outcrops

In large areas north of Snap Lake, there are large expanses of broken rock or boulder fields. The rock lies over massive bedrock at shallow depths but is so concentrated that transmission tower foundations require special attention in design and construction.

Anchor design must penetrate the broken rock surface into sound underlying bedrock. It is Teshmont's view that the depth of broken rock is related to frost penetration and is in the order of 2 meters. This is based upon field inspection and confirmation would be required. The construction operation would be to either move the large boulders and clear to sound rock or alternatively extend the length of the shaft by 2 meters and socket the anchors and base into sound rock.

Alternatively, a steel grid could be used and the boulders placed upon the grid to provide uplift resistance. In view of the large size of the boulders this may be difficult.

Heavily Weathered and broken Rock Outcrops
Figure 2-9

2.3.4.3 Permafrost Affected Soils

At latitudes above Snap lake large areas of permafrost-affected soils exist that will require special foundations. The permafrost is identified through frost polygonal features and pingo development. Often the frost polygonal features can be seen from the air extending under shallow lake indicating extensive and wide spread conditions difficult to span

Permafrost Affected Soils
Figure 2-10

2.3.4.4 Marsh and Swamp Zones

Marshes and swamps occupy the topographical low areas and the base of the bedrock etchings or grooves. Many of the marshes south of the Lockart River are wide expanses and may require special tower foundation design if they cannot be spanned.

Other soil types were also identified in eskers and beach development that originate from glacial streams and beaches where higher lake levels once existed. An attempt was made to identify and locate these features as a source of building material and road construction.

2.3.5 Baseline Option

With the terminal point at Twin Gorges, the distances listed in the first column of Table 2-11 apply to material types found through Air Photo Interpretation (API) supported by aerial field identification and the tabulated indicators applied in this project.

Length of the investigated section from Twin Gorges to Diavik Mine Terminal was 560 km.

Table 2-11
Soil Indicators Based on Aerial Photo and Field Identification

Position (km)	Terrain Type	Indicators
0 - 2	Alluvial silts, deep, relatively low strength with a high water table	- old river oxbows and river channels evident supporting spruce and deciduous tree growth. Normally there will be zones of sands and zones of silt. Permafrost unlikely
2 - 60	Granite Bedrock Exposures - high cliffs at 32 and 39 km – winter road access possible with some difficult ravine crossings	- bedrock undulating - crosses burn areas of exposed rock - rock etchings perp to line - wide swamps at 27 km and 50.2 km - deep ravines at 32/39.3 km
60 - 120	Granite Bedrock Exposures – winter road access *Needs Lidar mapping to obtain accurate alignment and avoid lakes*	- rock outcrops 30m high identified by exposures and by rock etchings from glacier movement. Depressions in bedrock may be marsh areas but are widely spaced - major marsh at 72.8 km and 99 km - old permafrost polygon melt at 104 km
120 - 171.4	Exposed bedrock – undulating surface – winter road access *Needs Lidar mapping to obtain accurate alignment and avoid lakes*	- old burn area at 147 km - no well-defined drainage features and what there is follows the bedrock etching pattern in a northeast direction. - Lower rock surface from 149-161 km approximately20 m high
171.4 - 181.2	Exposed bedrock undulating surface rel low grades – winter road access –crossing looks good	- exposed bedrock surface with glacier etchings low relief 20-40m - at 179 km an area of higher relief 30-60 m - major stream crossing at 182 km. sand beaches along south side- low marsh area on north with rock outcroppings
181.2 - 240	Exposed rock outcrops with some soil cover – winter road access looks feasible	- bedrock outcrops visible with a thin soil cover and lichens to 196 km - esker at 196 km - low undulating rock surface - crossing at Knox Lake 208.3 km looks good with rock outcrops both sides - wide low valley at 224 km
240 - 288	Shallow bedrock with a surface cover of silty clay – winter road difficult from 253 to 262 due to irregular rock surface	- high rock 50-100m– rough surface Lack of drainage features indicates that the soil cover is thin. Smooth lake shorelines - Light soil cover with bedrock control supporting black spruce vegetation - Snowdrift River at 252.4 - Esker at 262.2 - Wide marshes at 279 - Moss covered rock surface

Table 2-11
Soil Indicators Based on Aerial Photo and Field Identification

Position (km)	Terrain Type	Indicators
288-302	Shallow granite bedrock @ 302 km	- rocky shorelines evident exposing bedrock. Rock etchings visible through thin soil cover - high rock outcrops at 288 km
302 - 314	Rock Outcrops with little soil cover. Very high 300 m+, with deep valleys Helicopter construction	- exposed bedrock with deep etchings showing glacier movement direction northeast. - Line from PI 14[1] to PI 17[2] could not be inspected due to weather - Lockhart River at 314 km
314 - 337.2	Rock Outcrops- not inspected Hoarfrost River at 337.2 km	- rock outcrops – high - many rapids and high rock faces along the Hoarfrost River
337.2 - 341	Rock outcrops at 340.3 km helicopter access	- very high and rugged - heavy lichen cover over bedrock giving a light colour
341 - 342.6	Permafrost Area	- appears shallow with rock control
342.6 - 367.7	Rock Outcrops- very high 60-150m at 367.7 km Helicopter access	- very rugged area, 100 m rock cliffs difficult to access - rock outcrops throughout and sound rock, some large blocks broken from rock faces and having 2-3m separation - esker at 349 km - some soil cover 364-367.7 km
367.7 - 386.1	Rock outcrops irregular-not excessively high Gahcho Kué at 388.2 km	- esker at 375 km - many lakes and water bodies - some small permafrost polygon areas
386.1 - 406.2	Not inspected	- not inspected
406.2 - 445.35	Junction Line to Diavik	- not inspected
445.4 – 480.2	Diavik line	- not inspected
480.2 – 493.9	Various	- sand eskers along line 481-489 - permafrost area 489- 495 low lying many polygonal areas - rock outcrops at 496 - permafrost 496-502 - rock outcrops 502-503 flat tops - permafrost 503-509 - rock outcrops 509-518
493.9 – 25.6	Not inspected	- not inspected
525.6 - 559.7	Diavik Mine Terminal Silty clay over permafrost Shallow rock	- light silty clay soil cover in permafrost area. - Roads and cuts light fills placed over permafrost. Material for road construction likely from mine excavation (no evident borrow areas)

[1] PI 14 was revised and corresponds to PI 13, as per Table 2-20.
[2] PI 17 was revised and corresponds to PI 16, as per Table 2-20.

Table 2-12
Summary of Required Foundation Types

Length	Type 1 – Rock Foundations	Type 2 – Soil Foundations	Type 3 – Permafrost	Type 4- Fragmented Rock
560km	461	4	46	49

2.3.6 Structures

For the specific terrain conditions outlined above, four (4) foundation types can be considered for the Type A structure. The type A structure being similar to that currently existing of the Twin Gorges – Fort Smith line., The details of the structures and foundations are shown in Appendix C. The design requirements of each foundation are as follows.

2.3.6.1 Design Parameters – Ultimate Loads

a) Tower base, Max. vertical Loading = 336.2 kN
b) Anchor Tension = 160 kN less 1.2kN for foundation acting at 35 degrees to vertical
c) Rock Compressive Strength – 50 MPa for rock with 100 RQD . Anchors in tension utilize 50% of the compressive strength
d) Factor of Safety = 2

2.3.6.2 Rock Foundation/Anchor Options

Applies when the rock exposures are massive and solid with an RQD of 100 within 2 meters of the surface.

2.3.6.2.1 Tower Mast

On a steel footing sized to match the mast base but at least 400 x 400 and 25 thick with a grout pad and 4 – 20 mm bars as rock anchors for lateral wind forces. The anchors would be drilled into the rock and grouted.

2.3.6.2.2 Tower Anchors

Individual anchors 35 degrees to perpendicular installed into 100 mm diameter holes and grouted. The length of each anchor must have a rock embedment of at least 1500 mm into sound rock.

2.3.6.3 Permafrost Foundations

Applies in ice polygon areas where ice content may be at least 60% by volume and where allowing the soil to thaw will produce major settlement of the tower. The ballast will limit anchor capacity.

2.3.6.3.1 Tower Mast

Place a 200 mm thickness of high density Styrofoam insulation layer over the soil surface underlying the surface peat or lichen growth. The dimensions of the insulation should be at least 1.5 m x 1.5 m. Place a steel base with a riser over the insulation to distribute mast load to no more than 50 kPa and cover the base with at least 400 mm of granular fill.

2.3.6.3.1.1 Alternative Foundation Types

Thermo Piles: Utilize thermo piles on angle structures where high loads are anticipated. Thermo pile design is according to Arctic Foundation design manual

Screw piles: Another option to consider is the use of larger diameter (300 mm) screw piles. These can be installed in a drilled hole and or by torsion providing penetration can be achieved in permafrost. Further study will be required to determine the ice/soil ratio, which can be as high as 60% in soils exhibiting polygonal features or in pingos. It will be important to investigate the rate and longevity of freezeback for various fill or grout materials.

2.3.6.3.2 Tower Anchors

Anchors in permafrost should consist of a 1.5 m x 1.5 m steel grid placed upon the permafrost surface with a 150 mm high density Styrofoam and granular soil cover. The height of the ballast to resist uplift (FS=3) must be at least 1 meter.

2.3.6.3.2.1 Alternative Foundation Types

Thermo Piles: Thermo piles on angle structures are an option where high loads are anticipated. Thermo piles can be augured into the soil/ice and use the frozen soil strength to resist uplift.

Screw Piles: For the tower base, large diameter screw piles are an option for the anchor system. It is important again to evaluate freeze back issues and the feasibility of installing these piles into ice-rich soils.

2.3.6.4 Broken Rock Area Foundation

This type of foundation (See Plate 2) would apply in boulder field areas where sound rock is not identifiable from surface observation. The boulder fields are expected to have large rock blocks with widely spaced cracks or separation between each block.

2.3.6.4.1 Tower Foundations

The tower foundation should be set below the broken rock base or if very deep, on short steel pipe piles which extend to sound rock. Each pipe pile should be driven into the rock joint and tested to 200% of the design loading. 4-piles are recommended for each tower base grouted to the surrounding rock blocks to form a competent grout/rock mass.

2.3.6.4.1.1 Alternative Foundation Types

Driven Piles: It may be possible to penetrate the boulder surface using a truck or Nodwell mounted diesel pile driving hammer.

2.3.6.4.2 Tower Anchors

2.3.6.4.2.1 Defragmentation Grouting

Anchors in broken rock boulder field could utilize the larger fragments and insert rock anchors to provide uplift. The fragment must be at least 1.5m x 1.5m x 1.5m in order to provide sufficient anchor capacity. Alternatively several fragments could be cemented together to form a large ballast block of the required size.

2.3.6.4.2.2 Alternative Foundation Types

Steel grid with boulders as rock ballast: A steel grid set below the boulders and weighted with rock fragments may be another option for consideration. This would involve removing some of the boulders, laying the grid and replacement of the boulders. The size of the grid will depend upon the boulder fragments but would be at least 2 m x 2 m in size.

2.3.6.5 Marsh Tower Foundations

Tower foundations in low lying marsh areas will be subject to settlement and low strength soil support.

2.3.6.5.1 Tower Mast Foundation

For the vertical loading on the mast it is necessary to provide load distribution such that base loads equal or are less than overburden loading. The organic cover in marshes is compressible and should be removed under the mast down to a mineral soil.

A culvert base as shown on Plate 4 with a metal grid within the culvert backfill would provide support in wet conditions providing it was sufficiently large. In order to limit the bearing to 18 kPa at the base a 1600 mm diameter culvert would be required. These can be readily installed through soft peat deposits and the material removed from the inside prior to setting the steel grillage and backfilling.

2.3.6.5.2 Tower Anchor Foundations

In marsh areas a system of ballast will be required to provide anchor uplift resistance. Culvert installations can again be used. 1250 mm diameter culverts with 1.5 m of saturated granular backfill can provide adequate uplift resistance to meet design requirements. Installation is relatively simple and can be done during winter with excavation or during summer operations.

2.3.6.5.2.1 Alternative Foundation Types

Screw Piles: Another option to consider is the use of larger diameter (300 mm) screw piles. These can be installed in a drilled hole and or by torsion providing penetration can be achieved in soft soils. The length would be determined by knowing the marsh depth and base soil.

2.3.6.6 Seismic Considerations

The area of the transmission line routes is located in a seismic zone having horizontal ground velocities in the order of 0.004 m/s (re: Canadian Foundation Manual 3rd Edition) This similar to the Canadian Shield east of the sites which is considered low risk. This translates to a slight increase in design load requirement of 1.1 for foundations. More specific calculations for load/structure can be made in the later stages of the design.

2.3.7 Further Studies

The following areas require further study:

a) The route location should be modified on the basis of topographical features. The topographical highs normally reflect competent rock outcrops and the line should be adjusted to take advantage of this feature
b) Investigation into permafrost freezeback for the anchor and tower systems may allow foundations to be installed into large holes that may provide additional stability than the mat system presented herein.
c) The tower installatios within the boulder fields require further investigation with the objective of establishing a method of joining large fragments together.

2.4 ELECTROMAGNETIC FIELD STUDY

2.4.1 Introduction

This report summarizes the audible noise (AN), radio interference (RI), electric field and magnetic flux density calculations carried out for the Talston Hydroelectric Expansion Project 161 kV ac transmission line. These effects were calculated and compared with standards or with the regulations and limits adopted by various utilities.

The CORONA3 program was used to determine the levels of electric field, magnetic flux density, audible noise (AN) and radio interference (RI). The CORONA3 program was developed following extensive monitoring and measurements of both AC and DC lines carried out by Bonneville Power Administration (BPA) and is widely used in the industry. With the exception of static electric field and magnetic fields, which are exactly calculated based on voltage, current and line geometry, all of the calculation algorithms implemented in the CORONA3 program are empirically derived from measured data. Some care and judgement needs to be applied when using such empirical methods especially if the line configurations being studied are different from the lines originally used in the measurements.

The following are the data and configuration of lines for which the calculations of electrical effects were performed.

- Structure Type: Type ‘A’ 0-3 degree lattice steel structure, single circuit with horizontal configuration, presented in Figure 6-26 in the Appendix D.
- Ground Clearance: 4.3 m for energized conductors.
- Nominal voltage: 161 kV, 60 Hz
- Phase conductors: single ACSR conductors 716 Stilt, each carrying 0.194 kA.
- Rain rate: 2.54 mm/hr
- Altitude less than 1000 m a.s.l.

All the ‘measuring points’ are 1 m above ground level. It should be noted that selection of the lowest point of the conductor presents the worst case and for all other points the effects would be lower. Since corona is significantly affected by weather, the EMF effects are stochastic quantities. The values presented are L50, meaning the actual values are expected to exceed the calculated values 50 % of time.

2.4.2 Electric Field

There are several documents that provide guidelines on the permitted level of time-varying electric fields [1-5]. A review of available documents indicates that there are no uniform international standards for limiting maximum electric field strength due to HVAC lines. The reference electric field levels for 60 Hz for occupational and general public exposure are shown in Table 2-13.

Table 2-13
Reference Levels for Exposure to Electric Fields (kV/m) (rms values, 60 Hz)

	IEEE 2002 [2]	ICNIRP 1998 [1]	ACGIH 2000 [3]	NRPB 1993 [4]	EU 1999
Occupational	20	8.3	25	12	-
General Public	5[a]	4.2[a]	-	12	4.2[a]

[a] On the edge of right of way

In the frequency range up to 1 kHz, the general public reference levels for electric fields are one-half of the values set for occupational exposure. The value 8.3 kV/m for a 60 Hz occupational exposure includes a sufficient safety margin to prevent stimulation effects from contact currents under all possible conditions. Half of this value was chosen for the general public reference levels (4.2 kV/m), to prevent adverse indirect effects for more than 90% of exposed individuals.

Some jurisdictions have set their own limits on the magnitude of the electric field as presented in Table 2-14. Another survey [6] of different utilities in North America shows that maximum permitted value of electric field within the ROW falls between 8-20 kV/m and maximum permitted value at the edge of the ROW is 1-3 kV/m.

Table 2-14
Electric Field Limits for Overhead Power Lines

Jurisdiction	Within ROW, kV/m	Edge of ROW, kV/m
Florida	10 (500 kV) 8 (230 kV)	2
Minnesota	8	
Montana	7	1
New Jersey		3
New York	11.8	1.6
Belgium	10	

The electric field profiles for the considered tower configuration are given in the Appendix D, on Figure 6-27. The maximum calculated electric field is 5.7 kV/m and 50 m from the center of the transmission line the electric field is below 0.1 kV/m. These values are the worst case at the lowest point of the line; all other points are higher and would produce lower values of electric field. If the most stringent limit (Montana) is used, the edge of the right of way shall be no less than 14 m from the center line of the proposed transmission line (28 m ROW width) to give a maximum exposure to the general public of 0.8 kV/m. The minimum distance from center line to edge of right of way could be reduced to 7 m (14 m ROW width) if the IEEE 2002[2] level was chosen as the maximum acceptable exposure level for the general public.

2.4.3 Magnetic Field

Influence of the low-frequency magnetic field on humans and animals has been investigated for more than 25 years. The ICNIRP document [1] provides guidelines on the permitted levels of time-varying magnetic fields. In the low-frequency range, the general public reference levels for magnetic fields are set at a factor of 5 below the values set for occupational exposure. Values recommended by different organizations for long-term exposure are presented in Table 2-15. Only a very few jurisdictions have set limits of magnetic filed and they are presented in Table 2-16.

Table 2-15
Reference Levels for Exposure to Magnetic Fields (Gauss) (rms values, 60 Hz)

	IEEE 2002	ICNIRP 1998	ACGIH 2000	NRPB 1993	EU 1999
Occupational	27.1	4.167	10	13	-
General Public	9.04	0.833	-	13	0.83

Table 2-16
Magnetic Field Limits for Overhead Power Lines [1]

	Edge of ROW, Gauss
Florida	0.2 (500 kV) 0.15 (230 kV)
New York	0.2

The magnetic flux density profile is presented in Figure 6-28, in the Appendix D. The calculated maximum value of magnetic flux density is 0.1 Gauss. At a point 50 m away from the center line of the transmission line, the value is 0.004 Gauss. Therefore, at all points, the magnetic field generated by the proposed Talston transmission line is lower than the recommended maximums.

2.4.4 Audible Noise (AN)

Audible noise generated by corona on high voltage transmission lines is different from other noise sources (e.g. traffic). The human response to corona noise is subjective and depends on the background noise. For example, ac corona intensifies when it's raining but at the same time the background noise level is much higher, thus the annoyance level is lower. Therefore, the fair weather values are accepted as reference for AN. Generally it is accepted that noise between 35-45 dB A corresponds to a quiet library environment.

The audible noise profile is given in Appendix D, in Figure 6-29. Audible noise levels generated by the lines during fair weather are very low, below 30 dB, and therefore only the rainy weather profile, at no point higher than 35 dB, is presented. According to the US Environmental Protection Agency (EPA) the day-night average sound level in residential areas should be limited to 55 dB A outdoors and 45 dB A indoors. Therefore in all cases the audible noise generated by the proposed Talston transmission line are well below the recommended maximums.

Table 2-17
Audible Noise (AN)

Recommended average sound level limit (outdoors/indoors) [US EPA]	Maximum audible noise generated by the proposed Talston transmission line
55 dB A / 45 dB A	Less than 35 dB A

2.4.5 Radio Interference (RI)

Canadian Standards Association (CSA) has developed a standard [7], for interference from high voltage ac power systems. This standard applies to radio interference in the frequency range of 0.15 MHz- 30 MHz generated by ac power lines. The standard specifies that the fair weather interference field strength, measured at 15 m laterally from the outermost conductor of the power line shall not exceed 49 (dB μV/m) for 70-200 kV lines at frequency of 0.5 MHz.

The RI profile is given in Figure 6-30 in the Appendix D.

For the proposed configuration, 15 m away from the outer conductor the RI is 34 (dB μV/m). Therefore, the RI generated by the proposed Talston transmission line is well below the CSA standard maximum.

Table 2-18
Radio Interference (RI)

Maximum radio interference [CSA]	Maximum radio interference generated by the proposed Talston transmission line
49 dB μV/m	34 dB μV/m

2.4.6 Summary

A summary of EMF effects generated by the considered structure is presented in Table 2-19. All the parameters are below recognized limits and are similar compared to other ac lines with similar configuration. The values for AN and RI are L50, which means the actual AN and RI are expected to be below the calculated values 50% of the time.

Table 2-19
Summary of Results

	Type 'A' 0-3 Degree Tower
Electric Field	
a) Maximum[1] (kV/m)	5.7
b) 7 m from Center Line (kV/m)	4.7
c) 14 m from Center Line (kV/m)	0.8
b) 50 m from Center Line (kV/m)	0.1
Magnetic Induction	
a) Maximum (Gauss)	0.1
b) 50 m from Center Line (Gauss)	0.004
AN[2] (dBA)	35
RI[3] (dB µV/m)	34

2.4.7 References

1. ICNIRP Guidelines, Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (up to 300 GHz)
2. Institute of Electrical and Electronics Engineers (IEEE). IEEE PC95.6-2002 standard for safety levels with respect to human exposure to electromagnetic fields, 0 to 3 kHz. Prepared by Subcommittee III of Standards Coordinating Committee 28, IEEE Standards Department. New York: Institute of Electrical and Electronics Engineers, Inc.; 2002.
3. American Conference of Governmental Industrial Hygienists (ACGIH): 2002 TLVs® and BEIs®: threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists; 2002.
4. National Radiological Protection Board (NRPB). Restrictions on human exposure to static and time varying electromagnetic fields and radiation: scientific basis and recommendation for implementation of the Board's statement. Documents of the NRPB 1993;4:8–69.
5. B.J. Maddock, Guidelines and Standards for Exposure to Electric and Magnetic Fields at Power Frequencies (CIGRE, 1992 Session, 30 August – 5 September)
6. Teshmont Consultants LP, Factors Utilized by North American Utilities to Determine the Width of Right-of-Way
7. CSA C108.3.1-M84, Limits and Measurement Methods of Electromagnetic Noise from AC Power Systems 0.15 - 30 MHz

2.5 ROUTE ADJUSTMENTS

2.5.1 Final Route Mapping at Misery Point

An alternative line route was selected to avoid the major caribou movements near Misery Point and the east end of MacKay Lake, and be further away from the hunting camp on the east side of Lac du Gras. The alternative line route varied from approximately 5 to 10 km east of the originally proposed route. The revised line route would head in an eastern direction from Ekati and then south-eastward until PI 39. The revised line route then heads in a southern direction to intersect with the original alignment near the south end of Zyena Lake at PI 25.

All features i.e. terrain, topographical, vegetation, geotechnical, etc. are similar to the original alignment. The disadvantage of the alternative line route is that it is further away from the existing winter roads, and longer access roads to the line will be necessary, but this will become a non-issue if an access road is built directly along the line.

2.5.2 Final Route Mapping at Charlton Bay

This part of the line was previously assessed during the first field trip conducted from July 14th to 18th, 2008. The main objective this time was to conduct the geotechnical assessment based on the visual inspection of the rocks and soil. Another objective was to determine an alternate route from Lockhart River to Snowdrift River via Charlton Bay. The benefit of this alternative is bringing the line route as close as possible to the barging and assembly areas.

An alternate route was selected, enabling the line to come closer to Charlton Bay. The following additional PI's were selected for PI 10, 11, 12, 13 and 14, as per Table 2-20.

2.5.3 Final Baseline Route PI Points

Following the desktop and the field study, the final Baseline route was selected. It comprises of three sections, presented in Table 2-20, Table 2-21 and Table 2-22.

Table 2-20
Final Baseline route PI points – Twin Gorges to Ekati

PI	Easting (m)	Northing (m)	Length (m)	Chainage (km)
1	478,500	6,699,200		
2	484,000	6,698,750	5518.38	6
3	493,800	6,727,800	30658.48	36

Table 2-20
Final Baseline route PI points – Twin Gorges to Ekati

PI	Easting (m)	Northing (m)	Length (m)	Chainage (km)
4	499,500	6,738,800	12389.11	49
5	507,500	6,754,800	17888.54	66
6	506,800	6,759,800	5048.76	72
7	516,250	6,774,800	17728.58	89
8	550,110	6,850,410	82845.47	172
9	557,750	6,859,500	11874.25	184
10	593,000	6,915,000	65748.10	250
11	593,808	6,940,803	25815.65	276
12	602,826	6,949,411	12466.84	288
13	611,570	6,966,560	19249.56	307
14	611,300	6,967,999	1464.11	309
15	610,750	6,968,700	891.01	310
16	598,800	6,991,500	25741.84	335
17	600,000	7,019,000	27526.17	363
18	591,600	7,035,400	18426.07	381
19	590,000	7,035,400	1600.00	383
20	591,200	7,037,750	2638.65	386
21	590,260	7,038,600	1267.32	387
22	583,500	7,053,800	16635.43	403
23	565,500	7,075,700	28348.02	432
24	560,825	7,083,000	8668.66	440
25	560,869	7,085,393	2393.40	443
26	561,560	7,097,623	12249.51	455
27	562,336	7,099,115	1681.74	457
28	563,342	7,105,224	6191.28	463
29	562,792	7,112,710	7506.18	470
30	563,789	7,115,693	3145.20	474
31	561,528	7,123,571	8196.04	482
32	561,890	7,128,400	4842.55	487
33	556,500	7,128,900	5413.14	492
34	556,750	7,135,500	6604.73	499
35	557,600	7,137,600	2265.50	501
36	556,839	7,140,392	2893.85	504
37	557,308	7,144,448	4083.03	508
38	554,778	7,148,696	4944.33	513
39	556,105	7,157,003	8412.32	521
40	553,920	7,161,750	5225.73	526
41	550,000	7,165,825	5654.38	532

Table 2-20
Final Baseline route PI points – Twin Gorges to Ekati

PI	Easting (m)	Northing (m)	Length (m)	Chainage (km)
42	545,612	7,174,370	9605.81	542
43	541,229	7,177,807	5569.89	547
44	534,965	7,180,000	6636.79	554
45	522,500	7,178,200	12594.29	567
46	520,900	7,176,500	2334.52	569

Table 2-21
Final Baseline route PI points – Ekati to Diavik

PI #	Easting (m)	Northing (m)	Length (m)	Chainage (km)
46	520,900	7,176,500		
47	526,200	7,172,500	6640.03	7
48	531,800	7,160,999	12791.91	19
49	531,000	7,159,200	1968.86	21
50	529,000	7,155,400	4294.18	26
51	532,200	7,153,500	3721.56	29
52	532,600	7,151,000	2531.80	32

Table 2-22
Final Baseline route PI points – Gahcho Kué to Snap Lake

PI #	Easting (m)	Northing (m)	Length (m)	Chainage (km)
21	590,260	7,038,600		
53	587,920	7,038,000	2,416	2
54	583,540	7,036,830	4,534	7
55	576,320	7,040,150	7,947	15
56	574,825	7,041,380	1,936	17
57	572,130	7,042,750	3,023	20
58	571,340	7,043,330	980	21
59	568,400	7,044,200	3,066	24
60	544,800	7,049,100	24,103	48
61	534,400	7,045,599	10,973	59
62	531,000	7,043,600	3,944	63
63	524,600	7,044,200	6,428	69

Table 2-22
Final Baseline route PI points – Gahcho Kué to Snap Lake

PI #	Easting (m)	Northing (m)	Length (m)	Chainage (km)
64	522,500	7,042,600	2,640	72
65	511,200	7,044,800	11,512	84
66	511,000	7,045,600	825	84
67	509,100	7,047,500	2,687	87
68	507,100	7,049,600	2,900	90
69	506,400	7,051,800	2,309	92

2.6 CONSTRUCTION METHODOLOGY AND SCHEDULE

2.6.1 General Criteria

The following preliminary criteria were considered while investigating the line routes and staging areas during the field studies. These criteria would be preferred and would produce a feasible, economical, and safe line while mitigating the environmental impacts.

- utilize existing or construct new winter road next to line route as much as possible
- set line route as close as possible to winter road
- build temporary access trails along the line within the right of way, as much as possible and to and from winter roads as required
- access will be required for construction and maintenance
- stage camps and marshalling yards (3 to 5 ha) every 120 to 150 km apart if construction with ground access along the line otherwise stage small camps (< 35 workers) and marshalling yards (2 to 3 ha) every 50 to 60 km apart for construction with aerial access only
- haul materials and supplies as much as possible by winter road to line sections Twin Gorges to Nonacho Lake North, Ekati to Diavik to Gahcho Kué and as far south as possible from Gahcho Kué, and to Snap Lake, and distribute along winter road or line route as much as possible
- barge materials and supplies to Fort Reliance and other selected staging areas selected at the east arm of Great Slave Lake for construction with aerial access
- utilize guyed “Y” lattice steel towers for tangents (similar to those shown in Jan 2005 Feasibility Study, light, easy to assemble and climb for construction and maintenance) and either the guyed triple mast structure (similar to those shown in the Jan 2005 Feasibility Study) or self-supporting lattice steel towers for angles and dead ends
- utilize small diameter drilled and grouted anchors for foundations and anchors in rock and permafrost, and grillage type foundations and anchors in unfrozen mineral soils
- perform tree clearing by machine and mostly in winter season (hand clearing very dangerous and slow and only do if lack of access for machines)
- may consider hand clearing by aerial access during warm weather
- may consider installing rock foundations and anchors by aerial access during warm weather
- may consider assembling towers, and transporting and setting towers by aerial access during warm weather
- install grillage type foundations and anchors during cold weather on frozen ground unless access available during warm weather
- perform slack stringing during cold weather unless access available during warm weather
- aerial tension string in rough terrain and at poor or no ground access areas

The Taltson Hydroelectric Expansion Project Transmission Line Mapbook dated May 16 and July 28 2008 Rev 2 and 3 respectively, the Project Area Overview dated June 21, July 28, and

Aug 20 2008 Rev 0, 3, and 4 respectively, and the Project West Route Maps dated July 14, 2008 Rev 0, prepared by Golder Associates, were used as references for the desktop and field studies of the baseline route and its options. The Trans-Island Option Mapbook dated July 23 2008 was used as reference for the desktop and field studies of the trans-island option.

2.6.2 Baseline Option

The Baseline Option (baseline) 161 kV transmission line starts at Twin Gorges and extends north-east towards the Lockhart River near Reliance and continues north to north-west to the Gahcho Kué and Ekati mines. The baseline route continues with a 69 kV line south from Ekati to Diavik. The line length from Twin Gorges to Ekati is estimated at 571 km and from Ekati to Diavik is estimated at 33 km. The Baseline Option also includes a 69 kV transmission line which extends west from Gahcho Kué to Snap Lake with an estimated line length of 94 km.

The transmission line has been separated into four sections based on the line voltage, access, and construction methods proposed for these sections, which are as follows:

- Southern Section - Twin Gorges to Snowdrift River – 248 km at 161 kV
- East Great Slave Lake Section - Snowdrift River to Treeline – 104 km at 161 kV
- Northern Section – Treeline to Ekati – 217 km at 161 kV
- Ekati to Diavik Section – 32 km at 69 kV
- Gahcho Kué to Snap Lake Section – 92 km at 69 kV

2.6.3 Construction Access and Accommodations

Staging areas for construction of the Baseline option are presented in Figure 2-11.

2.6.3.1 Southern Section – Twin Gorges to Snowdrift River

Construction access to the Southern Section would be by the re-established existing winter road from Ft. Smith to Twin Gorges and continue along the proposed winter road from Twin Gorges to Sparrow Bay. Line and substation materials, clearing and construction equipment, fuel, supplies and camps would be hauled in by trucks from Ft. Smith to Twin Gorges and be distributed along the line at the various staging areas.

The proposed staging areas would be located at Twin Gorges, Indian Shack, King Lake, Taltson Lake, Taltson River, Nonacho Lake South, and Sparrow Bay. Specific locations for the staging areas would be selected upon receipt of detailed LiDAR survey information and further field reconnaissance. The staging areas would be utilized for material and fuel storage, assembly and marshalling yards. The area required for staging is estimated at 3 to 5 hectares for major staging areas and 2 to 3 hectares for minor staging areas. Workers, materials, and equipment would be transported daily either by ground or aerial access from these areas onto the line.

Temporary access trails are proposed where terrain permits and would be constructed in the winter where possible from the staging areas to the line and continuously along the line right of way. The temporary access trail would be a single 5 meter wide bladed “winter road” trail and would be used daily to transport workers, materials, and construction equipment up and down the line. Only where necessary will the trail leave the right of way to go around an obstacle ie high rock cliff or open waterway. Where the trail would deviate from the right of way, a path would be selected to minimize impact ie travel in the clearings and on the water bodies. If the terrain is suitable, pick-ups and trucks would be utilized.

Based on the terrain conditions in the Southern Section, it is assumed that tracked equipment for machine clearing, foundation construction, and conductor installation would be used on the temporary access trails. If the terrain permits, rubber tired vehicles and equipment would be used. Also in the Southern Section, it is assumed that all structure erection and some conductor stringing would be done using helicopter construction methods.

The proposed camps for accommodations would be located at Twin Gorges, Taltson Lake, and Sparrow Bay. Main camps would accommodate 50 to 80 persons and minor camps would accommodate less than 40 persons. Camps would be left in place until all construction activities for that line section specific to that camp are completed and may extend over a number of winter and summer seasons.

2.6.3.1.1 Twin Gorges Staging Area and Camp

Twin Gorges would serve as the main staging area and main camp for the South Section. This staging area would be used for the clearing and construction of the first 25 km of line. The terrain is difficult in this section and hand clearing and construction with aerial access is assumed. Closer to Twin Gorges with its surrounding all-weather and winter roads, temporary access trails may be feasible for tracked equipment. A minor staging area may be located where the proposed winter road crosses the line approximately 10 km north of Twin Gorges.

2.6.3.1.2 Indian Shack Staging Area

Indian Shack would serve as a minor staging area for the line section 10 km south and 17 km north of Indian Shack. The terrain is difficult in this section and hand clearing and construction with aerial access is assumed. Structure erection using helicopters is assumed for the line section 10 km south and 27 km north of Indian Shack.

2.6.3.1.3 King Lake Staging Area

King Lake would serve as a minor staging area for the line section 37 km south and 20 km north of King Lake. The terrain is less difficult in this section and construction of temporary access trails is assumed. Machine clearing, foundation construction, and conductor installation with tracked equipment is assumed. Structure erection and some conductor stringing using helicopters are assumed for the line section 27 km south and 20 km north of King Lake.

2.6.3.1.4 Taltson Lake Staging Area and Camp

Taltson Lake would serve as a major staging area for the line section 20 km south and 12 km north of Taltson Lake. Also it would serve as a main camp location. The terrain is less difficult in this section and construction of temporary access trails is assumed. Machine clearing, foundation construction, and conductor installation with tracked equipment is assumed. Structure erection and some conductor stringing using helicopters are assumed.

2.6.3.1.5 Taltson River Staging Area

Taltson River would serve as a minor staging area for the line section 12 km south and 14 km north of Taltson River. The terrain is less difficult in this section and construction of temporary access trails is assumed. Machine clearing, foundation construction, and conductor installation with tracked equipment is assumed. Structure erection and some conductor stringing using helicopters are assumed.

2.6.3.1.6 Nonacho Lake South Staging Area

Nonacho Lake South would serve as a minor staging area for the line section 14 km south and 14 km north of Nonacho Lake South. The terrain is less difficult in this section and construction of temporary access trails is assumed. Machine clearing, foundation construction, and conductor installation with tracked equipment is assumed. Structure erection and some conductor stringing using helicopters are assumed.

2.6.3.1.7 Sparrow Bay

Sparrow Bay would serve as a main staging area for the line section 14 km south and 33 km north of Sparrow Bay. Also it would serve as a minor camp location. The terrain is less difficult in this section and construction of temporary access trails is assumed. Machine clearing, foundation construction, and conductor installation with tracked equipment is assumed. Structure erection and some conductor stringing using helicopters are assumed.

2.6.3.2 East Great Slave Lake Section - Snowdrift River to tree line

Construction access to the East Great Slave Lake Section in the warm weather season would be by aerial access (helicopters or float planes) and barges to the lake staging areas and in the cold weather season by aerial access (helicopters and planes with skis) and by winter road from Yellowknife to the Treeline staging area. Construction access and delivery of materials and equipment to the line section would be mostly by helicopter and where possible by temporary access trails in the winter.

Line materials, clearing and construction equipment, fuel, supplies and camps would be hauled by trucks or trains to Hay River and barged to the Charlton Bay and McLeod Bay staging areas. Also line materials, clearing and construction equipment, fuel, supplies and camps would be hauled by trucks to Yellowknife and on winter roads to the Treeline staging area.

The proposed staging areas would be located at Charlton Bay, McLeod Bay, and Treeline.

In the East Great Slave Section it is assumed that a majority of this line section (between Glacier Creek and the tree line) would be constructed with aerial access. From Glacier Creek to the Snowdrift River it may be possible to construct temporary access trails in the winter. Only tracked equipment for machine clearing, foundation installation, and conductor installation would be used on the temporary access trails. Structure erection and some conductor stringing would be done using helicopters.

The proposed camps for accommodations would be located at Charlton Bay, McLeod Bay, and Treeline.

2.6.3.2.1 Charlton Bay Staging Area and Camp

Charlton Bay would serve as a barge landing site and major staging area for the line section approximately 30 km south towards the Snowdrift River and 14 km north-east towards Glacier Creek. Also it would serve as a main camp location. The terrain is less difficult in this section and construction of temporary access trails is assumed. Machine clearing, foundation construction, and conductor installation with tracked equipment is assumed. Structure erection and some conductor stringing using helicopters are assumed. Winter construction is assumed for this line section.

2.6.3.2.2 McLeod Bay Staging Area and Camp

McLeod Bay would serve as a barge landing site and major staging area for the line section approximately 16 km south towards Glacier Creek and 23 km north towards Treeline. Also it would serve as a main camp location. The terrain is difficult in this section and construction with aerial access only is assumed. Hand slashing is assumed in this section. Summer construction is assumed for this line section.

2.6.3.2.3 Treeline Staging Area and Camp

Treeline would serve as a minor staging area for the line section 22 km south towards the Lockhart River and 14 km north towards Gahcho Kué. Also it may serve as a minor camp location. The terrain south of Treeline is difficult and construction with aerial access only is assumed. Hand slashing is assumed in this section. Summer construction is assumed for this line section. For the line section north of Treeline refer to the Northern Section.

2.6.3.2.4 Northern Section – Treeline to Ekati

Construction access to the Northern Section would be via the winter roads to each of the mines, Gahcho Kué, Ekati, and Diavik. Additional winter roads are proposed to the staging areas, from Gahcho Kué to Treeline, from the winter road on MacKay Lake to East Reid Lake and East MacKay/Lockhart, and from the winter road on Lac du Sauvage to Lac du Sauvage South and North. Construction access and delivery of materials and equipment to the line section would be by temporary access trails in the winter and helicopters in the summer.

Line and substation materials, construction equipment, fuel, supplies, and camps would be transported by trucks from Yellowknife to each of the mines and staging areas.

The proposed staging areas would be located at Gahcho Kué, Treeline, East Reid Lake, East MacKay/Lockhart, Lac du Sauvage South and North, Ekati, and Diavik.

For the Northern Section it is assumed that the line would be constructed with the use of temporary access trails along the line in the winter. The terrain is typically tundra with flatter rolling hills and valleys interspersed with water bodies and are suitable for temporary access trails. No clearing is required in this line section as all of the line is above the tree line. All construction would be carried out along the line. Transport of workers and equipment, material delivery, foundation construction, structure assembly and crane erection, and conductor installation by slack stringing would all be carried out along the line. Some construction with aerial access may be carried out in the summer for scheduling purposes. Substations would be constructed in the summer.

It is assumed that the camps at the mines would be available for accommodations and the only other proposed camp would be located at Treeline. If accommodations at the mines are not available then independent camps would be provided for the line and substation construction.

2.6.3.2.5 Treeline Staging Area and Camp

Treeline would serve as a minor staging area for the line section 22 km south towards the Lockhart River and 14 km north towards Gahcho Kué. Also it would serve as a minor camp location. For the line section south of Treeline refer to the East Great Slave Section. The terrain north of Treeline is tundra with flatter rolling hills and valleys and construction of temporary access trails is assumed.

2.6.3.2.6 Gahcho Kué Staging Area and Camp

Gahcho Kué would serve as a major staging area for the substation and line section 15 km south towards Treeline, 15 km north towards East Reid Lake, and 18 km west towards Margaret Lake. Also it would serve as a main camp location.

2.6.3.2.7 East Reid Lake Staging Area

East Reid Lake would serve as a minor staging area for the line section 15 km south towards Gahcho Kué and 31 km north towards East MacKay/Lockhart. It is a convenient location to drop off and store materials for distribution along the line as it is close to the winter road in to Gahcho Kué. It reduces the amount of travel on the line for material delivery.

2.6.3.2.8 East MacKay/Lockhart Staging Area and Camp

East MacKay/Lockhart would serve as a major staging area for the line section 31 km south towards East Reid Lake and 28 km north towards Lac du Sauvage South. Also it would serve as a small camp location. It is a convenient location to drop off and store materials for distribution along the line as it is close to the winter road on MacKay Lake. It reduces the amount of travel on the line for material delivery and transport of workers.

2.6.3.2.9 Lac du Sauvage South Staging Area

Lac du Sauvage South would serve as a minor staging area for the line section 28 km south towards East MacKay/Lockhart and 10 km north towards Lac du Sauvage North. It is a convenient location to drop off and store materials for distribution along the line as it is close to the winter road on Lac du Sauvage. It reduces the amount of travel on the line for material delivery.

2.6.3.2.10 Lac du Sauvage North Staging Area

Lac du Sauvage North would serve as a minor staging area for the line section 10 km south towards Lac du Sauvage South and 11 km west towards Ekati. It is a convenient location to drop off and store materials for distribution along the line as it is close to the winter road on Lac du Sauvage. It reduces the amount of travel on the line for material delivery.

2.6.3.3 Ekati to Diavik Section – 69 kV

Construction access to the Ekati to Diavik Section would be via the winter roads to the each of the mines.

Line and substation materials, construction equipment, fuel, supplies, and camps would be transported by trucks from Yellowknife to each of the mines.

It is assumed that the camps at the mines would be available for accommodations. If accommodations at the mines are not available then independent camps would be provided for the line and substation construction.

2.6.3.3.1 Ekati Staging Area and Camp

Ekati would serve as a major staging area for the substation and the line section 11 km east towards Lac du Sauvage North and 17 km south towards Diavik. Also it would serve as a main camp location.

2.6.3.3.2 Diavik Staging Area and Camp

Diavik would serve as a staging area for the substation and the line section 17 km north towards Ekati. Also it would serve as a main camp location.

2.6.3.4 Gahcho Kué to Snap Lake Section

Construction access to the Gahcho Kué to Snap Lake Section would be via the winter roads to the each of the mines. Additional winter roads are proposed to the staging areas, from Snap Lake to Lac Capot, from the winter road to Gahcho Kué on Margaret Lake to south end of Margaret Lake. Construction access and delivery of materials and equipment to the line section would be by temporary access trails in the winter and helicopters in the summer.

Line and substation materials, construction equipment, fuel, supplies, and camps would be transported by trucks from Yellowknife to each of the mines and staging areas.

The proposed staging areas would be located at Gahcho Kué, Margaret Lake, Lac Capot, and Snap Lake.

For the Gahcho Kué to Snap Lake Section similar construction to that used in the Northern Section is assumed. The line would be constructed with the use of temporary access trails in the winter. The terrain is typically tundra with flatter rolling hills and valleys interspersed with water bodies and are suitable for temporary access trails. No clearing is required in this line section as all of the line is above the tree line. All construction would be carried out along the line.

Transport of workers and equipment, material delivery, foundation construction, structure assembly and crane erection, and conductor installation by slack stringing would all be carried out along the line. Some construction with aerial access may be carried out in the summer for scheduling purposes. Substations would be constructed in the summer.

It is assumed that the camps at the mines would be available for accommodations. If accommodations at the mines are not available then independent camps would be provided for the line and substation construction.

2.6.3.4.1 Gahcho Kué Staging Area and Camp

Gahcho Kué would serve as a major staging area for the substation and the line section 18 km west towards Margaret Lake. Also it would serve as a main camp location.

2.6.3.4.2 Margaret Lake Staging Area

Margaret Lake would serve as a minor staging area for the line section 18 km east towards Gahcho Kué and 18 km west towards Lac Capot. It is a convenient location to drop off and store materials for distribution along the line as it is close to the winter road in to Gahcho Kué. It reduces the amount of travel on the line for material delivery.

2.6.3.4.3 Lac Capot Staging Area

Lac Capot would serve as a minor staging area for the line section 18 km east towards Margaret Lake and 11 km west towards Diavik. It is a convenient location to drop off and store materials for distribution along the line. It appears that a winter road could easily be constructed from Snap Lake with the majority of the road on Lac Capot. It reduces the amount of travel on the line for material delivery.

2.6.3.4.4 Snap Lake Staging Area and Camp

Snap Lake would serve as a major staging area for the substation and the line section 11 km west towards Lac Capot. Also it would serve as a main camp location.

2.6.3.5 Clearing

The transmission line right of way for the 161 kV is assumed at 30 meters wide. Clearing will be required from Twin Gorges to the tree line for an estimated length of 356 km. The amount and width of clearing will be variable depending on the density and height of trees. The minimum width recommended is 15 meters directly under the line to reduce the potential damage to the conductors and insulators due to fire. An average of 20 meters was assumed for estimating purposes. Clearing of the right of way would be by machine methods during the cold weather season where temporary access trails are feasible and by hand slashing where there is only aerial access. Hand slashing and bucking would be carried out during the warm weather season but may also be carried out during the cold weather season if the schedule requires. Machine clearing would be done either by mulching the brush to the ground level with excavator mounted brush cutters or knocked down and cut off by a bulldozer mounted V-blade or by a rotary drum mulcher in the swamp areas. Brush raking, piling, and burning may be necessary, if not cleared by mulching, in some sections to eliminate the newly cut brush which is fuel for fires. Each tower site would have to be cleared to ground level with an area of 30 meters by 30 meters minimum. Temporary access trails would be cleared to ground level. Normal brush relative to the area was observed at the south end near Twin Gorges and around the Lockhart River area. At some line sections the brush was sparse (approximately 30% of the line length with brush). Along the line there are numerous burnt areas (approximately 10% of the line length with brush) with little or no clearing required.

For machine clearing, an average clearing rate of 8 hectares per day (4 km/day) was assumed.

For hand slashing, an average clearing rate of 0.25 hectares per day (0.5 km/day) was assumed for one 3-person crew working 1 shift of 11 hours.

2.6.3.6 Temporary Access Trails

Temporary access trails at 5 meters wide would be constructed where possible by blading with a skidder or nodwell or snowcat. Hagglund tracked vehicles would be used to construct the “winter road” ice crossings and to initially cross the frozen waterways. Construction of the temporary access trails is estimated at 3 to 5 km per day depending on the terrain. The construction of the temporary access trails would be done in conjunction with the clearing operation.

2.6.3.7 Foundation Construction

Foundation construction would normally be done during the cold weather season with the use of the temporary access trails except for those line sections identified as aerial access only in which case the foundations may be constructed in the warm or cold weather season.

In the Section 2.3, four different soil types have been identified along the line route as follows: bedrock outcrops; heavily weathered and broken rock outcrops; permafrost affected soils; and marsh and swamp areas. Each of the four different soil types has different foundation and anchor recommendations. The line route is predominantly bedrock outcrops with approximately 85% of the foundations and anchors being founded in rock. For the bedrock outcrops, rock anchors would be used for the tower mast foundation and anchors. For the permafrost soils, broken rock outcrops, and swamp areas, preference would be to install overburden drilled anchors or micro piles.

For rock anchor installation, tracked or skid mounted air track drills, compressors, and grout pumps and containers, or nodwell tracked vehicles equipped with rock drills would be used. For the overburden drilled anchors or micro piles, nodwell tracked vehicles equipped with backhoes, cranes, dual rotary drills with down the hole hammers, and tracked excavators with buckets or drills would be used. Temporary access trails along the line are required for the above equipment. In areas using helicopter construction methods similar equipment except much smaller and lighter would be used that could be transported by helicopters.

For rock anchor foundations and anchors, a crew size of 6 persons working 2 shifts of 11 hours per day is estimated to achieve 6 tower sites per day.

For the overburden drilled anchors or micro pile foundations and anchors, a crew size of 6 persons working 2 shifts of 11 hours per day is estimated to achieve 4 tower sites per day.

2.6.3.8 Structure Assembly

Structure assembly would be carried out at the staging areas for the Southern and East Great Slave Lake Sections. For the Northern and Gahcho Kué to Snap Lake Sections structure assembly would be carried out at each of the tower sites.

A 6 person crew size is estimated to complete the assembly of a tower in an average time of 8 hours.

2.6.3.9 Structure Erection

Structure erection in the Southern and East Great Slave Lake Sections would be carried out using helicopter construction methods. A heavy lift helicopter (S61) would pick, haul, and set the towers on the foundations. Medium lift helicopters would transport a crew size of 5 to 6 persons to the tower sites. Based on an average distance of 15 km from the staging area to the tower site, an estimate of 17 towers per 11 hour shift would be erected.

For the Northern and Gahcho Kué to Snap Lake Sections structure erection by crane would be carried out at each of the tower sites. With a crew size of 6 persons, an estimate of 12 towers per 11 hour shift would be erected.

2.6.3.10 Conductor Installation

Conductor installation in parts of the Southern and East Great Slave Lake Sections would be carried out using helicopter construction methods during the warm weather season. A medium lift helicopter would be used to tension string the conductor. An estimate of 2 circuit km of line per day is assumed.

For the Northern and Gahcho Kué to Snap Lake Sections and parts of the Southern and East Great Slave Lake Sections, conductor installation by slack stringing would be carried out during the cold weather season. An estimate of 3.5 circuit km of line per day is assumed.

2.6.3.11 Substations

A new switching/step-up station is proposed near the existing Twin Gorges substation and new step-down substations are proposed at each of the mine sites next to their existing diesel generating plants.

Substation footprints would be typically 35 m x 45 m. Substation civil works would involve the construction of an access road, site drainage, compacted granular pad sized to the substation footprint, limited amount of reinforced concrete foundations for equipment and structures (most equipment would be skid mounted and placed directly on the granular pad), structural steel support structures, structural steel A-frame termination structure, precast concrete cable trenches at road crossings within the substation, above ground cable trays, and chain link fence. Substation electrical works would involve the installation of pre-manufactured and pre-wired control building on skids, limited amount of rigid bus, shallow ground grid, grounding, Pad mounted transformer and breaker. If required by environmental regulations, containment pits would be constructed for the transformers. Grounding will have to be determined depending on soil resistivity tests and further study. Based on the results of the grounding study, drilled grounding wells may be required. All materials would be truck transportable. Transformers would be jacked and rolled off trucks to their final position.

2.6.3.12 Schedule

The project schedule is shown in Figure 2-12 and Figure 2-13. The construction schedule of the transmission lines and substations is based on an expected construction start in January 2010 and in-service date of March 2012. The environmental approval is expected in September 2009. Engineering and Issue for Construction packages must be completed by this date and material procurement purchase orders ready for issue. It is assumed that the existing winter road from Ft. Smith to Twin Gorges will be re-established in January 2010 and the new winter road from Twin Gorges to Nonacho Lake will be started early and completed in the 2009/2010 winter season. Also it is assumed that the winter roads to the mines will be available in January 2010.

2.6.3.12.1 Transmission Lines

The transmission lines project schedule is based on the estimated production rates and construction seasons listed in the construction methodology and the availability of the winter roads as stated above. With a construction start in October 2009, the estimated completion date is September 2011.

2.6.3.12.2 Substations

Substation construction is estimated to take 16 to 20 weeks. Warm weather construction is assumed. As an option, modularized skid mounted substations may be supplied and is estimated to take 6 to 8 weeks for installation.

2.6.3.13 Material and Construction Cost Estimates

Cost estimates are high level opinions of probable costs in 2008 Canadian dollars without contingencies or taxes.

Cost components included in the cost estimate are presented in the Table 2-23. A short description of the cost components is given below.

Material prices are based on recent bids and current market conditions.

Construction costs include estimates for labour, including project management, safety personnel, equipment, fuel, and camp costs to construct the items of work. Construction costs are based on recent bids and current market conditions and are escalated for the remoteness of the project.

Preliminary design and bid quantity includes preparation of the preliminary design, estimate of the weights and quantities for all types of normal towers to be used for the transmission line.

Lidar Survey component assumes flying over the route to collect aerial laser digital ground data and digital orthorectified images, and data conversion to a format suitable for PLS-CADD software (feature coding).

Ground surveying includes surveying the transmission line route and substation location based on GPS coordinates provided by the owner's engineer. This also includes locating various transmission line towers on the route, locating the right of way and intimating any problems at the site.

Engineering and line design consists of design of line towers and substation structures, design of foundations, transmission line design and preparation of drawings.

Geotechnical investigation includes boring test holes to investigate soil/rock parameters in order to carry out the foundation design. This is to be conducted at pre-selected locations along the transmission line route and substation locations, based on expected soil variations.

Construction support activity includes design support during construction for unforeseen situations at the site.

Table 2-23
Cost components Included in the Cost Estimate

Cost Component	Included
Preparation of specification	✓
Preliminary design and bid quantity	✓
Preliminary and final design	✓
LiDAR Survey and ground survey	✓
Engineering and line design	✓
Material	✓
Construction	✓
Right of way clearing	✓
Construction and maintenance of winter roads	✓
Construction and maintenance of construction trails	✓
Geotechnical investigation	✓
Design support during construction	✓
Taxes	-
Bonds	-
Insurances	-
Land acquisition and easements	-
Environmental assessment and monitoring	-
Forestry practices	-
Owners administration	-
Allowance of Funds Used During Construction (AFUDC)	-

The cost estimates are based on the selected line route, staging areas and camp locations, substation locations, foundation and structure preliminary designs, and construction methodologies and schedules presented in previous sections of this report.

The cost estimates are based on working 11 hours per day and a work schedule of 21 days on and 7 days off.

2.6.3.13.1 Transmission Lines

Transmission line cost estimates are broken down into the four line sections and major work items.

No provisions were allowed for grounding, lightning protection, or communications in the transmission lines.

2.6.3.13.1.1 Mobilization and Demobilization

The estimated cost of Mobilization and Demobilization includes the transportation and delivery of workers, equipment, fuel, camp materials, and other incidentals to project staging areas and camps, and clean-up. It also includes the estimated cost of set-up and take-down, operation and maintenance of the camps.

2.6.3.13.1.2 Clearing

The estimated cost of Clearing includes the labor, equipment, and fuel to clear the trees and vegetation to ground level by machine methods or hand slashing. The average transmission line right of way width was assumed to be 20 meters. Helicopter transportation costs have been included for those line sections with helicopter access only.

2.6.3.13.1.3 Access

The estimated cost of Access includes the construction and maintenance during construction of temporary access trails along the transmission line and to and from the staging areas. Access also includes the estimated cost of constructing and maintaining winter roads from the annually constructed winter roads to the project sites during construction.

2.6.3.13.1.4 Foundations

The estimated cost of Foundations includes the supply and installation of tower mast foundations and guy anchors by machine or helicopter methods in rock or soil. Soil includes all other geotechnical conditions such as permafrost affected soils and swampy areas. The amount of rock was assumed at 85% and soil at 15% of the line length.

2.6.3.13.1.5 Structures

The estimated cost of Structures includes the supply and installation of tangent, angle, and dead end structures with erection by crane or helicopter methods. The type of structures was based on the guyed Y lattice steel tangent structure and guyed two and three mast lattice steel angle and dead end structures as shown in the IHI January 2005 report. No provision was made for grounding, lightning protection, or communications, including peaks for overhead ground wire or fiber optic ground wire. The quantity of structures was determined based on an average span of 333 meters and assumptions that 90% were tangents and 5% were light and medium angles and 5% were heavy angle and dead ends. The estimated cost of insulators, hardware, and guys was added to the structure material costs.

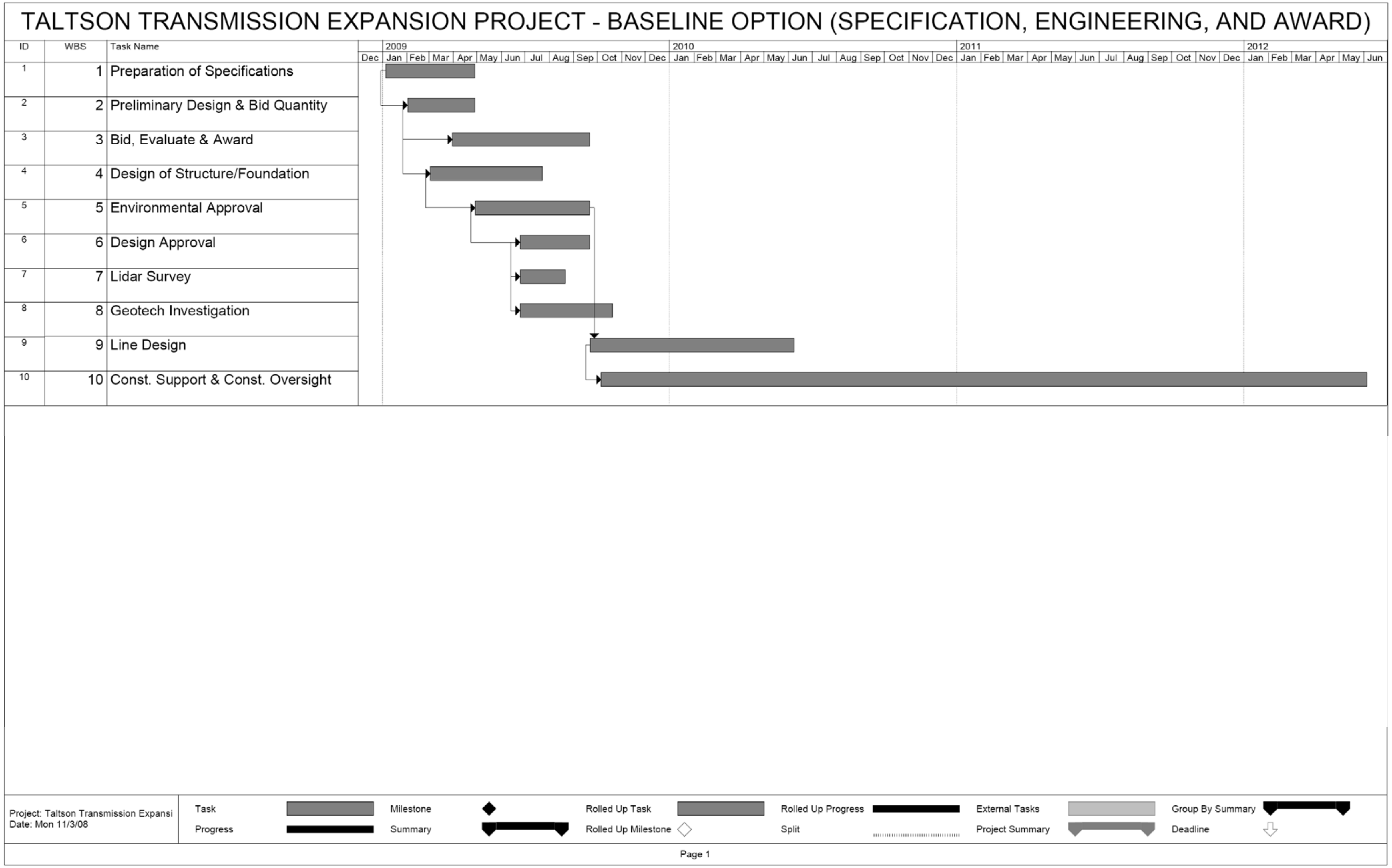
2.6.3.13.1.6 Conductors

The estimated cost of Conductors includes the supply and installation of the phase conductors by slack or tension stringing by machine or helicopter methods. The conductors assumed were Stilt for the 161 kV lines and Ostrich for the 69 kV lines. No provisions have been included for an overhead ground wire or optical ground wire.

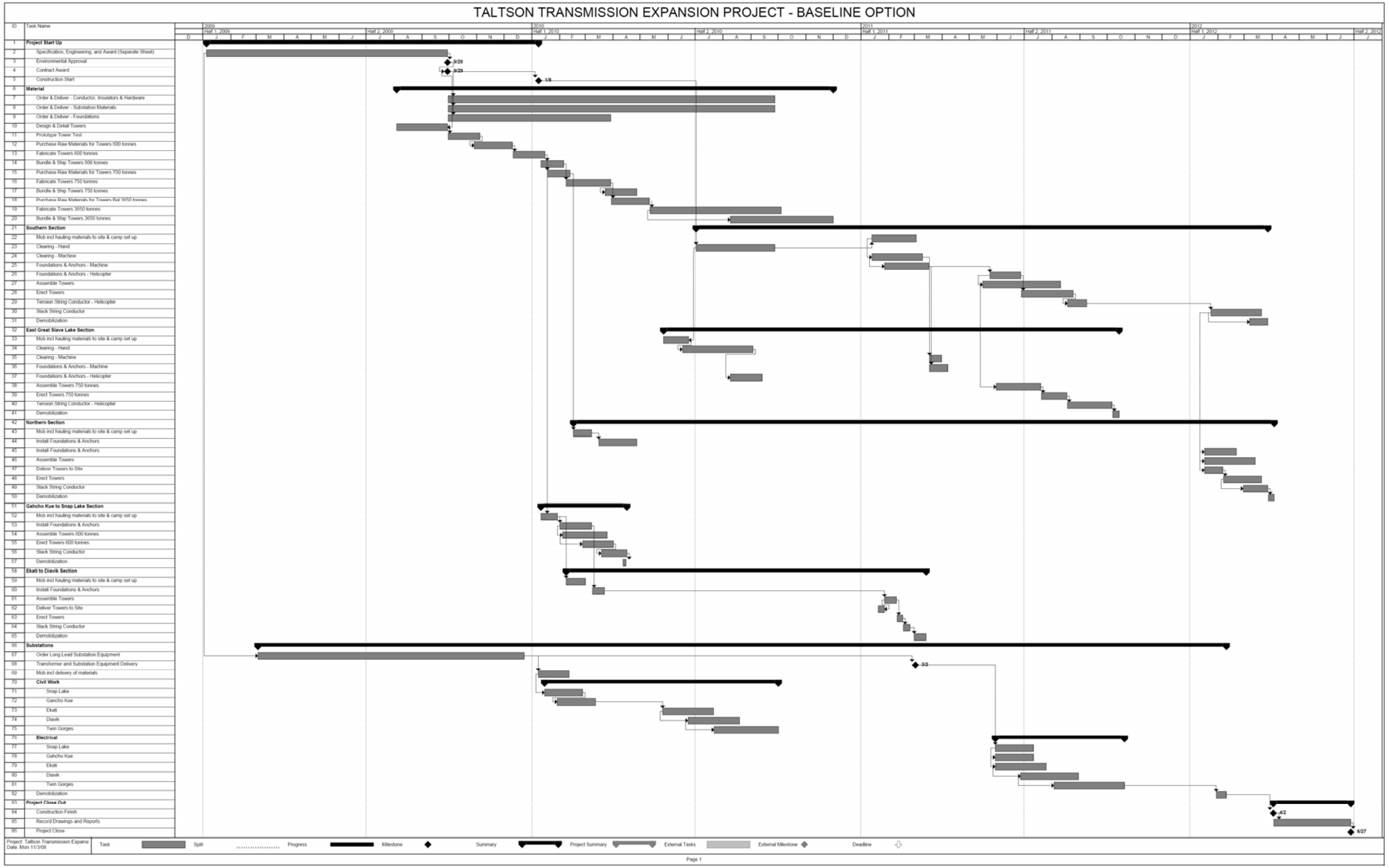
2.6.3.13.2 Substations

Cost estimates for Substations are broken down into the three Options and further broken down for each of the mine sites and Twin Gorges. Option 1 is the Baseline Option East Route with 161 kV from Twin Gorges to Ekati, 69 kV from Ekati to Diavik, and 69 kV from Gahcho Kué to Snap Lake. Option 2 is the same as Option 1 except for the substitution of 161 kV from Gahcho Kué to Snap Lake. Option 3 is the Baseline Option West Route with 161 kV from Twin Gorges to Ekati, and 69 kV from Ekati to Diavik. The substation cost estimates are based on single line diagrams and equipment costs provided by Teshmont as appended. The substation cost estimates include material, construction, and commissioning costs. It is assumed that the disconnect switches are crated fully assembled. It is assumed that construction power is available at the site at no cost to the contractor. The cost estimates do not include an allowance for substation connection to the mine electrical system, or permit costs.

Staging areas for construction of the Baseline option
Figure 2-11



Schedule for Specification, Engineering and Contract Award for Baseline Option
Figure 2-12



Construction Schedule for Baseline Option
Figure 2-13

2.7 COST ESTIMATE

The cost estimates developed in this report are high level, with level of accuracy in the range of -25% to +40%. The components of the cost estimate are listed in Table 2-23.

The cost estimates do not include taxes and are based on year 2008 prices. The material and construction costs are based on current market conditions and recent bids. Wherever possible, at least two suppliers were contacted for material budgetary prices information. Most of the suppliers validated the price for the period of two to three months. Guyed Y lattice-steel tangent structures and guyed two and three-mast latticed-steel angle and dead-end structures were assumed for this estimate, as proposed in IHI report from January 2005. For calculating the total quantities of the structures, a span of 335 m was assumed. Based on the geotechnical report, it was assumed that 85% of the structures will be on rock foundations and the remaining 15% will be on soil foundation.

The cost estimate does not include cost of bonds, insurances, taxes, land acquisition and easement, environmental assessment and monitoring. The cost of forestry practices such as timber cruises, salvaging merchantable timber, stumpage fees and credit for timber fees is not included. The construction costs include the estimate for the labour including project management, safety personnel, equipment, fuel and camps. The construction cost is escalated for the remoteness of the region.

The cost of right of way clearing includes the labour, equipment and fuel. The clearing assumes mechanized or hand slashing of the trees and other vegetation. The average right of way width was assumed to be 20 m.

The cost of access includes the construction and maintenance of the temporary trails along the line and to and fro the staging areas, during the transmission line construction period. Access cost includes the construction and maintenance of the winter roads made exclusively for the purpose of this project.

The cost of Owner's administration and Allowance for Funds Used During Construction (AFUDC/IDC) are not considered in this cost estimate.

The cost estimate for the baseline option is presented in Table 2-24.

Table 2-24
Baseline Option Cost Estimate

Item	Section	Mobilization and De-mobilization	Clearing	Access	Foundation	Structures	Conductors	Total
1	Preparation of specifications							[redacted]
2	Preliminary Design & Bid quantity							[redacted]
3	Lidar Survey							[redacted]
4	Ground Surveying							[redacted]
5	Geotchnical investigation							[redacted]
6	Southern Section - 161kV (248km)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
7	East Great Slave Section - 161kV (104km)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
8	Northern Section - 161kV (217km)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
9	Ekati to Diavik - 69kV (32km)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
10	Gahcho Kué to Snap Lake - 69kV (92km)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
11	Material Cost for Substation							[redacted]
12	Construction Cost for Substation							[redacted]
13	Engineering & Line Design							[redacted]
14	PLC Communication							[redacted]
15	Lightning protection of three spans from substations							[redacted]
16	Construction support							[redacted]
	Total							[redacted]

Table 2-24
Baseline Option Cost Estimate

Item	Section	Mobilization and De-mobilization	Clearing	Access	Foundation	Structures	Conductors	Total
17	Contingency of 15%							[redacted]
	Total with contingency							[redacted]

3 ALTERNATIVE ROUTES STUDY

3.1 DESKTOP ROUTING STUDY

3.1.1 Introduction

Desktop route studies were carried out for alternative transmission options from Twin Gorges generation facilities on the Taltson River. Trans-Island, Submarine Cable and West options were investigated based on topographical, environmental, social, geological and construction considerations. All three routes have common segments, from Snap Lake to Gahcho Kué, and Snap Lake to Ekati, and then Ekati to Diavik. These common sections are considered in Section 3.1.3.

Topography maps procured from the Survey and Mapping Branch, Department of Energy, Mines and Resources were used as reference. Probable routes were plotted on these maps using AutoCAD.

3.1.2 Desktop Study of the Alternative Routes

3.1.2.1 Trans Island Route

This line route is from Twin Gorges to Snap Lake and crosses Great Slave Lake using a number of islands around Simpson Island, as presented in Volume 2, Appendix K. It can be classified into three sections. The first section is the land route from Twin Gorges to Great Slave Lake, to PI 26, east of Preble Island. The second section is crossing Great Slave Lake using the islands around Simpson Island, starting at the lake shore east of Preble Island and exiting at McKinley point, north of Blanchet Island. The third section is an overland route starting from McKinley point and extending north to Snap Lake.

The first section of the line starts from Twin Gorges power house and moves north towards Great Slave Lake. The line manoeuvres through various swamps and creeks, and passes west of big obstacles like Tortuous Lake, Drywood Lake and O'Connor Lake. There is only one existing winter road on this route. Temporary access winter roads will have to be built for construction and maintenance, which will increase the cost of the line. This part of the line spans through difficult terrain with steep hills and cliffs, frequent swamps in the valleys and numerous marshy areas.

The second section of the line crosses Great Slave Lake through a series of islands of varied size, around Simpson Island. The line enters the lake crossing through Hornby Channel, east of Preble Island. This overhead crossing consists of two big crossings of about 1150 m and 700 m, provided that the intermediate small island is capable of supporting a 100 m high self supporting tower. Field verification is needed to confirm the feasibility of an overhead crossing. If it is not feasible, a cable should be used to cross this section. From Preble Island the line crosses to Simpson Island. The stretch of line over Simpson Island is about 50 km long and passes through very rough terrain comprised mostly of rocks and smaller lake crossings. The line zigzags on to Seton Island, and then to Blanchet Island. The crossing between Seton and Blanchet Islands is more than 2000 m wide. As no intermediate rocky island can be located on the maps to break the span for overhead crossing, a submarine cable will most likely be needed. This has to be field verified. From Blanchet Island, the line crosses to the mainland at the narrowest stretch of Hearne Channel near McKinley Point. The 5000 m wide water crossing will require a submarine cable. Based on available bathymetric maps, the depth of the lake at this point is 320 m. A detailed submarine survey will be required before finalizing the route.

The disadvantage of the crossing at McKinley point is the depth of the lake. Forces imposed on the cable will require double sheathed cable, which will affect the cost. Waters are not that deep further east of Blanchet Island; however, the total length of the crossings would be longer. The island configuration in that region will require more than one cable crossing and many extremely tall structures for overhead crossings.

The second section of the route will require about 10 crossings ranging from 400 m to 1050 m. It will be necessary to use self supporting towers ranging from 50 m to 110 m in height to span these stretches. This will greatly contribute to line cost increase.

The third and last section of this route starts from McKinley Point and goes northwards towards Snap Lake. A number of lakes and swamps are in the way of the line, which meanders around several lakes, like Rainy Lake, Tanco Lake, Rolfe Lake, Walverine Lake, Coombe Lake and Hilltop Lake. As there is no existing winter road on this route, temporary access winter roads will have to be built for construction and maintenance. Steep hills and cliffs, frequent swamps in valleys and numerous marshy areas are features of the terrain on this line segment. Marshy areas are more prevalent in later parts of the route.

The proposed line route is preliminary and a field survey will be required for refinement. Details for the PI points such as GPS location, distance between the PI, chainage, and remarks regarding special features are listed in the Table 3-1. The number of PI could increase based on the final survey and the actual terrain and soil conditions.

Table 3-1
Taltson Hydroelectric Expansion Project-Trans Island Option

PI #	Easting (m)	Northing (m)	Length (m)	Chainage (km)	Remarks
PI 1	478,500	6,698,000			Twin Gorges, Power House
PI 2	475,470	6,703,750	6,499	6	Some swamp areas
PI 3	472,139	6,708,474	5,780	12	PI 3-PI 11 - lakes and water bodies

Table 3-1
Taltson Hydroelectric Expansion Project-Trans Island Option

PI #	Easting (m)	Northing (m)	Length (m)	Chainage (km)	Remarks
PI 4	468,776	6,716,530	8,730	21	Some swamp areas
PI 5	466,168	6,719,627	4,031	25	PI 5 to PI 8 going along Konth River, some swamp areas
PI 6	464,000	6,725,443	6,225	31	Konth River, water bodies
PI 7	461,834	6,729,707	4,783	36	Water bodies & swamp areas
PI 8	459,161	6,733,782	4,873	41	Water bodies & swamp areas
PI 9	458,289	6,738,618	4,914	46	Some swamp areas
PI 10	458,625	6,740,167	1,584	47	Tortuous Lake, water bodies & swamp areas
PI 11	452,806	6,763,400	23,950	71	Water bodies & swamp areas
PI 12	449,360	6,782,900	19,802	91	East of Little Deskenatlata Lake swamp areas
PI 13	448,880	6,786,170	3,305	94	West of Drywood Lake, crossing Rutledge River
PI 14	446,441	6,789,630	4,233	99	Some swamp areas
PI 15	446,140	6,793,649	4,030	103	Water bodies
PI 16	444,640	6,794,740	1,855	105	
PI 17	440,300	6,803,410	9,695	114	Small lakes and water bodies, lake crossing close to PI 17, crosses a winter road
PI 18	439,407	6,812,680	9,313	124	Small lakes and water bodies, forest, clear area
PI 19	437,940	6,814,110	2,049	126	Small lakes and water bodies, lake crossing
PI 20	438,520	6,820,030	5,948	132	Thubun River, Lake of the Rock, hilly terrain, max. elevation 700 ft
PI 21	436,010	6,822,920	3,306	135	Closer to PI 21 lake crossing
PI 22	432,965	6,828,523	6,854	142	Water bodies and swamp areas
PI 23	441,387	6,834,639	10,408	152	La Loche River, water bodies
PI 24	439,941	6,840,397	5,936	158	
PI 25	437,864	6,841,791	2,502	161	PI 25 to PI 29 across Hornby Channel (Great Slave Lake) over small islands
PI 26	436,282	6,841,000	1,752	162	
PI 26A	435,784	6,841,548	753	163	PI 26 to PI 26A approximately 750 m lake crossing
PI 27	434,676	6,841,385	1,119	164	PI 26 A to PI 27, approximately 1120 m lake crossing

Table 3-1
Taltson Hydroelectric Expansion Project-Trans Island Option

PI #	Easting (m)	Northing (m)	Length (m)	Chainage (km)	Remarks
PI 28	434,166	6,841,505	524	165	PI 27 to PI 28, approximately 550 m lake crossing
PI 29	433,310	6,840,170	1,585	166	Over the island
PI 30	432,321	6,837,344	2,974	169	PI 30 to PI 31 lake crossings (over small islands)
PI 31	428,561	6,836,400	3,933	173	Preble Island, approximately 400 m lake crossing
PI 32	415,742	6,837,912	12,908	186	Simpson Island
PI 33	413,331	6,849,758	12,089	198	Simpson Island, hilly terrain and small water bodies
PI 33A	429,043	6,861,920	19,868	218	
PI 34	439,754	6,868,573	12,609	231	Simpson Island, hilly terrain and small water bodies
PI 35	439,185	6,869,574	1,152	232	Approx. 500 m lake crossing
PI 36	438,779	6,870,000	587	232	Over a small island
PI 37	438,370	6,870,716	820	233	2 lake crossings (approximately 400 m)
PI 38	439,282	6,871,307	1,090	234	Over an island
PI 39	439,163	6,872,000	702	235	600 m lake crossing
PI 40	437,510	6,874,776	3,230	238	Approx. 900 m lake crossing
PI 41	437,651	6,877,031	2,259	241	PI 40 to PI 41 lake crossing (approximately 2400 m) PI is on small island between Seton & Blanchet islands
PI 42	436,157	6,877,480	1,560	242	PI is on small island between Seton & Blanchet Islands
PI 43	433,631	6,876,182	2,840	245	
PI 44	432,256	6,876,554	531	245	
PI 45	430,895	6,875,543	2,568	248	
PI 46	430,287	6,877,062	1,637	250	
PI 47	429,889	6,877,916	941	251	Lake crossing , approx. 950 m
PI 48	427,983	6,880,207	2,980	254	Blanchet Island, along Hearne Channel, cable start point
PI 49	424,350	6,884,000	5,278	259	McKinley Point, cable end point (approx. 4000 m cable crossing)
PI 50	425,256	6,885,193	1,494	260	PI 49 to PI 50 steep slope elevation varies 550 ft to 900 ft
PI 51	425,753	6,891,868	6,693	267	PI 51 to PI 52A hilly terrain

Table 3-1
Taltson Hydroelectric Expansion Project-Trans Island Option

PI #	Easting (m)	Northing (m)	Length (m)	Chainage (km)	Remarks
PI 52	429,625	6,894,841	4,882	272	Water bodies and hilly terrain
PI 52A	430,677	6,903,543	8,765	281	Water bodies and hilly terrain
PI 53	432,226	6,904,265	1,708	282	Water bodies and swamp areas
PI 54	439,624	6,921,542	18,795	301	Water bodies and swamp areas
PI 55	442,000	6,924,648	3,910	305	Water bodies and swamp areas
PI 56	445,532	6,934,991	10,930	316	Water bodies and swamp areas
PI 57	450,587	6,941,477	8,223	324	Small lake crossings, elevation change from 350 ft to 1100 ft
PI 58	456,216	6,954,381	14,079	338	Hilly terrain, small water bodies, max. elevation 1300 ft
PI 59	456,346	6,955,437	1,063	339	Small lake crossing
PI 60	461,067	6,968,535	13,924	353	Hilly terrain, small water bodies, max. elevation 1400 ft
PI 61	463,109	6,969,113	2,122	355	
PI 62	469,176	6,981,738	14,007	369	West of McKinlay Lake, hilly terrain, small water bodies, max. elevation 1400 ft
PI 63	471,169	6,984,658	3,535	373	
PI 64	471,723	6,988,669	4,049	377	PI 63 to PI 64 elevation change from 1400 ft to 400 ft
PI 65	477,045	6,995,817	8,912	386	Line goes between Cache Lake and another small lake
PI 66	478,191	6,997,367	1,928	388	
PI 67	481,583	7,000,436	4,573	392	River crossing at McKinlay River at a narrow point, approx. 200 m
PI 68	483,035	7,003,917	3,771	396	
PI 69	487,956	7,009,567	7,493	404	Line goes between Wolverine Lake and Coombe Lake
PI 70	491,500	7,017,852	9,011	413	Forest, water bodies and swamp areas
PI 71	499,836	7,020,918	8,882	422	South of Hill Top Lake, forest, water bodies and swamp areas
PI 72	505,159	7,041,658	21,412	443	Water bodies, lake crossings
PI 73	506,400	7,051,800	10,217	453	Water bodies, esker. (Snap Lake Mine #24)

3.1.2.2 Submarine Cable Option

The route from Twin Gorges to Snap Lake using submarine cable west of Simpson Island, as presented in Volume 2, Appendix L, can be classified into three sections. The first section is the land route from Twin Gorges to the cable termination point at the bank of Great Slave Lake, marked as PI 5. The second section is the crossing of Great Slave Lake using 60 to 70 km long submarine cable. The third section is a land route from cable termination point PI 6 north-east to Snap Lake.

The first section of the line starts from Twin Gorges power house moving northwards to Great Slave Lake. The line manoeuvres through various swamps and creeks. It crosses the Konth River and passes to the east of Taltson River, Tsu Lake and Germain Bay. The initial part of this section is dominated by marshy areas. Later, the line crosses the approximately about 1000 m wide Deskenatlata Lake. Marshy areas are frequently encountered once this lake is crossed. There is only one existing winter road on this route about 10 km from Great Slave Lake. Temporary access winter roads will have to be built for construction and maintenance. This part of the line has tough terrain with steep hills and cliffs, frequent swamps in the valleys and many marshy areas.

The second section of the line crosses Great Slave Lake using submarine cable. The final cable route can only be established once the hydrographic survey has been conducted. Maximum water depth as per the available bathymetry map is about 100 m. Two types of cable are available for this purpose. One is three core design and the other is single core design. The design type selection depends on reliability, cost and maintenance requirements. At this depth a single sheath cable should be sufficient.

The third and last section of this route starts from PI 6 and goes north-east towards Snap Lake. The line manoeuvres through various lakes, marshes and swamps. The initial part of this line passes through a series of marshy stretches. This will result in costly and heavy tower foundations. The initial part meanders beside various lakes, including Watta Lake, Hearne Lake, Zigzac Lake, Trout Lake, Gilmour Lake, Goose Lake and Cleft Lake. There is no existing winter road on this route. Temporary access winter roads will have to be built for construction and maintenance. This part of the line has tough terrain with steep hills and cliffs, frequent swamps in the valleys and many marshy areas. The later part of the line is equally difficult and passes besides various lakes, including Sunset Lake, Rolfe Lake, Walverine Lake, Coombe Lake and Hilltop Lake. There is no existing winter road on this route.

The proposed line route is preliminary and will require refinement based on a field survey. Details for the PI points such as GPS location, distance between the PI's, chainage and remarks regarding special features are listed in the following table. The number of PI points will increase based on the final survey and actual site conditions. The total length of this line is approximately 448 km.

Table 3-2
Taltson Hydroelectric Expansion Project-Submarine Cable Option

PI #	Easting (m)	Northing (m)	Length (m)	Chainage (km)	Remarks
PI 1	478,500	6,698,000			Twin Gorges, Power House
PI 2	464,830	6,718,130	24332.81	24	Water bodies and some swamp areas
PI 2A	462,514	6,723,106	5488.57	30	Small lake crossings, water bodies, swamp areas
PI 3	445,428	6,750,679	32437.66	62	PI 2A to PI 3 Crossing Konth River
PI 4	438,824	6,753,990	7387.53	70	PI 3 to PI 4 crosses Deskenatlata River (approx. 1000 m crossing)
PI 5	409,558	6,812,191	65144.88	135	Small lake crossings, water bodies, swamp areas
PI 6	379,350	6,856,752	53834.99	189	Cable start point on Great Slave Lake
PI 7	371,146	6,874,681	19716.86	208	Cable end point
PI 8	369,414	6,878,988	4642.21	213	Crossing Devils Channel, water bodies and swamp areas
PI 8A	381,917	6,889,963	16636.58	230	PI 8 to PI 8A Goulet Bay crossing (400 m), swamp areas and water bodies
PI 9	383,487	6,896,119	6353.05	236	Water bodies and some swamp areas
PI 10	389,553	6,907,368	12780.31	249	Between Hearne Lake and Beaulieu Watta Lake, 700 m lake crossing
PI 11	394,286	6,916,664	10431.53	259	Between Trout and Zigzag Lake, water bodies and swamp areas
PI 12	434,412	6,971,833	68218.14	327	Between PI 11 and PI 12 there are a few lake crossings. Longer crossings can be eliminated by adding of couple of PI points during the design phase.
PI 13	441,065	6,975,492	7592.81	335	Lake crossings, swamp areas and water bodies
PI 14	454,941	6,989,384	19634.94	355	West of Drywood Lake, crossing Rutledge River. South of Rolfe Lake.
PI 15	472,714	6,990,000	17783.67	372	Some swamp areas. South of Rolfe Lake.
PI 16	478,192	6,997,368	9181.28	382	Water bodies (Cache lake)
PI 17	481,583	7,000,436	4572.91	386	Crosses McKinlay River. (East of McKinlay River)

Table 3-2
Taltson Hydroelectric Expansion Project-Submarine Cable Option

PI #	Easting (m)	Northing (m)	Length (m)	Chainage (km)	Remarks
PI 18	483,035	7,003,917	3771.69	390	Small lakes and water bodies, wooded and cleared areas. East of McKinlay River.
PI 19	487,956	7,009,567	7492.58	397	Small lakes and water bodies, swamp areas. Coombe Lake.
PI 20	491,500	7,017,853	9012.09	406	Small lakes and water bodies, wooded and cleared areas
PI 21	504,000	7,024,472	14144.30	421	Small lakes, swamp areas, water bodies, wooded and cleared areas. Hilltop Lake.
PI 22	504,964	7,042,453	18006.82	439	Small lakes and water bodies, swamp areas, lake crossings (By adding two PI points, long crossings can be eliminated)
PI 23	506,400	7,051,800	9456.66	448	Small lakes and water bodies, swamp areas, lake crossings (By adding one or two PI points, long crossings can be eliminated).

3.1.2.3 West Route of Great Slave Lake

This route is from Twin Gorges to Snap Lake, going around the western side of Great Slave Lake via Fort Smith, Fort Providence and Yellowknife. The route maps are presented in Volume 2, Appendix M. This route can be broken down into five sections. The first section runs south-west from Twin Gorges to Fort Smith. The second section runs north-west from Fort Smith to Fort Providence. The third section runs north-east from Fort Providence to Frank Channel between Marian Lake and the north arm of Great Slave Lake. The forth section runs south-east from Frank Channel to Yellowknife. The fifth section runs north-east from Yellowknife to Snap Lake.

The first section of the line starts from Twin Gorges power house and moves south-east to the outskirts of Fort Smith. The line moves beside an existing winter road toward Fort Smith. Initially it crosses Taltson River and later moves parallel to Powell Creek and crosses Tethul River. This part of the line route passes through tough terrain with steep hills and cliffs, frequent swamps in the valleys and many marshy areas. After crossing Tethul River the terrain is relatively plain and encounters marshy lands and wooded area.

The second section of the line moves east from Fort Smith, and goes parallel to Slave River until it reaches the north end of Wood Buffalo National Park. Here the line crosses the 700 m wide

Slave River and starts to move eastward to Fort Providence. As most of the terrain is plain, the line passes through large wooded and marshy areas. It also passes various narrow rivers, including Buffalo River, Hay River and Kakisa River. In the later part of the route, the line runs parallel to Mackenzie Highway before it reaches the outskirts of Fort Providence. This part of the line route is dominated by wooded and marshy areas.

The third section of the line starts from the outskirts of Fort Providence. The line crosses two wide rivers, Snye River and Mackenzie River. Both are about 700 to 800 m wide, and towers at least 80 m high will be required to span these crossings. The line then moves north-east to Frank Channel between Marian Lake and the north arm of Great Slave Lake. This portion of the line follows the Yellowknife Highway for most of the route. The terrain during the initial part of the route is mostly plain with wooded and marshy areas, frequent changes in elevation and shallow swamps along the way. The last part of the route near Frank Channel has many water crossings between Marian Lake and the north arm of Great Slave Lake. The soil along this section looks very fragile with lower load bearing capacity, and locating structures in this section is likely to result in heavy and costly foundations.

The fourth section of the line is between Frank Channel and Yellowknife. This line section is on the north side of the north arm of Great Slave Lake and generally follows the Yellowknife Highway. It crosses various swamps and frequent marshy areas. The line also crosses the wide Martin Lake in the outskirts of Yellowknife City.

The fifth and last section of this route is from Yellowknife to Snap Lake. The terrain on this stretch is more difficult than other sections of the line route, with steep hills and cliffs, frequent swamps and valleys, and many marshy areas. Initially the line passes through Walsh Lake and Prosperous Lake. Prosperous Lake is about 900 m wide and will require towers at least 90 m high for overhead crossing. The line manoeuvres through various lakes, including Prelude Lake, Bliss Lake, Blaisdell Lake and Waite Lake. It passes Cameron River and moves across Allan Lake, Spenser Lake, Sosan Lake, and Sans-Distant Lake before it reaches Snap Lake. As there is no existing winter road along this route, temporary access winter roads will have to be built for construction and maintenance.

The proposed line route is preliminary and will require refinement based on a field survey. Details for the PI points, such as the GPS location, distance between the PI’s, chainage and remarks regarding special features are listed in the following table. The number of PI points will increase based on final survey and actual site conditions. The total length of this route is approximately 966 km.

Table 3-3
Taltson Hydroelectric Expansion Project-West Route Option

PI #	Easting (m)	Northing (m)	Length (m)	Chainage (km)	Remarks
PI 1 Twin Gorges	478,500	6,698,000			Penstock Power House
PI 2	472,282	6,680,143	18,909	19	Passes through some swamp areas
PI 3	469,224	6,673,884	6,965	26	Some swamp areas, forest
PI 4	465,334	6,669,132	6,141	32	Some forest, some wooded swamp
PI 5	460,206	6,665,563	6,248	38	Passes through some swamps
PI 6	450,088	6,656,399	13,651	52	Outskirts of Fort Smith City
PI 7	439,848	6,657,738	10,327	62	Mostly forest
PI 8	419,126	6,708,612	54,932	117	Forest, some marsh land, crosses Slave River
PI 9	412,377	6,709,749	6,844	124	Passes swamp and wooded area
PI 10	369,452	6,731,604	48,169	172	Mostly swamps and woods
PI 11	337,001	6,732,999	32,482	205	Mostly forest
PI 12	662,900	6,731,000	4,562	209	Zone changes from 12 to 11 (watch out for coordinate change)
PI 13	607,518	6,710,950	58,899	268	Forest, intermittent lake, sink hole, swamp area
PI 14	576,379	6,710,297	31,147	299	Forest, intermittent lake, swamp area
PI 15	547,187	6,711,847	29,233	329	Passes swamp and wooded area
PI 16	540,521	6,718,379	9,333	338	Crosses Hay River crossing
PI 17	535,336	6,721,643	6,127	344	Water bodies, swamp area
PI 18	515,000	6,747,084	32,570	377	Passes some water bodies
PI 19	499,997	6,752,404	15,919	392	Passes some water bodies
PI 20	491,855	6,756,958	9,328	402	Passes some swampy areas
PI 21	486,890	6,760,457	6,074	408	Passes some swampy areas
PI 22	480,875	6,766,246	8,349	416	Crossing Kakisa River and some forests
PI 23	472,911	6,770,602	9,077	425	Passes swamp and wooded area
PI 24	470,755	6,784,241	13,809	439	Passes swamp and wooded area
PI 25	465,000	6,795,138	12,323	451	Water bodies, swamp (wooded) area
PI 26	465,490	6,796,832	1,764	453	Crosses wide Snye River
PI 27	467,802	6,797,552	2,422	456	Crosses wide Providence Rapids
PI 28	491,282	6,825,333	36,374	492	Line is parallel to Yellowknife Highway 3
PI 29	493,026	6,835,836	10,647	503	Passes some water bodies

Table 3-3
Taltson Hydroelectric Expansion Project-West Route Option

PI #	Easting (m)	Northing (m)	Length (m)	Chainage (km)	Remarks
PI 30	503,855	6,840,144	11,654	514	Line is parallel to Yellowknife Highway 3
PI 31	513,622	6,851,938	15,313	530	Line is parallel to Yellowknife Highway 3
PI 32	513,040	6,878,931	26,999	557	Passes forest, intermittent lakes and swampy area
PI 33	517,852	6,925,145	46,464	603	Passes intermittent lake and water bodies
PI 34	538,993	6,951,098	33,474	637	Crosses swampy area, water bodies, crossing trail, cutline, portage
PI 35	554,284	6,964,598	20,398	657	Crosses Yellowknife Highway 3 and Frank Channel
PI 36	607,854	6,933,902	61,742	719	Crossing lakes, ponds and Yellowknife Highway 3
PI 37	635,772	6,936,239	28,015	747	Passes besides Yellowknife City
PI 38	643,737	6,940,955	9,256	756	Crosses swamps and ponds
PI 39	651,097	6,941,529	7,383	763	Swamp, contours
PI 40	653,600	6,946,000	5,125	768	Crossing river, lake
PI 41	347,000	6,946,998	2,599	771	Zone changes from 11 to 12 (watch out for coordinate change)
PI 42	356,774	6,951,111	10,604	782	Cleared area, lakes, crossing winter roads
PI 43	362,618	6,954,699	6,858	789	Ponds and lakes
PI 44	370,797	6,961,504	10,640	799	Ponds and swamps
PI 45	383,534	6,966,496	13,681	813	Forest and lakes
PI 46	403,408	6,982,768	25,686	839	Crossing Cameron River, lake, swamp and water bodies
PI 47	427,822	6,999,660	29,688	868	Crosses hills, swamps, and lakes
PI 48	443,196	7,009,303	18,148	886	Crosses water bodies and lakes
PI 49	469,218	7,016,901	27,109	913	Crosses lake and forest
PI 50	474,124	7,028,527	12,618	926	Crosses lakes, hills, forest
PI 51	492,592	7,037,653	20,600	947	Crosses lake and forest
PI 52	506,400	7,051,800	19,769	966	Crosses lake (Snap Lake)

3.1.3 Common Sections

The section between Diavik and Ekati is common for all transmission options, including the Baseline Option. The PI points for this section are presented in Table 2-21.

The section between Snap Lake and Gahcho Kué is also common for all transmission options, including the Baseline Option. The PI points for this section are presented in Table 2-22.

The section between Snap Lake and Diavik is common for the three alternative routes. The PI points for this section are presented in Table 3-4.

Table 3-4
PI Points for Snap Lake to Ekati (Common for all Three Alternatives)

PI #	Easting (m)	Northing (m)	Length (m)	Chainage(km)	Remarks
variable*	506,400	7,051,800			
76	513,400	7,060,500	11,166	11.2	Crosses proposed winter road and Snap Lake
77	513,500	7,070,400	9,901	21.1	Crosses King Lake
78	516,500	7,075,000	5,492	26.6	Water bodies
79	516,500	7,078,200	3,200	29.8	Water bodies
80	515,880	7,079,560	1,495	31.3	Esker, watercourse and water body
81	515,705	7,079,935	414	31.7	Approaches MacKay lake
82	515,970	7,080,585	702	32.4	Crosses MacKay Lake
83	516,195	7,080,995	468	32.8	Crosses MacKay Lake
84	516,585	7,081,665	775	33.6	Crosses MacKay Lake
85	517,000	7,083,100	1,494	35.1	Crosses MacKay Lake
86	512,600	7,089,200	7,521	42.6	Wet land, water body, watercourse
87	510,100	7,112,100	23,036	65.7	Wet land, water body, watercourse
88	498,000	7,138,800	29,314	95.0	Wet land, water body, watercourse
89	489,700	7,151,800	15,424	110.4	Crosses Copper Mine River
90	493,500	7,168,000	16,640	127.0	Esker, water body
91	513,300	7,177,900	22,137	149.2	Esker, watercourse and water body

Table 3-4
PI Points for Snap Lake to Ekati (Common for all Three Alternatives)

PI #	Easting (m)	Northing (m)	Length (m)	Chainage(km)	Remarks
92	516,500	7,174,400	4,742	153.9	

*Variable indicates that this PI location is numbered as PI 73 for Trans Island option, PI 23 for Submarine cable option, and PI 52 for West Route option.

3.1.4 Conclusion

The Trans Island Route requires tall structures to cross the channels between islands. From Blanchet Island to McKinley, a cable crossing of 5 km will be required. The lake depth at this location is 320 m, which will require double sheath cable. A field survey is necessary to determine the cable landing locations and cable terminal stations, as steep lake banks are not suitable. From McKinley to Snap Lake, the terrain is difficult with many marshy areas and swamps. Very tall structures will be needed at several locations.

The Submarine Cable Option uses long submarine cable, and extensive hydrographic survey is required in order to route the cable. Depending on the lake depth, single or double sheath cable may be used. The section from the north bank of Slave Lake to Snap Lake is difficult, with many marshy areas. Very tall structures will be required at several locations.

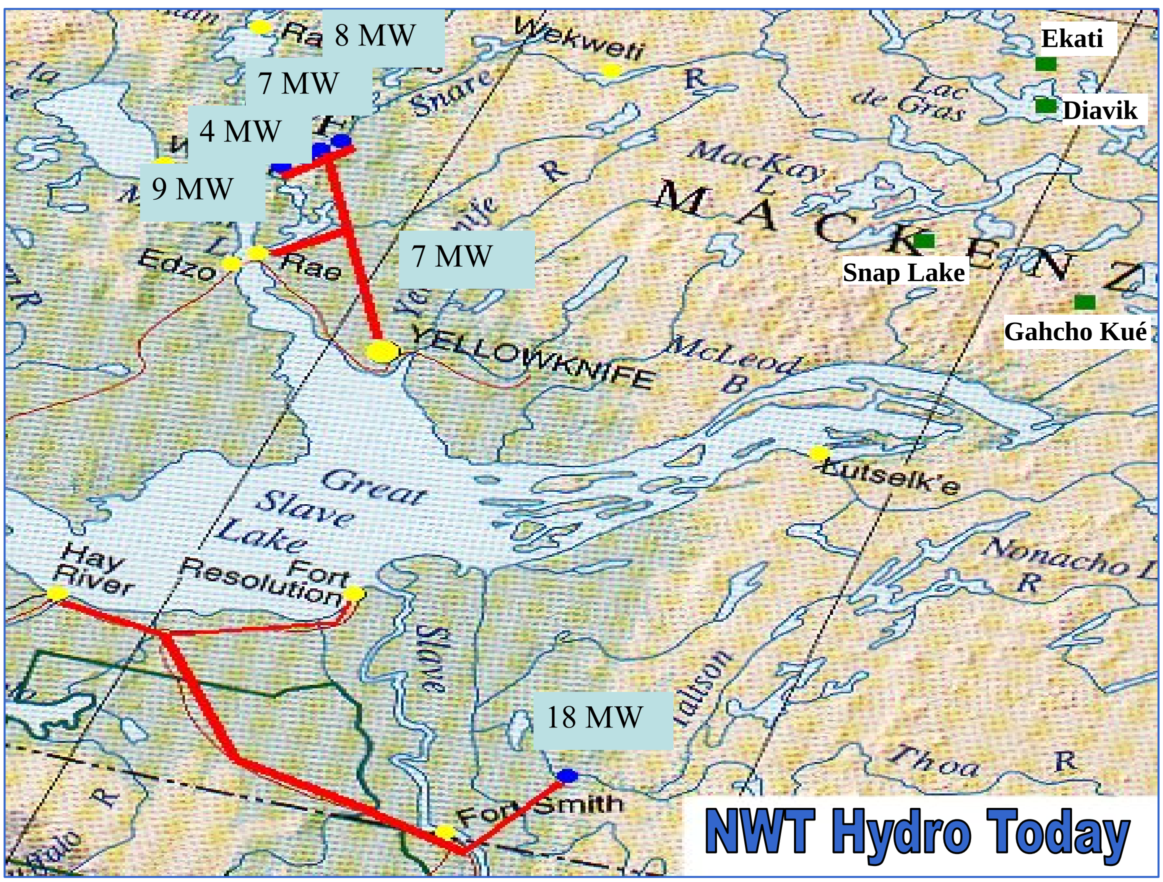
The West Route is the longest alternative. The section parallel to Slave River will have to cross either the north end of Wood Buffalo Park, the First Nation Reserve, or both. At Fort Providence the line will have to cross Mackenzie River and Snye River, which will require tall structures. At the Frank Channel there are many water crossings, and based on the maps, the soil conditions may require heavy and expensive foundations. The section from Yellowknife to Snap Lake is also difficult with many swamps and marshy areas. At several locations extremely tall structures are required.

Based on the routing study of the three alternatives, Teshmont's opinion is that the Trans Island Option should be investigated further as an alternative to the Baseline Option.

3.2 SYSTEM STUDIES FOR ALTERNATIVE TRANMISSION ROUTES

3.2.1 Introduction

The Taltson Hydroelectric Expansion Project (the “Expansion Project” or “Project”) is an infrastructure development that adds a new 36 MW power plant at the existing 18 MW Taltson Twin Gorges Plant and interlinks the expanded generation facilities through a new transmission line to supply hydropower to operating diamond mines at Ekati, Diavik and Snap Lake sites, and the proposed Gahcho Kué mine. These sites are shown in Figure 3-1. The Project would supply approximately 350 GWh per year of renewable-source electricity to the mines, displacing a significant portion of the current diesel generation at those mine sites. The Expansion Project would continue to supply approximately 70 GWh per year to the existing customer base of the Taltson Twin Gorges plant in addition to the power supply to the mines. The existing generation and transmission system in the Great Slave Lake area is shown in Figure 3-1.



Existing generation and transmission system in Great Slave Lake area
Figure 3-1

3.2.2 Scope and Objectives

The scope and methodology of the study comprises of the following steps:

a) Establish steady state voltage criteria to enable evaluating acceptable performance
b) Undertake an assessment of line voltage requirements, line losses, required amount of shunt compensation;
c) Need for Static Var Compensation (SVC);
d) Perform preliminary studies, if required, to access the amount of required static and dynamic shunt compensation.

3.2.3 Criteria and Assumptions

3.2.3.1 Criteria

The acceptable range for the voltage variation along the transmission line is assumed to be ±5%. The phase angle difference between generator bus and the load bus should be less than 40°.

3.2.3.2 Assumptions

Since at this stage a conceptual design has been considered, it was assumed that there is a possibility to build substation at any point along the line. However in the detail design stage the number of substations and their locations must be optimized.

This study was done prior to the determination of the exact routing for the lines and cables and therefore there might be a discrepancy between the length of the lines used in this study and what are given in other reports. These discrepancies will not affect the conclusions and equipment rating, as well as the cost of the equipment and the substations.

The load is assumed to be connected at 34.5 kV bus at the mine site.

3.2.4 System Data

3.2.4.1 Tower head and Conductor Data

The tower configuration and conductor data shown in Figure 3-2 and Figure 3-3 have been used for 161 kV lines in the system. Stilt conductor with 715.5 kcmil size is used for three phases and no shield wire is considered.

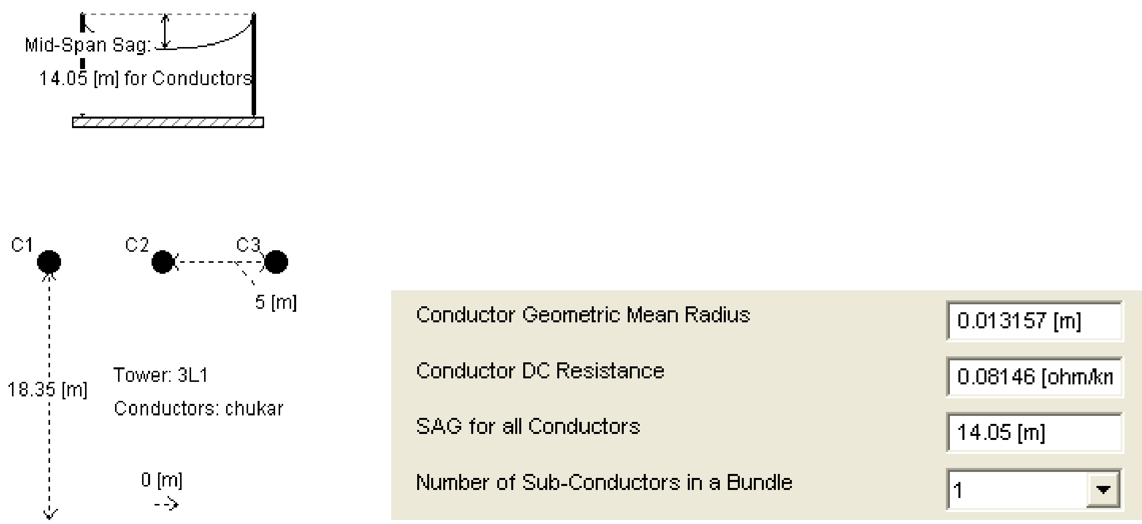
Figure 3-3 shows the parameters of the cable. Three separate 161 kV cables have been used in this study. A sensitivity study for using 44 kV cable is also conducted.

3.2.4.2 Total Generation

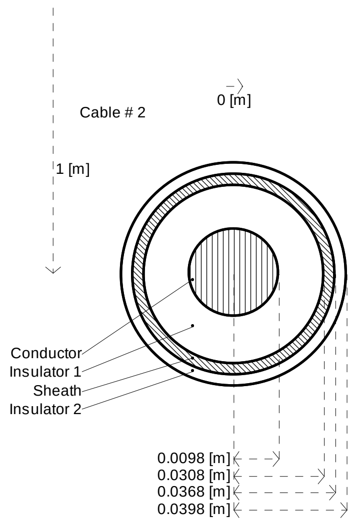
Sum of the existing and planned generation at Twin George plant is 54 MW.

3.2.4.3 System Load

In this conceptual design the existing load is simulated as a single 10 MW load connected to the Twin George facility through a 150 km, 161 kV line. The rest of the available power is provided to the mine sites. Mine load is modeled as a single load and the amount of load is calculated after deduction of losses from available generation.



Towerhead configuration for 161 kV lines
Figure 3-2



Cable resistance and capacitance

AC resistance	0.178 ohm/km
Capacitance	0.12 µF/km

Parameters of 161 kV cable
Figure 3-3

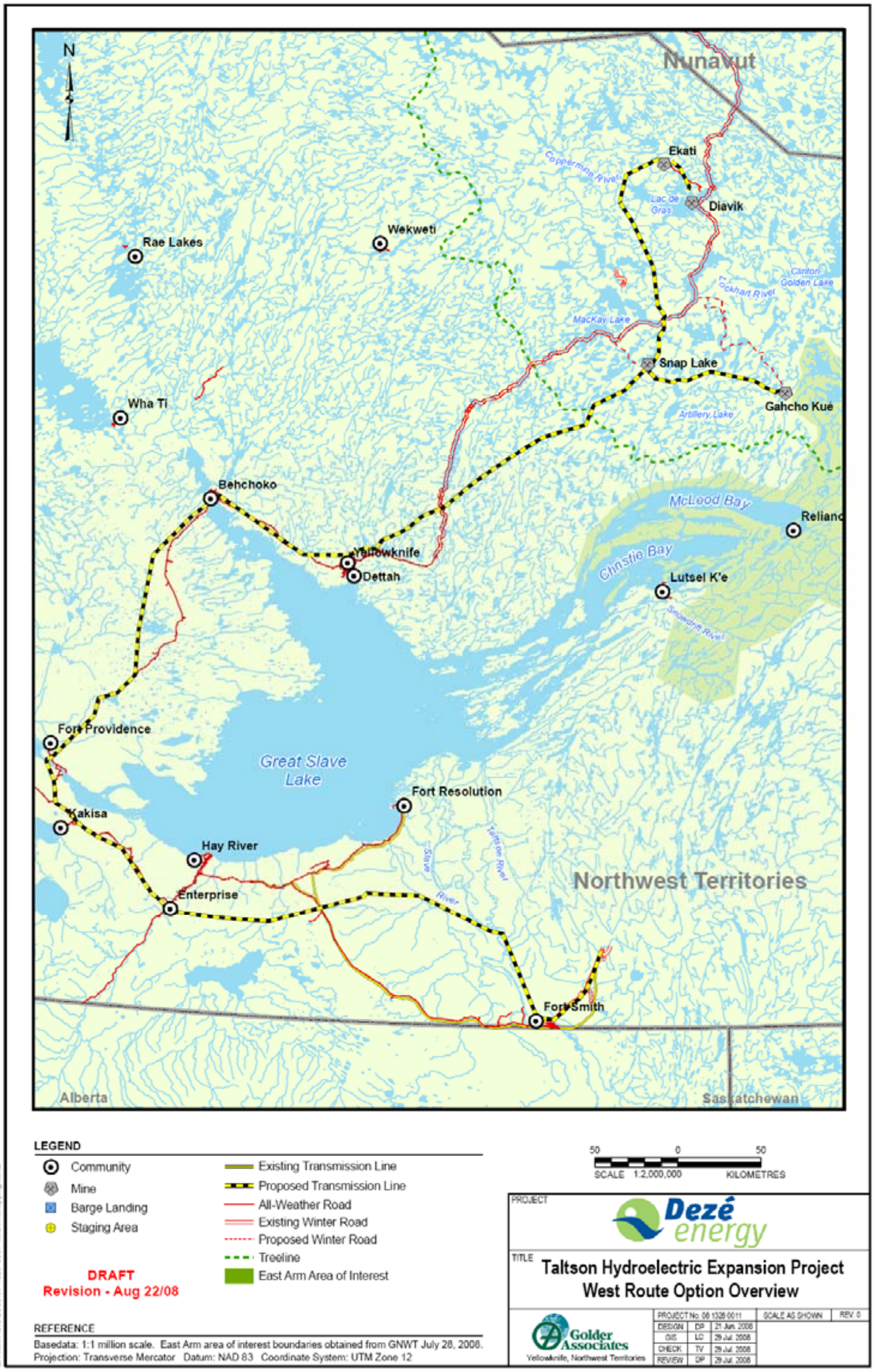
3.2.5 Study of the Routing Options

Using the available system data a load flow model was developed using the PSS/E version 30.3.2. No-load and full load operating conditions were simulated and the equipment which are required to provide satisfactory voltage profile along the line have been assessed. In this section the summary of analysis are given for the following three alternatives:

- West Route of Great Slave Lake
- Marine Cable Option across Great Slave Lake;
- Trans-Island Option with Marine Cable Placements

3.2.5.1 West Route of Great Slave Lake

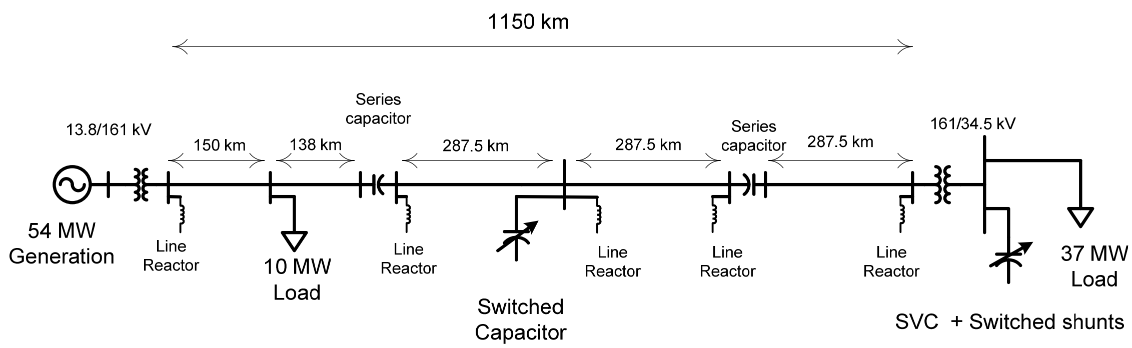
The West route is shown in Figure 3-4. Although the route goes through Yellowknife but in this study no interconnection to other networks in the area are being considered.



The West Routing Option
Figure 3-4

In this alternative an 1150 km, 161 kV line is considered for the interconnection of the generation facilities at Twin George to the loads in the northeast. A steady state analysis was conducted to assess the required equipment to make the operation of this line possible.

Using the tower head configuration given in Figure 3-2 the parameters for the 1150 km line and also sections of the line between substations are calculated and given in Table 3-5. Line parameters calculations are done using PSCAD V4.2. A schematic diagram of the system is shown in Figure 3-5.



Schematic Diagram of the West Route Option and Required Equipment
Figure 3-5

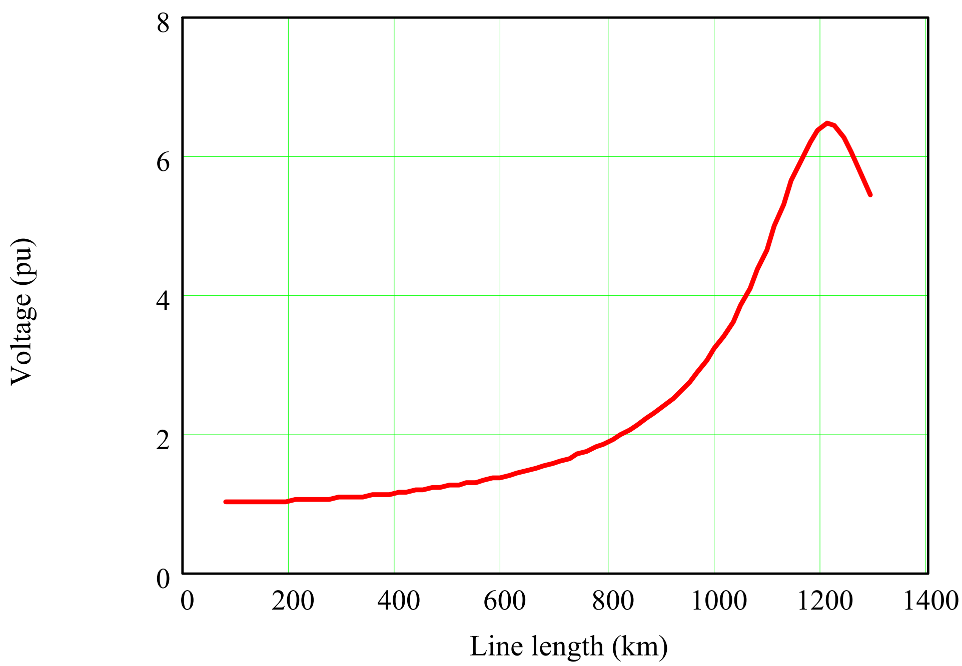
Table 3-5
Overhead Transmission Line Parameters for the West Route

Transmission line	Line Length (km)	Voltage (kV)	R (pu)	X (pu)	B (pu)	G (pu)
Whole line	1150	161	0.13899	1.45759	1.26290	0.05271
Mid point to series caps	287.5	161	0.08717	0.52350	0.25940	0.00056
Twin George – local load	150	161	0.04724	0.27816	0.13406	~0
Local load to series capacitor	137.5	161	0.04330	0.25498	0.12289	~0

3.2.5.1.1 No Load Condition

Voltage at the receiving end in no load condition versus the length of the line is given in Figure 3-6. For an 1150 km uncompensated line, because of the Ferranti effect the voltage at the receiving end will go as high as 5.8 p.u. The reason for such a high voltage is that the length of the line is close to 1250 km which is one fourth of the wavelength for 60 Hz system.

To limit the voltage around ±5% range along the line, shunt inductors required in no-load. Simulation results show that five 25 Mvar shunt reactors are needed along the line to bring the voltage within acceptable range. Approximate locations of these inductors are shown in Figure 3-5. Due to the large overvoltage in case of a load rejection, these inductors should be always connected to the line.



Receiving End Voltage in Per Unit for an Uncompensated Line
Figure 3-6

3.2.5.1.2 Full Load Condition

By increasing the load, the transmission line consumes reactive and at full-load condition the reactive power demand is at its maximum.

Generator at the sending end is a source of reactive power. A reactive power source is required at the load end as well. Switched capacitors, synchronous condensers and Static Var Compensators (SVCs) are able to provide variable reactive power. The final selection depends on the load characteristics. For the midpoint substation a switched capacitor is required to keep the voltage within acceptable limits. Simulation results show that 5 blocks of 4 Mvar capacitors are required at the mid-point to keep the voltage within standard range.

At full load condition the transmission line needs 40 Mvar reactive power at the load end. The load reactive power should be supplied locally and will be extra. The largest motor is assumed to be 0.75 MW which at start up will require around 5 Mvar of reactive power. Assuming that not more than two of these motors might start at the same time, an SVC with size of ±10 Mvar is sufficient to supply the reactive power demand. The rest of reactive power should come either from switched shunts or synchronous condensers.

3.2.5.1.3 Power/Energy Loss

The total loss on the line at full load is around 7 MW or 15% of the load. This power loss translates to around 60 GWh loss of energy per year. The total power which could be delivered to the load is 47 MW from which 10 MW is local and the rest will be delivered to the mines.

3.2.5.1.4 Series Compensation

The other parameter which comes into the picture is the 55° phase angle difference between the generator bus at Twin George and the load bus at the remote end. A typical value for this parameter would be in the range of 30 to 40 degrees. To reduce the phase angle difference, series compensation of the line is required. As a first draft the series capacitors are assumed at two locations; quarter and 3 quarter of the length of the line which altogether will compensate 50% of the line reactance. The approximate location of the series capacitors are shown in Figure 3-5.

3.2.5.1.5 Summary of Required Equipment for West Route

Based on the results of the steady state analysis, equipment listed in Table 3-6
are required to keep the voltage within acceptable range in all the operating points. The values are estimated assuming typical load characteristics. These parameters should be optimized further in detail design stage.

Table 3-6
Required Equipment for West Route Option

Description	Voltage Rating	Power Rating	Quantity
Line connected reactors	161 kV	25 Mvar	5
Switched Capacitor	161 kV	5 x 4 Mvar	1
Series Capacitor	161 kV	140 Ω	2
SVC	34.5 kV	±10 Mvar	1
Synchronous condenser or switched capacitors	34.5 kV	0 to 30 Mvar	1
Substation (for series capacitors and switched capacitors)	161 kV	Series caps and mid-point	3

3.2.5.2 Marine Cable Option across Great Slave Lake

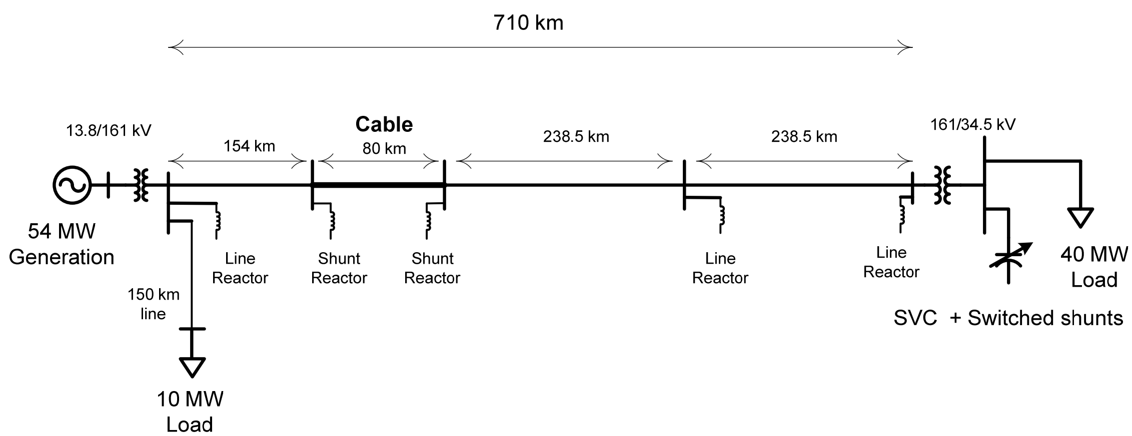
The marine cable option is shown in Figure 3-7.

The Marine Cable Option
Figure 3-7

In this alternative a 154 km, 161 kV line connects the generators at Twin George to an 80 km submarine cable at Great Slave Lake. The other end of the cable will be connected to the load by a 477 km, 161 kV transmission line. The cable crossing distance in the routing studies is shorter (the length is 73 km), however due to the characteristics of the lakebed, the actual routing of the cable will probably result in a longer cable and therefore in the simulation a longer length is considered. A steady state analysis was conducted to assess the required equipment to make the operation of this line possible.

In general, the maximum length of a cable for ac power transmission is considered to be around 50 km. Using 80 km cable needs proper and accurate compensation to prevent excessive voltage stress on the cable from no load to full load condition.

Using the cable and tower head configuration given in Figure 3-2 and Figure 3-3 the parameters for the overhead lines and the cable are calculated and given in Table 3-7. Line and cable parameters calculations are done using PSCAD V4.2. A schematic diagram of the system is shown in Figure 3-8.



Schematic Diagram of the Marine Cable Option And Required Equipment
Figure 3-8

Table 3-7
Overhead Transmission Line Parameters for the Marine Cable Option

Line Length (km)	Voltage (kV)	R (pu)	X (pu)	B (pu)	G (pu)
477	161	0.13349	0.83644	0.43891	0.00247
238.5	161	0.07231	0.43428	0.21519	0.00046
150	161	0.04724	0.27816	0.13406	~0
80 (cable)	161	0.01194	0.04012	0.93030	~0

3.2.5.2.1 No Load Condition

Voltage at the receiving end of the line versus the length of the line is given in Figure 3-6. For a 700 km uncompensated line from which 80 km is a cable, in no load condition, because of the Ferranti effect the voltage at the receiving end will go as high as 2.2 p.u. and the cable will experience a voltage of 1.8 p.u. As shown in Figure 3-8 to limit the voltage around ±5% range along the line, shunt compensation is required at both ends of the cable, at both sending and receiving end and a mid-point. Simulation results show that 50 Mvar shunt reactor at each end of the cable and a total of three 20 Mvar shunt inductors connected at the generator bus, at the remote load bus and at the mid-point between the cable and the load brings the voltage along the line within acceptable range. These inductors are called line reactors and should be always connected to the line.

3.2.5.2.2 Full Load Condition

By increasing the load, the transmission line consumes reactive and at full-load condition the reactive power demand is at its maximum.
Generator at the sending end is a source of reactive power. A reactive power source is required at the load side as well. Switched capacitors, synchronous condensers and Static Var Compensators (SVCs) are able to provide variable reactive power. The final selection depends on the characteristic of the load and its variations. There is no need for reactive power source in the middle of the line as the voltage at full load is within the acceptable range.

Simulation results show that a total of 30 Mvar reactive power should be provided for the line demand at the load end. The load reactive power should be supplied locally and will be extra. The largest motor is assumed to be 0.75 MW which at start up will require around 5 Mvar of reactive power. Assuming that not more than two of these motors might start at the same time, an SVC with size of ±10 Mvar is sufficient to supply the reactive power demand. The rest of reactive power should come either from switched shunt capacitors or synchronous condensers.

3.2.5.2.3 Power Loss

The total loss on the line at full load is around 4 MW or 8% of the load. This power loss translates to around 35 GWh loss of energy per year. The total power which could be delivered to the load is 50 MW from which 10 MW is local and the rest will be delivered to the mines.

3.2.5.2.4 Series Compensation

Based on the steady state analysis the phase angle difference between generator and load at the remote end is around 35° which is within the limit and series compensation is not required for this option.

3.2.5.2.5 Summary of Required Equipment for Marine Cable Option

Based on the results of the steady state analysis, equipment listed in Table 3-8 are required to keep the voltage within acceptable range in all the operating points. The values are estimated assuming typical load characteristics. These parameters should be optimized further in detail design stage.

Table 3-8
Required Equipment for Marine Cable Option

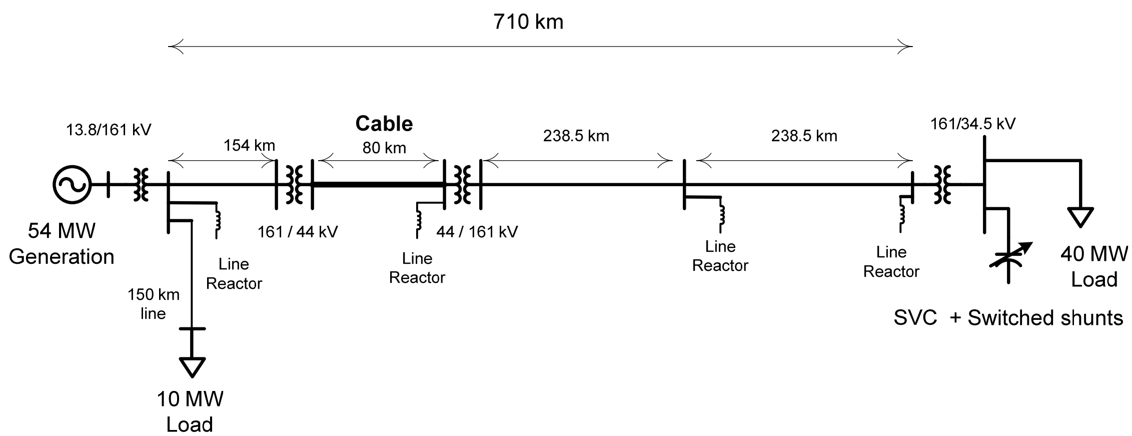
Description	Voltage Rating	Power Rating	Quantity
Line connected reactors	161 kV	20 Mvar	3
Cable connected reactors	161 kV	50 Mvar	2
SVC	34.5 kV	±10 Mvar	1
Synchronous condenser or switched capacitors	34.5 kV	0 to 20 Mvar	1
Substation (for shunt reactors)	161 kV	-	3

3.2.5.2.6 Impact of Using Lower Voltage Cable

Another alternative for the marine cable is reducing the cable voltage to 44 kV using transformers. A schematic diagram of this alternative is shown in Figure 3-9.

The advantage of this design is that using the lower voltage cable makes it easier to use a 3-core cable rather than 161 kV cable. Besides, since the voltage is reduced to around one-forth of the original 161 kV, reactive power generation by the cable is lower and 10 Mvar shunt reactor at one end of the cable shown in Figure 3-9 is required. The rest of the equipment remains the same, with a slight increase in the phase angle difference between generator and load bus.

The major drawback of this option is the addition of two transformers and associated equipment. The final decision depends on detailed cost comparison between these two viable alternatives.



Schematic Diagram of Low Voltage Cable for the Marine Cable Option
With Lower Cable Voltage
Figure 3-9

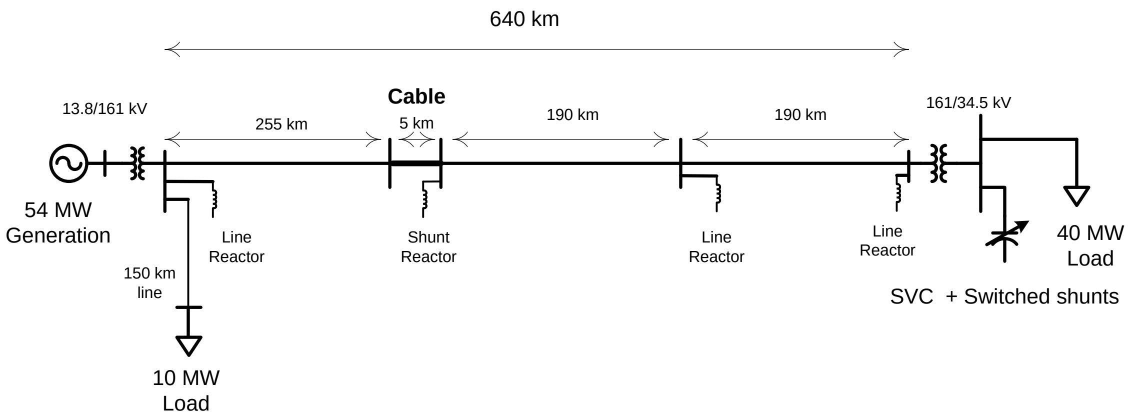
3.2.5.3 Trans-Island Option with Marine Cable Placements

The Trans-Island option is shown in Figure 3-10.

The Trans-Island Option
Figure 3-10

In this alternative a 255 km, 161 kV line connects the generators at Twin George to a 5 km submarine cable at Great Slave Lake. The other end of the cable will be connected to the load by a 380 km, 161 kV transmission lines. A steady state analysis was conducted to assess the required equipment to make the operation of this line possible.

Using the cable and towerhead configuration given in Figure 3-2 and Figure 3-3 the parameters for the 380 km line are calculated and given in Table 3-9. Line and cable parameters calculations are done using PSCAD V4.2. A schematic diagram of the system is shown in Figure 3-11.



Schematic Diagram of the Marine Cable Option and Required Equipment
Figure 3-11

Table 3-9
Overhead transmission line parameters for the Marine Cable Option

Line Length (km)	Voltage (kV)	R (pu)	X (pu)	B (pu)	G (pu)
380	161	0.11167	0.68175	0.34552	0.0012
255	161	0.07842	0.46748	0.22927	~0
150	161	0.04724	0.27816	0.13406	~0
5 (cable)	161	0.00304	0.00369	0.05700	~0

3.2.5.3.1 No Load Condition

Voltage at the receiving end of the line versus the length of the line is given in Figure 3-6. For a 640 km uncompensated line from which 5 km is a cable, in no load condition, because of the Ferranti effect the voltage at the receiving end will go as high as 1.55 p.u. and the cable will experience a voltage of 1.4 p.u. As shown in Figure 3-11 to limit the voltage around ±5% range along the line, shunt compensation is required at one end of the cable, at both sending and receiving end and a mid-point. Simulation results show that a total of four 15 Mvar shunt inductors are needed; at the generator bus, at the remote load bus and at the mid-point between the cable and the load and at one end of the cable. These inductors are called line reactors and should be always connected to the line.

3.2.5.3.2 Full Load Condition

By increasing the load, the transmission line consumes reactive and at full-load condition the reactive power demand is at its maximum.
Generator at the sending end is a source of reactive power. A reactive power source is required at the load side as well. Switched capacitors, synchronous condensers and Static Var Compensators (SVCs) are able to provide variable reactive power. The final selection depends on the characteristic of the load and its variations. There is no need for reactive power source in the middle of the line as the voltage at full load is within the acceptable range.

Simulation results show that a total of 25 Mvar reactive power should be provided for the line demand at the load end. The load reactive power should be supplied locally and will be extra. The largest motor is assumed to be 0.75 MW which at start up will require around 5 Mvar of reactive power. Assuming that not more than two of these motors might start at the same time, an SVC with size of ±10 Mvar is sufficient to supply the reactive power demand. The rest of reactive power (15 Mvar) should come either from switched shunt capacitors or synchronous condensers.

3.2.5.3.3 Power Loss

The total loss on the line at full load is around 3.8 MW or 7.5% of the load. This power loss translates to around 33 GWh loss of energy per year. The total power which could be delivered to the load is 50 MW from which 10 MW is local and the rest will be delivered to the mines.

3.2.5.3.4 Series Compensation

Based on the steady state analysis the phase angle difference between generator and load at the remote end is around 35° which is within the limit and series compensation is not required for this option.

3.2.5.3.5 Single Line Diagrams of the Substations for the Trans-Island Option

The single line diagrams were developed for the substations that are necessary for Trans-Island Option. They are presented in the Appendix H. The main equipment required for these substations is listed in the following section.

3.2.5.3.6 Summary of Required Equipment for Trans-Island Option

Based on the results of the steady state analysis, equipment listed in Table 3-10 are required to keep the voltage within acceptable range in all the operating points. The values are estimated assuming typical load characteristics. These parameters should be optimized further in detail design stage.

Table 3-10
Required Equipment for Trans-Island Option

Description	Voltage Rating	Power Rating	Quantity
Line connected reactors	161 kV	15 Mvar	4
SVC	34.5 kV	±10 Mvar	1
Synchronous condenser or switched capacitors	34.5 kV	0 to 20 Mvar	1
Substation (for shunt reactors)	161 kV	-	2

3.2.6 Summary and Conclusions

This study shows that all the following three routing options are viable from electrical parameters point of view.

- West Route of Great Slave Lake (~ 1150 km)
- Marine Cable Option across Great Slave Lake (~ 700 km (80 km cable))
- Trans-Island Option with Marine Cable Placements (~ 640 km (5 km cable))

However because the lines and cables are long, a combination of shunt reactors, switched capacitors, synchronous condensers, SVCs and series capacitors are required along the line to keep the voltage within acceptable limits from no-load to full load conditions.

The final selection of components should be done based on the characteristics of the load and the acceptable range of voltage variations in steady state and transient situations.

3.3 GEOTECHNICAL CONSIDERATIONS

3.3.1 Terrain Typing

The terrain typing was initially conducted through examination of aerial photography available from satellite photography. A search was made for low-level photography, which proved unattainable in the available time frame. Based upon the photographic evidence and indicators shown on the appended sheets, each route was evaluated independently with bedrock outcrops, soil types, and permafrost conditions identified broadly. The methodology employed by the writer followed the Dr. GD Mollard approach that had extensive experience in northern landscapes and in road, dikes and transmission line routing.

3.3.2 Field Reconnaissance

On August 11 through August 15,2008 an aerial field reconnaissance of the transmission line routes were made. The reconnaissance commenced at the Twin Gorges generation station and proceeded northward along Route B (Trans Island Route) through to Great Slave lake and then northward to Snap Lake and the Ekati diamond mines. From the diamond mines, Route A known as the Base Line Route was followed back to Twin Gorges. A small section of the route was missed due to low clouds and poor weather.

3.3.3 Topography

The topography of all three-line options varies from flat, low lying rock plateaus to sharp near vertical rock faces of over 200 meters in height. Most of the high relief areas border the shores of Great Slave Lake with more moderate topography north of Snap Lake and South of the Snowdrift River.

To establish the most economical and accessible route with tower locations will require detailed survey such as Lidar surveying that is used extensively with GPS horizontal control.

3.3.4 Basic Soil Types

The basic terrain of the area was found to be comprised of four types. These are:

a) Bedrock Outcrops
b) Heavily weathered and broken Rock Outcrops
c) Permafrost affected soil
d) Marsh and swamp areas

3.3.4.1 Bedrock Outcrops

Most of the routes passed over bedrock outcrops, the rock being granite gneiss with heavily weathered surfaces and lichen cover. The bedrock is massive, of high strength, and occurs at elevations above the surrounding lake level of over 300 m. At lake shorelines, the rock has been shattered into large boulders through frost action. Boulder sizes range up to 2 m in diameter. The rock surface has been modified by glacial action, which has created grooves or etchings. The direction of glacial movement is primarily northeast, nearly perpendicular to the transmission line direction. While the etchings make construction of winter road difficult, it does allow longer swing spans taking advantage of higher rock topography.

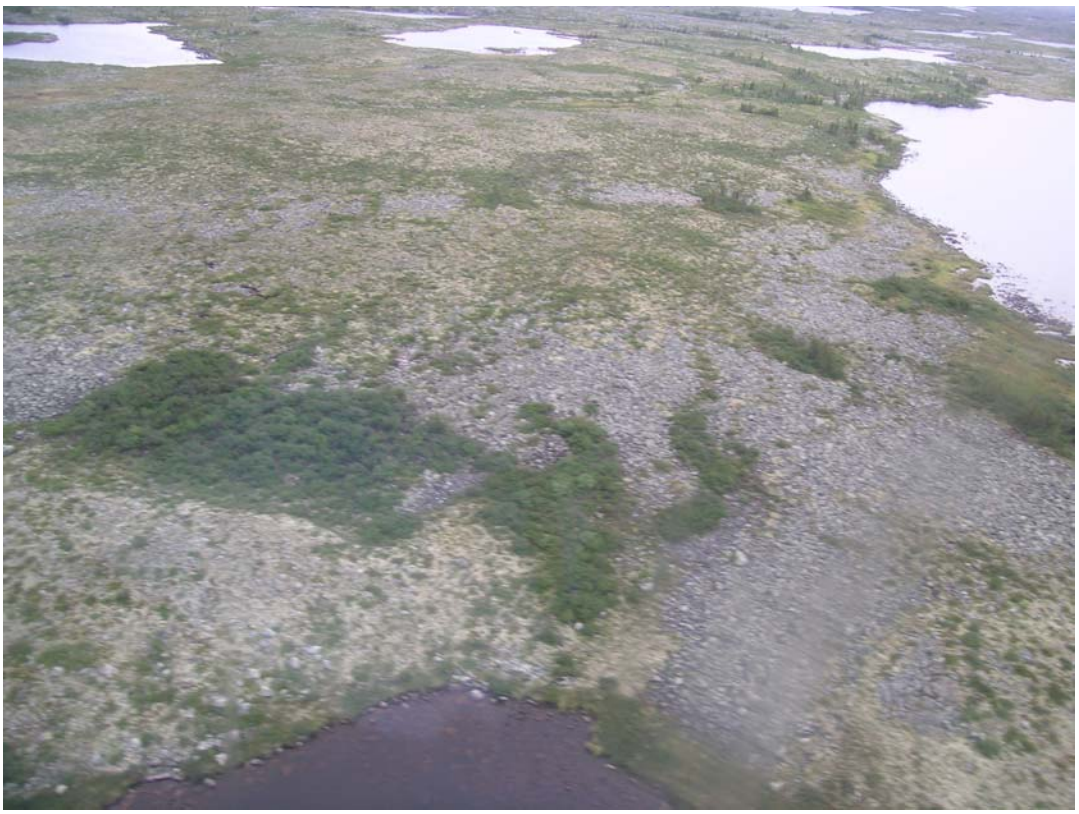
Bedrock Outcrops
Figure 3-12

3.3.4.2 Heavily Weathered and Broken Rock Outcrops

In large areas north of Snap Lake, there are large expanses of broken rock or boulder fields. The rock lies over massive bedrock at shallow depths but is so concentrated that transmission tower foundations require special attention in design and construction.

Anchor design must penetrate the broken rock surface into sound underlying bedrock. It is the writer's view that the depth of broken rock is related to frost penetration and is in the order of 2 meters. This is based upon field inspection and confirmation would be required. The construction operation would be to either move the large boulders and clear to sound rock or alternatively extend the length of the shaft by 2 meters and socket the anchors and base into sound rock.

Alternatively, a steel grid could be used and the boulders placed upon the grid to provide uplift resistance. In view of the large size of the boulders this may be difficult.



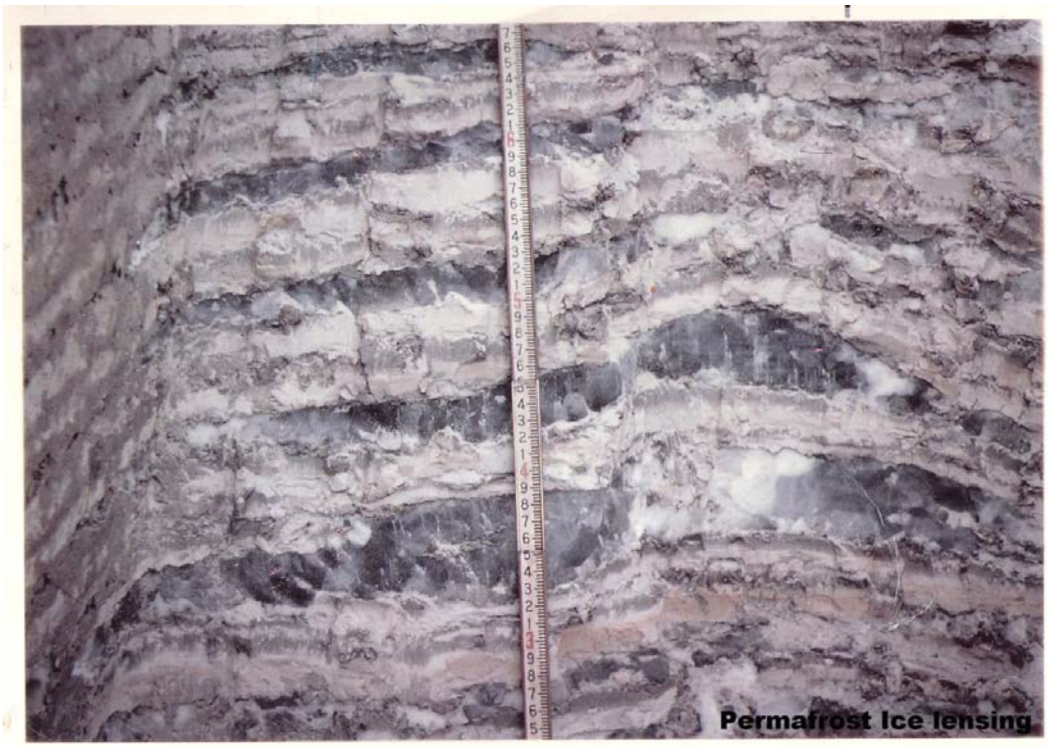
Heavily Weathered and Broken Rock Outcrops
Figure 3-13

3.3.5 Description of API Indicators Applied in Trans - Island Route

3.3.5.1 Permafrost Topography

Permafrost topography is generally low lying with little relief. It is typified by frost polygonal features in the barren land areas, and these features were found to extend through large areas and under the shallow lakes. The lakes are believed to have been formed through permafrost melting, but would normally freeze to the bottom during winter, thus preserving the permafrost soil condition. Because of the wide expanse of many of these areas, it is doubtful that they can be avoided, consequently a design approach is provided.

Tower foundations in permafrost areas must recognize the soil ice composition and the amount of ice space that can translate into structure settlement or liquefied soils of extremely low strength incapable of providing structure support. A typical cross section of permafrost is presented in Figure 3-14.



A typical cross section of permafrost
Figure 3-14

3.3.5.2 Marsh Areas

The marsh areas are typical of those in southern regions and are found between lakes and or in rock crevasses. The width of these can vary, however, in most cases they can be either avoided or spanned with careful positioning of the structures. A typical marsh area is presented in Figure 3-15.

Marsh Areas
Figure 3-15

Table 3-11
Terrain Type Aerial and Field Interpretation Indicators

Position (km)	Terrain Type	Indicators
0-6.3	Bedrock Terrain- helicopter access Twin Gorges to PI 2	- Rock exposures throughout with glacial etchings. - Very rough irregular rock outcrops with deep crevasses
6.3 –140.9	Bedrock Terrain- possible winter road access	- Rock outcrops, lower and more gentle slopes - Tortuous Lake crossing at 46.5 km has rock abutments acceptable span length - Crossings at 93 Rutledge and Konth River within 400 m spans – rock abutments - Crossings at 102.2/113.6 km and 124 km are within allowable spans.

Table 3-11
Terrain Type Aerial and Field Interpretation Indicators

Position (km)	Terrain Type	Indicators
140.9-155.7 alt route	Bedrock Exposures- possible winter road access	- Possible line relocation between PI 22 and PI 24 which would shorten line by 1.5 km - Rock terrain with glacial etchings and water filled depressions without defined drainage channels. - Lake shorelines irregular and rock controlled.
155.7-193.7	Island and water crossing – Hornby Channel	- Very high rock outcrops at south shoreline - Island crossings to Hornby Channel possible with very long swing spans. - High 100 m+ south abutment and deep channel make a cable crossing questionable - North abutment rock controlled but l
193.7-232.0	Preble Island Crossing – road access possible	- Primarily rock control with smooth shorelines indicating soil cover and circular lakes with some drainage patterns in a direction 90 degrees to glacial etchings
232.0- 243.9	Preble Island - Road access possible	- 232-235 km rock outcrops - 235-241.5 km soil cover over bedrock probably frozen
243.9-276	Irregular rock surface- deep crevasses helicopter construction	- High rock outcrops with sharp drop-offs about 100 km - -1.5 m in height
276-286.4	Water crossing and islands – water access	- 1200 m spans between low rock islands - North island rock boulders and will need raising.
286.4-293.2	Island swing spans	- Rock outcrops on islands - Distance between rock highs within allowable limits
293.2-299.1	Island swing spans	- Rock outcrops on shorelines

Table 3-11
Terrain Type Aerial and Field Interpretation Indicators

Position (km)	Terrain Type	Indicators
299.1-302.6	Water crossing – Hearne Channel	- 4000 m water crossing - Deep water, 320 m according to the hydrometric maps - Very steep south abutment 100-200 m near vertical - Suspect near vertical underwater cliff which may eliminate a cable crossing - No available small islands that can be improved.
302.6-316.8	Bedrock controlled topography	- Low rock outcrops and uniform rock surface texture. - Occasional old frost polygon
316.8-356.6	Bedrock topography medium relief	- 100 m marsh crossing at 330 km
356.6-387.9	Bedrock topography medium relief	- Weathered rock surface with large broken fragments from 370 km north - Major lake crossing at 385.4 km - Black spruce
387.9-402.3	Boulder field over bedrock – depth of boulder pack unknown	- Boulders ranging from 1 m to 3 m in size randomly placed, with sharp unweathered edges
402.3-414.2	Bedrock topography	- Rounded bedrock surface with occasional boulder fragment on surface - Light grey rock
414.2-447.5	Bedrock topography	- Boulder fields from 414 to 424 km and 435- 443 km over exposed rock - Lake crossing at 424 km on solid rock - Permafrost polygons 432-436 km
447.5-452.6	Bedrock topography	- Rounded surface, low lying, some large boulders
452.6-461.3	Permafrost area	- Numerous frost polygonal features which extend under shallow lakes
461.3-482.0	Rock topography	- Low lying, rounded rock surface - Many small lakes that probably can be cleared with careful tower placement - No drainage outlets from lakes

Table 3-11
Terrain Type Aerial and Field Interpretation Indicators

Position (km)	Terrain Type	Indicators
482.0-492.7	Rock topography	- Low lying rounded rock surface exposures - Permafrost areas predominate frost polygons - No trees, low vegetation - Large esker at 493.5 km
492.7	Snap Lake	- Roads and cuts light fills placed over permafrost. Material for road construction likely from mine excavation (no evident borrow areas)

In summary, the lengths and tower requirement are proposed as follows for this route:

Table 3-12
Summary of Foundation Types

Length (km)	Type 1 – Rock Foundations	Type 2 – Soil Foundations	Type 3 – Permafrost	Type 4- Fragmented Rock
493	421	6	21	45

3.3.6 Description of API Indicators Applied Between Snap Lake and Gahcho Hué

Table 3-13
Terrain Type Aerial and Field Interpretation Indicators

Position (km)	Terrain Type	Indicators
0-7.5	Bedrock terrain	- Rock exposures throughout with glacial etchings. Low smooth outcrops with occasional fragment - Esker at 5.9 km
7.5- 19.4	Boulder field over bedrock	- Rock outcrops, lower and more gentle slopes, large boulders on surface depth unknown - Crossings at 13.6 lake within 400 m swing spans – rock abutments

Table 3-13
Terrain Type Aerial and Field Interpretation Indicators

Position (km)	Terrain Type	Indicators
19.4-22.0	Bedrock exposures- possible winter road access	- Low bedrock exposure, no defined drainage channels. - Boulder field at 20.4 - Lake shorelines irregular and rock controlled
22.0-28.2	Bedrock exposures – several deep gorges	- Low rock outcrops 30 m cliff at 24
28.2-58.0	Bedrock with boulders	- Primarily with lake having rocky shorelines - Boulder fields to 37 km then exposed low bedrock - At 45.5 to 47.5 km permafrost low area with polygonal features - High sharp cliff at 47.5 km - Rock controlled topography 47.5 to 58 km
58.0 -75	Bedrock controlled area with permafrost low areas	- 58 – 64 km bedrock outcrops - 64 – 67.2 km permafrost area – polygonal features extending under shallow lakes
75.0 – 82.7	Low area, without drainage features	- permafrost area,
82.7-93.3	Rock controlled	- low rock outcrops with a boulder field at 88.5 km
93.3	Gahcho Kué intersection with Base Line 389 km	

In summary, the lengths and tower requirement are proposed as presented in Table 3-14.

Table 3-14
Summary of Foudation Types

Length (km)	Type 1 – Rock Foundations	Type 2 – Soil Foundations	Type 3 – Permafrost	Type 4- Fragmented Rock
93.3	31.4	0	12.9	49

3.3.7 Structures

For the specific terrain conditions outlined above, four (4) foundation types can be considered for the Type A structure. The type A structure being similar to that currently existing of the Twin Gorges – Fort Smith line., The details of the structures and foundations are shown appended. The design requirement of each foundation as provided by Teshmont Consultants are as follows:

3.3.7.1 Design Parameters – Ultimate Loads

a) Tower base max. vertical loading = 336.2 kN
b) Anchor tension = 160 kN less 1.2kN for foundation acting at 35 degrees to vertical
c) Rock compressive strength – 50 mPa for rock with 100 RQD . Anchors in tension utilize 50% of the compressive strength
d) Factor of safety = 2

3.3.7.2 Rock Foundation/Anchor Options

Applies when the rock exposures are massive and solid with an RQD of 100 within 2 meters of the surface.

3.3.7.2.1 Tower Mast

On a steel footing sized to match the mast base but at least 400 x 400 and 25 t hi ck with a grout pad and 4- 20M bars as rock anchors for lateral wind forces. The anchors would be drilled into the rock and grouted.

3.3.7.2.2 Tower Anchors

Individual anchors 35 degrees to perpendicular installed into 100mm diameter holes and grouted. The length of each anchor must have a rock embedment of at least 1500 mm into sound rock.

3.3.7.3 Permafrost Foundations

Applies in ice polygon areas where ice content may be at least 60% by volume and where allowing the soil to thaw will produce major settlement of the tower. The ballast will limit anchor capacity.

3.3.7.3.1 Tower Mast

Place a 200 mm thickness of high density Styrofoam insulation layer over the soil surface underlying the surface peat or lichen growth. The dimensions of the insulation should be at least 1.5 m x 1.5 m. Place a steel base with a riser over the insulation to distribute mast load to no more than 50 kPa and cover the base with at least 400 mm of granular fill

3.3.7.3.1.1 Alternative Foundation

Thermo Piles: Utilize thermo piles on angle structures where high loads are anticipated. Thermo pile design is according to Arctic Foundation design manual

Screw piles: Another option to consider is the use of larger diameter (300 mm) screw piles. These can be installed in a drilled hole and or by torsion providing penetration can be achieved in permafrost. Further study will be required to determine the ice/soil ratio, which can be as high as 60% in soils exhibiting polygonal features or in pingos. It will be important to investigate the rate and longevity of freezeback. For various fill or grout materials.

As for the tower base, large diameter screw piles are an option for the anchor system. It is important again to evaluate freeze back issues and the feasibility of installing these piles into ice-rich soils.

3.3.7.3.2 Tower Anchors

Anchors in permafrost should consist of a 1.5 m x 1.5 m steel grid placed upon the permafrost surface with a 150 mm high density Styrofoam and granular soil cover. The height of the ballast to resist uplift (FS = 3) must be at least 1 meter.

3.3.7.3.2.1 Alternative Foundation types

Thermo Piles: Utilize thermo piles on angle structures where high loads are anticipated. Thermo piles can be augured into the soil/ice and use the soil strength to resist uplift.

3.3.7.4 Broken Rock Area Foundation

This type of foundation (See Plate 2) would apply in boulder field areas where sound rock is not identifiable from surface observation. The boulder fields are expected to have large rock blocks with widely spaced cracks or separation between each block.

3.3.7.4.1 Tower Foundations

The tower foundation should be set below the broken rock base or if very deep, on short steel pipe piles which extend to sound rock. Each pipe pile should be driven into the rock joint and tested to 200% of the design loading. 4-piles are recommended for each tower base grouted to the surrounding rock blocks to form a competent grout/rock mass.

3.3.7.4.1.1 Alternative Foundations

Driven Piles: It may be possible to penetrate the boulder surface using a truck or Nodwell mounted diesel pile driving hammer.

3.3.7.4.2 Tower Anchors

3.3.7.4.2.1 Defragmentation Grouting

Anchors in broken rock boulder field could utilize the larger fragments and insert rock anchors to provide uplift. The fragment must be at least 1.5 m x 1.5 m x 1.5m in order to provide sufficient anchor capacity. Alternatively several fragments could be cemented together to form a large ballast block of the required size.

3.3.7.4.2.2 Alternative Foundations

Steel grid with boulders as rock ballast: A steel grid set below the boulders and weighted with rock fragments may be another option for consideration. This would involve removing some of the boulders, laying the grid and replacement of the boulders. The size of the grid will depend upon the boulder fragments but would be at least 2 m x 2 m in size.

3.3.7.5 Marsh Tower Foundations

Tower foundations in low lying marsh areas will be subject to settlement and low strength soil support.

3.3.7.5.1 Tower Mast Foundation

For the vertical loading on the mast it is necessary to provide load distribution such that base loads equal or are less than overburden loading. The organic cover in marshes is compressible and should be removed under the mast down to a mineral soil.

A culvert base as shown on Plate 4 with a metal grid within the culvert backfill would provide support in wet conditions providing it was sufficiently large. In order to limit the bearing to 18 kPa at the base a 1600 mm diameter culvert would be required. These can be readily installed through soft peat deposits and the material removed from the inside prior to setting the steel grillage and backfilling.

3.3.7.5.2 Tower Anchor Foundations

In marsh areas a system of ballast will be required to provide anchor uplift resistance. Culvert installations can again be used. 1250 mm diameter culverts with 1.5 m of saturated granular backfill can provide adequate uplift resistance to meet design requirements.. Installation is relatively simple and can be done during winter with excavation or during summer operations.

3.3.7.5.2.1 Alternative Foundations

Screw Piles: Another option to consider is the use of larger diameter (300 mm) screw piles. These can be installed in a drilled hole and or by torsion providing penetration can be achieved in soft soils. The length would be determined by knowing the marsh depth and base soil.

3.3.8 Seismic Considerations

The area of the transmission line routes is located in a seismic zone having horizontal ground velocities in the order of 0.004 meters per second (re: Canadian Foundation Manual third Edition) This similar to the Canadian Shield east of the sites which is considered low risk. This translates to a slight increase in design load requirement of 1.1 for Foundation. More specific calculations for load/structure can be made in the later stages of the design.

3.3.9 Further Studies

The following areas require further study

a) The route location should be modified on the basis of topographical features. The topographical highs normally reflect competent rock outcrops and the line should be adjusted to take advantage of this feature.
b) Investigation into permafrost freezeback for the anchor and tower systems may allow foundations to be installed into large holes that may provide additional stability than the mat system presented herein.
c) The tower installations within the boulder fields require further investigation with the objective of establishing a method of joining large fragments together.

3.4 GENERAL SUBMARINE CABLE CROSSING CONSIDERATIONS

All submarine cable crossings would be required to perform in following the environmental and power system conditions.

3.4.1 Environmental Conditions

Ambient air temperature	32° C (Maximum) -3° C (Average) -52° C (Minimum)
Ambient soil temperature at 1.0m depth	5° C (Maximum) -52° C (Minimum)
Ambient water temperature at bottom	5° C (Maximum) 0° C (Minimum)
Cable burial depth on land and shallow water	1.0 m
Maximum wind velocity (at terminals)	113 km/hour

3.4.2 Power System Conditions

System grounding	solidly grounded
System frequency	60 Hz
Nominal system voltage	161 kVrms
Highest continuous voltage	170 kVrms
BIL	750 kVcrest
Total required power transmission capacity	60 MVA*
Total required current transmission capacity at 161 kV	215 A

* This is transformer capacity at Twin Gorges. MW capacity depends on results of load flow and long range planning studies.

3.4.3 Submarine Cable Descriptions

Two cable types are feasible for this application: three core design and single core design.

3.4.3.1 Three-core design

Each phase conductor would be cross-linked polyethelene (XLPE) insulated, lead sheathed and polyethylene (PE) jacketed, then tri-plexed and armoured, ready for shipping and cable laying as a unit (see Figure 3-16).

Three-Core Submarine Cable
Figure 3-16

Advantages:

- Only one relatively compact cable is required for a three phase circuit.
- Manufacturing cost is somewhat lower than for three single-core cables.
- Armour losses are somewhat lower.
- Cable laying costs can be lower for a complete circuit, if transportation of larger reels is possible and local vessels are available.

Disadvantages:

- Cable weight and diameter is relatively high compared to a single-core cable.
- Cable reel or drum size is relatively large compared to a single-core cable, which is an important consideration for transportation to, and laying at, relatively remote locations like Great Slave Lake.
- Cable failure due to external damage or internal breakdown could take almost a year to repair, unless a second circuit is installed as a standby. This would approximately double cable costs.

3.4.3.2 Single-Core Design:

Each phase conductor would be XLPE insulated, lead sheathed, PE jacketed and armoured, ready for shipping and cable laying. Three such cables are required for a three-phase circuit (see Figure 3-17).

Single-Core Submarine Cable
Figure 3-17

Advantages:

- Weight and diameter of each cable is relatively low compared to a three-core design.
- Reel or drum sizes for each cable can be smaller than for a three-core design, important for transportation to, and laying at, Great Slave Lake.
- By adding one more spare cable, the outage duration due to a failed cable can be reduced to the time to switch out the failed cable and switch in the spare. This would increase cable costs by about one third.

Disadvantages:

- Three cables are required for a three-phase circuit (four if a spare is desired).
- Armour losses are somewhat higher.
- Manufacturing cost for three single-core cables is somewhat higher than for one three-core cable.

It is proposed that final selection of cable type be based on competitive bidding and a review of acceptability of long outages to make submarine cable repairs, if and when necessary.

3.4.4 Cable Conductor Size Selection

Usually conductor size is selected to achieve a certain desired current rating without exceeding temperature limits. However, when system voltage is high and transmission capacity requirements are relatively low, as in this case, conductor size is selected to minimize electric stresses within the cable and accessory insulation. For 161 kV cables, maximum stress at the conductor shield should not exceed about 9 kV/mm, as described in AEIC CS9.

For cables with a semi-conducting conductor shield, nominal ac electric stress at any point in the insulation is calculated using the following formula:

$$G_r = \frac{V_g}{r \times \ln \frac{r_i}{r_s}}$$

Where:

G_r = nominal ac voltage stress at radius r (kV/mm)
V_g = nominal phase-to-ground voltage (kV)
r_i = nominal radius over the insulation (mm)
r_s = nominal radius over the conductor shield (mm)
r = radius of a point of interest in the insulation (mm)

The nominal internal ac stress (G_{max}) occurs at the interface between the conductor shield and the insulation, when $r = r_s$.

The nominal external ac stress (G_{min}) occurs at the outside of the insulation, when $r = r_i$.

In order to not exceed the maximum stress criteria at the conductor shield of 9 kV/mm, a 240 mm^2 conductor would be required. Since as described below, ampacity is not a consideration, the conductor would be aluminum, to reduce weight and costs. A suitable cable core (before lay-up in the case of a three-core cable, and before armouring) would have approximately the following nominal construction:

Conductor outside diameter	18.1 mm
Conductor shield thickness	1.5 mm (approx)
Insulation thickness	21.0 mm
Insulation shield thickness	1.5 mm (approx)
Longitudinal water block thickness	1.0 mm
Lead alloy sheath thickness	3.5 mm
PE anti-corrosion jacket thickness	3.0 mm
Overall core diameter	81.1 mm (approx)

For a three-core design with single wire armour and polypropylene yarn serving:

Polypropylene yarn armor bedding thickness	3.0 mm
Armour wire thickness	6.0 mm
Polypropylene yarn armor serving thickness	5.0 mm
Overall cable diameter	203.0 mm (approx)
Overall cable weight	50 kg/m (approx)

For a single-core design with single wire armour and polypropylene yarn serving:

Polypropylene yarn armor bedding thickness	3.0 mm
Armour wire thickness	6.0 mm
Polypropylene yarn armor serving thickness	5.0 mm
Overall cable diameter	109.0 mm (approx)
Overall cable weight	20 kg/m

Regardless of whether a single-core or three-core construction, this results in a cable core with approximately the same electrical characteristics:

DC Resistance at 20 C	0.125 Ohm/km
AC Resistance at max conductor temperature	0.176 Ohm/km
Capacitance	0.13 uF/km
Charging current per phase	4.4 A/km
Current rating (continuous)	~ 400 A

For water depths greater than about 200 m, counter-helical double wire armour would probably be required, in order to withstand the tensions and torsion forces, depending on supplier recommendations. Aluminum armour wires could be considered rather than steel, in order to reduce weight. Although aluminum armour has had poor performance in sea water, with proper design fresh water performance could be expected to be better, subject to supplier agreement.

To reiterate, at least a 240 mm^2 conductor size is required, in order to keep the electric stress at the conductor shield to approximately within typical design limits of 9 kV/mm. An aluminum conductor is considerably less expensive and lighter than copper, and provides a current rating of approximately 400 A, when only about 215 A is required to match the Twin Gorges transformer capacity of 60 MVA. This leaves a substantial margin to carry cable charging current in quadrature, which should not exceed 135A toward each cable terminal for the longest 61 km crossing.

3.4.5 Cable Standards

Cables would be specified with cross-linked polyethylene insulation, to meet the requirements of:

IEC 62067	Power Cables with Extruded Insulation and their Accessories for Rated Voltages above 150 kV up to 500 kV - Test Methods and Requirements
ELECTRA 171	Recommendations for Mechanical Tests on Submarine Cables
ELECTRA 189-1	Recommendations for Testing of Long AC Submarine Cables with Extruded Insulation for Voltage above 30 to 150 kV

IEC 62067 requires a one year Pre-Qualification test to be done on a complete system of cables and accessories, representative of the application. It is not known whether many suppliers have completed PQ tests for a system capable of operation at the minimum air temperature of -52 C.

Confirmation would be required should any of the alternatives requiring submarine cables proceed.

3.4.6 Cable Installation Methodology

3.4.6.1 Transportation to Site

Investigations have shown that the most practical ways to move large equipment to the Great Slave Lake area is up the McKenzie River from the Arctic Ocean. The closest sea port would be Tuktoyaktuk, which has limited summer openings for shipping from east and west. The background documentation for this study has shown that minimum 500 tonne loads can be delivered to Tuktoyaktuk and transferred to barges for delivery up the McKenzie to Great Slave Lake.

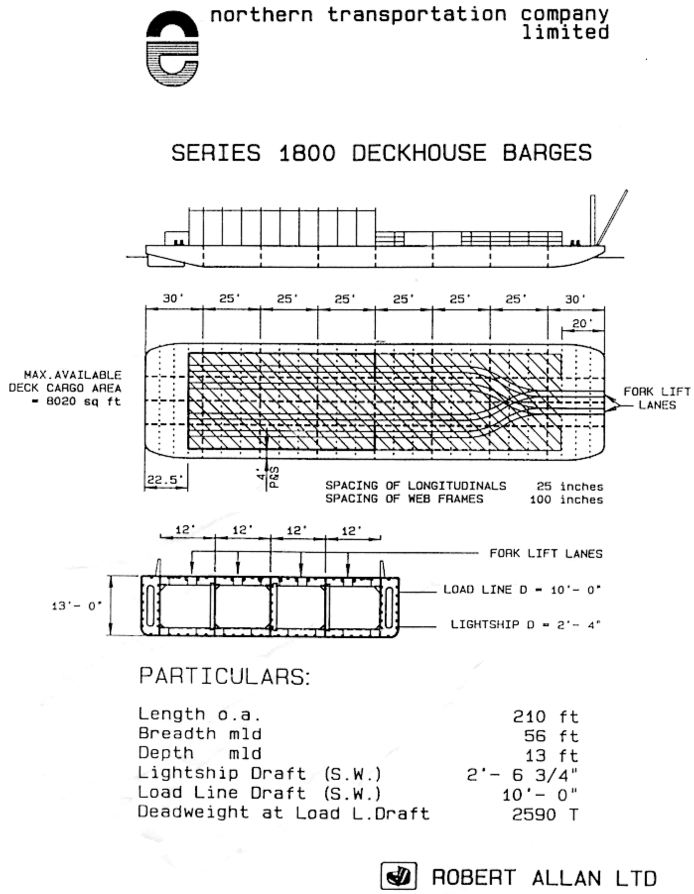
A 500 tonne cable storage basket or drum could hold about 9.5 km of three-core cable weighing 50 kg/m, with an allowance for basket weight. The same basket would hold approximately 24 km of single-core cable.

To make transportation and laying easier, smaller baskets with less cable could be used, provided that continuous lengths were provided between cable terminals.

3.4.6.2 Cable Laying

The Northwest Transportation Company Ltd. (NTCL) has an extensive fleet of tugs and barges, which could assist with cable delivery from Tuktoyaktuk to Great Slave Lake (www.ntcl.com). They also appear to have the capability to assist with assembling a custom cable laying spread from their base in Hay River. Specialized equipment such as cable tensioners, could be delivered in trucks from Edmonton to Hay River.

A description of an NTCL Series 1800 barge is given in Figure 3-18 below.



NTCL Series 1800 Barge
Figure 3-18

3.4.6.3 Cable Laying Schedule

Cable transport and installation is possible during the summer months, when the Arctic Ocean, MacKenzie River and Great Slave Lake are not covered with ice. The schedule will be driven by the length of ice-free season.

Another issue that increases schedule uncertainty is the manufacturing of the cable, since most of the cable suppliers in the world are currently overbooked. According to the latest information received from suppliers, if the cable is ordered by June 2009, it should be ready for shipment by Dec 2010. This would allow delivery to Tuktoyaktuk, transfer to barge(s), floating upstream on the MacKenzie River and laying in summer 2011. Other equipment like cable terminations and joints could be supplied on 9 month notice period and arrive at the site earlier. Shorter cable manufacturing time will be needed for the Trans-Island cable crossing; however, summer 2011 is the earliest time window for installation.

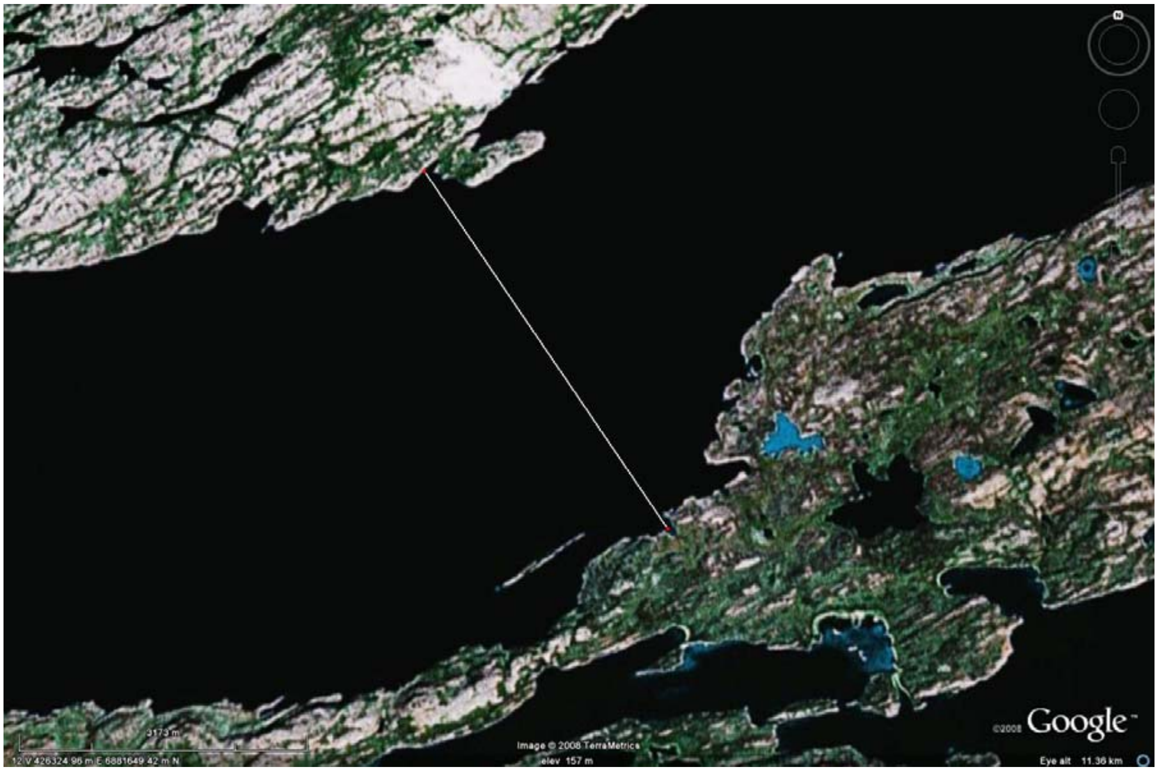
3.4.7 Island Crossing of Great Slave Lake (Hearne Channel Submarine Cables)

3.4.7.1 Route Description

This alternative proposes cable(s) crossing from the vicinity of McKinley Point to Blanchet Island, following a route that minimizes:

- water depth
- route length
- exposure to natural hazards, such as steep underwater features or slides
- cable landing and mechanical protection costs
- terminal station costs
- overhead line approach costs

An approximate 5 km submarine cable route is shown in Figure 3-19. Bathymetry information is poor for this part of Great Slave Lake, but maximum water depth is believed to be about 320 m. Cable supply and installation costs could be reduced if a shallower crossing location can be found in the vicinity, even if it means longer cables. However, based on cable storage basket weight and length limits, it appears that there would be no difficulty transporting and laying continuous cable lengths between terminals. Further investigations are recommended should interest in this alternative proceed further, in order to optimize routing and cable type. Initial concerns are the steep underwater slopes to the lake bottom on both sides of Hearne Channel. Finalizing a route would require a detailed hydrographic survey of the area.



Hearne Channel Crossing
Figure 3-19

3.4.8 All Submarine Cable Crossing of Great Slave Lake

3.4.8.1 Route Description

This alternative proposes the cable(s) cross from the vicinity of Gros Cap to a zone between Stony Island and William Point, following a route that minimizes:

- water depth
- route length
- exposure to natural hazards, such as steep underwater features or slides
- cable landing and mechanical protection costs
- terminal station costs
- overhead line approach costs

An approximate 61 km submarine cable route is shown in Figure 3-20. Maximum water depth is believed to be about 100 m. From the above descriptions of maximum allowable cable lengths, it is clear that multiple cable lengths would be required for this alternative. For a single three-core cable there would be approximately six lengths and five three-phase field joints. Using three single-core cables, there would be three cable lengths and two single-phase field joints for each phase. There is a concern with this route that not all cable could be transported to the site and installed during one summer season. Regardless, should interest in this alternative proceed, further investigations would be required to optimize routing and cable type. A detailed hydrographic survey would also be required before finalizing a route.

Great Slave Lake Crossing
Figure 3-20

3.4.9 Environmental Impact of Alternatives

3.4.9.1 Environmental Impact During Construction

Impact to the lake bottom is expected to be minimal, since the cables would not be buried for most of the route. However, in shallow areas and on land to the cable terminal stations, the cables would be buried to protect against natural hazards, such as ice flow abrasion. Selection of landing sites would attempt to locate areas where excavation was easy, however the need for some rock fracturing may be unavoidable.

The cable terminal stations would occupy an area that depends in part on what other equipment is required, other than the cable terminations and line arresters. For example, there may be a need for line disconnects, ground disconnects and reactors at some stations. There would be a loss of habitat proportional to the area of the terminal stations.

Concrete aggregates and backfill materials would be brought to the terminal station sites from regional sources.

Emissions from internal combustion engines would be released by excavators, tugs, generators and light equipment during cable transportation, laying and construction of the cable terminal stations.

3.4.9.2 Environmental Impact During Operation

The cables would not contain any insulating fluids that could possibly leak out into the lake environment.

The cables would emit heat at the rate of about 0.5 W/m for each phase when energized but unloaded, plus the amount of losses per metre of the cable for each phase when fully loaded. This is anticipated to have a negligible effect on the aquatic habitat.

The cables would contain a lead alloy sheath, which forms a metallic moisture barrier to keep the insulation dry – a necessity for this 161 kV voltage level. However the lead is contained within a polyethylene anti-corrosion jacket, so is not exposed to the environment.

3.5 FIELD STUDY

This report is the second of two field observation surveys that were planned for evaluation of the route alternatives for the Taltson Transmission Expansion Project. The field study and geotechnical assessment were performed on the Trans Island Option, as defined in the project background documentation. One day was also used to re-examine the Snowdrift to Snap Lake portion of the Baseline Alternative for any possible refinement.

The field study started on Monday August 11th with the team members traveling to Twin Gorges. On Tuesday August 12th, the group examined the line route for the proposed Trans Island Option from Twin Gorges to PI 56. The main objective was to examine the line route hopping through various islands (Preble, Simpson and Blanchet) on Great Slave Lake. On Wednesday August 13, the team examined the line route from PI 40 on the Trans Island option to PI 73 (Snap Lake) and went further north to re-examine MacKay Lake Crossing using three small islands, partially the line route to Ekati, Diavik and around the east end of MacKay Lake. On Thursday August 14, the team examined the route from Snap Lake to Gahcho Kué to Hoarfrost River. Low cloud forced the team to exit the line and travel down Hoarfrost River to Great Slave and on to Reliance for fuel. The team then examined an alternate route adjacent to Charlton Bay and south to the proposed line at Snow Drift River. The team also examined the line route from PI 13 south to Twin Gorges. The main objective was to select a possible alternate route to the Baseline Alternative from Lockhart River to Snowdrift River via Charlton Bay. The team returned back to Twin Gorges on August 14.

Prior to field studies Teshmont performed desktop studies of the following three route alternatives based on topographic maps obtained from Canada Map office, Department of Energy, Mines & Resources, Canada:

- Trans Island Option, presented in Volume 2, Appendix K
- Marine Cable Option, presented in Volume 2, Appendix L
- West Route, presented in Volume 2, Appendix M.

The objective of the field study was to examine the line route based on the desktop studies for Trans Island Option proposed by Teshmont and to conduct geotechnical assessment of this route option and the Baseline route. The Trans Island Option route prepared by Teshmont dated July 23, 2008 was considered as the reference for this study along with the Taltson Hydroelectric Expansion Project Transmission Line mapbook dated July 28, 2008 revision # 3.

The following observations were made during the field study. It was acknowledged that the proposed line route was preliminary, and refinement during design would be required to avoid large water and swamp crossings.

3.5.1 Twin Gorges to PI 55 for Trans Island Option (Tuesday August 12, 2008)

The proposed line route in general seems reasonable with the given topography features and water bodies. For the first 90 km the proposed route is parallel to Taltson River & Rutledge River, which enables the line to be near a possible winter road. These rivers are about 4 to 6 km from the line in some sections and can be used for transportation during winter. The line could probably be moved closer to them in some sections.

An existing winter road crosses the proposed line about 110 km from Twin Gorges. Its origin and destination are unknown and require further study.

The line route can be realigned between PI 22 and PI 24, as this will prove to be a shorter and easier route.

Vegetation up to the south shore of Great Slave includes evergreen and deciduous trees, some shrubs and grasses, lichen covered rock and sand, moss and peat covered muskeg.

Clearing of the right of way will be required, and is variable with denser, tall trees and vegetation in some sections and short and scanty tress in other sections based on the soil/rock conditions. There are some sections with little tree clearing required due to large burn areas i.e. near PI 5, 13 and 14.

The line route for crossing Great Slave Lake over Preble, Simpson & Blanchet Islands will require at least 8 to 10 tall self supporting structures and 2 cable crossings.

As per the desk top studies for this line route it seemed that between PI 40 and PI 41 the crossing would be possible using overhead lines by using a small island (WP 40A E 437949 & N 6876244) between these 2 PI's. However the visual inspection showed that this island is very small & shallow and cannot support the tower structure as-is. One option is to build up this island with rock and boulders, and a second option is to provide a cable crossing to bridge this stretch. However both of these options are expensive and will have to be developed and evaluated.

Possible landing sites for cable crossing of the Hearne Channel near McKinley Point were examined. Landing point selections were based on the desire to provide a naturally protected bay to reduce wave energy in the shallow waters. Also, a relatively sharp descent below the shoreline is required to reduce the possibility of ice damage. There are some other considerations that can be checked only once the complete underwater study is done.

Aerial construction will be required on the islands over Great Slave Lake and some parts of the line near the south and north shores of Great Slave Lake.

Potential barging/staging areas on both sides of the lake were selected, as shown in Figure 3-21.

The majority of this route passes over bedrock outcrop with occasional patches of marshes and swamps, which occupy the topographical low areas and the base of the bedrock. At lake shorelines, the rock has been shattered into large boulders due to frost action. The rock surface has been modified by glacial action, which has created grooves and etching. The direction of the glacial movement is primarily north east, nearly perpendicular to the transmission line.

3.5.2 PI 40 to Snap Lake and Further North to McKay Lake Crossing – Trans Island Option (Wednesday, August 13, 2008)

The line route starting from PI 40 moving northward was again looked into, to verify the possibility of using the existing island between PI 40 & PI 41 to support a tower. Possible landing sites for a cable crossing between the 2 PI's were also evaluated. The final selection will be based on feasibility and economic criteria.

More photos were taken for possible cable landing sites for Hearne crossing and PI 40 & PI41.

The proposed line route on this option from the north shore of Great Slave Lake to Snap Lake was reasonable given the topography. There is no existing winter road near this part of the line, and making new winter roads will be difficult considering the absence of permanent water bodies along the line.

There are no construction features along the line route except the mine sites.

The vegetation changes from tall deciduous trees to small plants and shrubs as we move northwards on the transmission line route.

Numerous tracks from Caribou migration are visible.

From the north shore of Great Slave Lake to Snap Lake, more exposed broken rocks are visible. Large fields of broken rock and cobbles are visible on the tundra surface. Permafrost fields in the form of polygons can be observed.

The MacKay Lake crossing, which is hopping over a series of islands, was examined. There is concern that at least two of these islands may not have the ability to support self supporting towers and prevent lake ice from crashing into them. The elevation of these islands might have to be increased by piling boulders and soil on them. Artificial bin walls or another type of retaining wall may need to be used.

The majority of this route passes over bedrock outcrop; however as we move northward above 6,970,000 N, the bedrock starts changing to a large expanse of broken rocks or boulder fields. The rock lies over massive bedrocks at shallow depth but is so concentrated that transmission tower foundation design and construction shall require special attention.

In latitudes above Snap Lake large areas of permafrost affected soil exist that will require special foundations. The permafrost is identified through frost polygon features and pingo development.

3.5.3 Snap Lake to Twin Gorges Along the Baseline Alternative (Thursday, August 14, 2008)

This part of the line was previously assessed during the first field trip from July 14 to 18, 2008. The main objective this time was to conduct the geotechnical assessment based on visual inspection of the rocks and soil. Another objective was to determine an alternate route from Lockhart River to Snowdrift River via Charlton Bay. The benefit of this alternative is bringing the line route as close as possible to the barging and assembly areas.

An alternate route was selected, enabling the line to come closer to Charlton Bay. The following additional locations were selected for PI # 10A, 10B, 10C, 10D & 10E.

Vegetation along the section below Lockhart River includes evergreen & deciduous trees, some shrubs and grasses, lichen covered rock and sand, moss and peat covered muskeg.

Clearing of the right of way will be required, and is variable with denser, tall trees and vegetation in some sections and short and scanty tress in some sections, based on soil/rock conditions. There are some sections with little tree clearing required due to large burn areas.

Some sections of the forest were still burning as was evident from the thick smoke, to the south of Snowdrift River.

The majority of this route passes over bedrock outcrop, with broken rocks or boulder fields and permafrost affected soil in the north portion. As we move southwards, especially below Lockhart River, the bedrock outcrop is more evident, with occasional patches of marshes and swamps, which occupy the topographical low areas and the base of the bedrock. At some places, the bedrocks are massive, of high strength and are elevated up to 300 m above the lake.

3.5.4 General Comments

The proposed Trans Island alternative between Twin Gorges and Snap Lake is possible, however the cost and environmental impact have to be evaluated.

Most of the islands that the proposed Trans Island route crosses (Preble, Simpson and Blanchet Islands) are considered critical wildlife areas, inhabited by beavers and muskrat. The environmental impact will have to be evaluated.

Overhead crossing of Great Slave Lake will require erection of huge self supporting structures (from 40 m to almost 100 m high) across the lake, which will potentially result in significant environmental and visual impact.

3.6 CONSTRUCTION METHODOLOGY AND SCHEDULE

3.6.1 Trans-Island Option

The Trans-Island Option 161 kV transmission line starts at Twin Gorges and extends north towards Hornby Channel, Great Slave Lake and across the Preble, Simpson, and Blanchet Islands to McKinley Point on the north shore of Great Slave Lake and continues north-east to Snap Lake and Ekati mines and then south-east from Ekati to the Diavik mine. The line length from Twin Gorges to Ekati is estimated at 603 km and from Ekati to Diavik is estimated at 33 km. The Trans-Island Option also includes a 69 kV transmission line which extends east from Snap Lake to Gahcho Kué with an estimated line length of 94 km. It also includes a marine cable crossing between PI 48 and 49 across the Hearne Channel. Refer to "Trans-Island Option Overview – Aug 19/08" in the Appendix.

The transmission line has been separated into four sections based on the line voltage, access, and construction methods proposed for these sections, which are as follows:

- Southern Section - Twin Gorges to Hornby Channel – 146 km at 161 kV
- Trans-Island Section – Hornby Channel to McKinley Point – 113 km at 161 kV
- Northern Section – McKinley Point to Ekati – 344 km at 161 kV
- Ekati to Diavik – 33 kV at 69 kV
- Snap Lake to Gahcho Kué Section – 94 km at 69 kV

3.6.1.1 Construction Access and Accommodations

The staging areas for the Trans-Island options are presented in Figure 3-21.

3.6.1.1.1 Southern Section – Twin Gorges to Hornby Channel – 146 km at 161 kV

Construction access to the southern section would be by re-established the existing winter road from Fort Smith to Twin Gorges. Line and substation materials, clearing and construction equipment, fuel, supplies and camps would be hauled in by truck from Ft. Smith to Twin Gorges and distributed along the line up to the Cooke Creek staging area. Line materials, clearing and construction equipment, fuel, supplies and camps would also be barged to the Hornby Channel barge landing and staging area and distributed along the line to the Rutledge River staging area.

The proposed staging areas would be located at Twin Gorges, Cooke Creek, Rutledge River, and Hornby Channel on Great Slave Lake. The staging areas would have similar characteristics to the staging areas in the Baseline Option.

Similarly to the Baseline Option, temporary access trails are proposed where terrain permits, and would be constructed in the winter where possible from the staging areas to the line and continuously along the line right of way.

Based on terrain conditions in the southern section, it is assumed that tracked equipment for machine clearing, foundation construction, and conductor installation would be used on the temporary access trails. If the terrain permits, rubber tired vehicles and equipment would be used. Also in the southern section, it is assumed that all structure erection and some conductor stringing would be done using helicopter construction methods.

The proposed camps for accommodations would be located at Twin Gorges, Rutledge River, and Hornby Channel. Main camps would accommodate 50 to 80 persons, and small camps would accommodate less than 40 persons. Camps would be left in place until all construction activities for that line section specific to that camp are completed, and may extend over a number of winter and summer seasons.

3.6.1.1.1.1 Twin Gorges Staging Area and Camp

Twin Gorges at kilometre 0 would serve as the main staging area and main camp for the south section. This staging area would be used for clearing and construction of the first 19 km of line. The terrain is somewhat difficult in this section but temporary access trails may be feasible for tracked equipment.

3.6.1.1.1.2 Cooke Creek Staging Area

Cooke Creek (7 km north of PI 12) at kilometre 19, with coordinates of N6715000 and E469500 would, serve as a minor staging area for the line section 37 km north of Cooke Creek. The terrain is difficult in this section and hand clearing and construction with aerial access are assumed.

3.6.1.1.1.3 Rutledge River Staging Area and Minor Camp

Rutledge River (near PI 13) at kilometre 93, with coordinates of N6785000 and E449000, would serve as a staging area and minor camp for the line section 37 km south towards the Cooke Creek staging area and 26.5 km north towards the Hornby Channel staging area. The terrain is difficult in the section 37 km south towards the Cooke Creek staging area, and hand clearing and construction with aerial access is assumed. For the line section 26.5 km north towards the Hornby Channel staging area, the terrain is less difficult and a temporary access trail is proposed along the line. Machine clearing, foundation construction, and conductor installation with tracked equipment is assumed in this section. Structure erection and conductor stringing using helicopters are assumed for the line section 37 km south. Structure erection using helicopters is assumed for the line section 26.5 north.

3.6.1.1.1.4 Hornby Channel Barge Landing, Staging Area, and Main Camp

Hornby Channel (near PI 22) at kilometre 146, with coordinates of N6832000 and E435000, would serve as a barge landing, staging area, and main camp for the line section 26.5 km south towards the Rutledge River staging area and 26 km north towards the PI 33 barge landing and staging area. For the line section 26.5 km south towards the Rutledge River staging area the terrain is less difficult and a temporary access trail is proposed along the line. Machine clearing, foundation construction, and conductor installation with tracked equipment is assumed in this section. Structure erection using helicopters is assumed for this line section 26.5 south. For the line section 26 km north, refer to the Trans-Island Section.

3.6.1.1.2 Trans-Island Section Hornby Channel to McKinley Point – 113 km at 161 kV

Construction access to the Trans-Island Section in the warm season would be by aerial access (helicopters or float planes) and barges to the lake staging areas. Construction access in the cold season may be by aerial access (helicopters and planes with skis) and by winter road from Fort Resolution to the Hornby Channel and PI 33 staging areas and possibly from Yellowknife to the McKinley Point staging area. Construction access and delivery of materials and equipment to the line section would be mostly by helicopter and where possible by temporary access trails in the winter.

Line materials, clearing and construction equipment, fuel, supplies and camps would be hauled by trucks or trains to Hay River and barged to the Hornby Channel, PI 33 and McKinley Point staging areas. Line materials, clearing and construction equipment, fuel, supplies and camps may also be hauled by trucks to Ft. Resolution and/or Yellowknife and on winter roads to the staging areas.

The proposed staging areas would be located at Hornby Channel, PI 33, and McKinley Point.

In the Trans-Island Section it is assumed that all of this line section would be constructed with aerial access.

The proposed camps for accommodations would be located at Hornby Channel and McKinley Point.

3.6.1.1.2.1 Hornby Channel Barge Landing, Staging Area, and Main Camp

Hornby Channel (near PI 22), at kilometre 146 with coordinates of N6832000 and E435000, would serve as a barge landing, staging area, and main camp for the line section 26.5 km south towards the Rutledge River staging area and 26 km north towards the PI 33 barge landing and staging area. For the line section 26 km north, the terrain is difficult in this section and hand clearing and construction with aerial access is assumed.

3.6.1.1.2.2 PI 33 Barge Landing and Staging Area

PI 33 at kilometre 198 with coordinates of N6849758 and E413331 would serve as a barge landing and staging area for the line section 26 km south towards the Hornby Channel staging area and 30.5 km north towards the McKinley Point staging area. The terrain is difficult in this section and hand clearing and construction with aerial access is assumed.

3.6.1.1.2.3 McKinley Point Barge Landing, Staging Area, and Main Camp

McKinley Point (PI 49), at kilometre 259 with coordinates of N6883800 and E423000, would serve as a barge landing, staging area, and main camp for the line section 30.5 km south towards the PI 33 staging area and 48 km north towards the PI 61 staging area. For the line section 30.5 km south, the terrain is difficult in this section and hand clearing and construction with aerial access is assumed. For the line section 48 km north refer to the Northern Section.

3.6.1.1.3 Northern Section – McKinley Point to Ekati – 344 km at 161 kV

Construction access to the northern section would be as described above to the McKinley staging area and via the winter roads to each of the mines, Snap Lake and Ekati, and by winter road to MacKay Lake staging area. Construction access and delivery of materials and equipment to the line section would be by temporary access trails in the winter and helicopters in the summer.

Line and substation materials, construction equipment, fuel, supplies, and camps would be transported by trucks from Yellowknife to each of the mines and staging areas.

The proposed staging areas would be located at McKinley Point, PI 61, Snap Lake, MacKay Lake, and Ekati.

For the Northern Section it is assumed that the line would be constructed with the use of temporary access trails along the line in winter. The terrain is typically tundra with flatter rolling hills and valleys interspersed with water bodies, and is suitable for temporary access trails. Clearing is required to the treeline near PI 69. No clearing is required north of this point. All construction would be carried out along the line. Transport of workers and equipment, material delivery, foundation construction, structure assembly and crane erection, and conductor installation by slack stringing would all be carried out along the line. Some construction with aerial access may be carried out in the summer for scheduling purposes.

It is assumed that the camps at the mines would be available for accommodations, and the other proposed camps would be located at McKinley Point, PI 61, and MacKay Lake Lodge. If accommodations at the mines are not available then independent camps would be provided for line and substation construction.

3.6.1.1.3.1 McKinley Point Barge Landing, Staging Area, and Main Camp

McKinley Point (PI 49), at kilometre 259 with coordinates of N6883800 and E423000, would serve as a barge landing, staging area, and main camp for the line section 30.5 km south towards the PI 33 staging area and 48 km north towards the PI 61 staging area. For the line section 48 km north, the terrain is less difficult, and a temporary access trail is proposed along the line. Machine clearing, foundation construction, structure erection, and conductor installation with tracked equipment is assumed in this section.

3.6.1.1.3.2 PI 61Staging Area and Minor Camp

PI 61, at kilometre 355 with coordinates of N6969113 and E463109, would serve as a staging area and minor camp for the line section 48 km south towards the McKinley Point staging area and 49 km north towards the Snap Lake staging area.

3.6.1.1.3.3 Snap Lake Staging Area and Main Camp

Snap Lake (PI 73), at kilometre 453 with coordinates of N7051800 and E506400, would serve as a major staging area for the substation and the line section 49 km south towards PI 61 and 17.5 km north towards the MacKay Lake staging area. Also it would serve as a main camp location.

3.6.1.1.3.4 MacKay Lake Staging Area and Main Camp

MacKay Lake (PI 81), at kilometre 486 with coordinates of N7079935 and E515705, would serve as a staging area and main camp for the line section 17.5 km south towards the Snap Lake staging area and 58.5 km north towards the Ekati staging area.

3.6.1.1.3.5 Ekati Staging Area and Main Camp

Ekati would serve as a major staging area for the substation and the line section 58.5 km south towards MacKay Lake staging area and 17 km south towards Diavik. It would also serve as a main camp location.

3.6.1.1.4 Ekati to Diavik – 33 kV at 69 kV

Construction access and accommodations for this section are similar to the Baseline Option.

3.6.1.1.5 Snap Lake to Gahcho Kué Section – 94 km at 69 kV

Construction access and accommodations for this section are similar to the Baseline Option.

3.6.1.2 Clearing

Clearing will be required from Twin Gorges to PI 69 for an estimated line length of 404 km. The construction methodology for clearing is the same as that described for the Baseline Option.

3.6.1.3 Temporary Access Trails

The construction methodology for temporary access trails is the same as that described for the Baseline Option.

3.6.1.4 Foundation Construction

The construction methodology for Foundation Construction is the same as that described for the Baseline Option.

3.6.1.5 Structure Assembly

The construction methodology for Structure Assembly is the same as that described for the Baseline Option.

3.6.1.6 Structure Erection

The construction methodology for Structure Erection is the same as that described for the Baseline Option.

3.6.1.7 Conductor Installation

The construction methodology for Conductor Installation is the same as that described for the Baseline Option.

3.6.1.8 Substations

The construction methodology for Substations is the same as that described for the Baseline Option.

3.6.1.9 Schedule

The project schedule is shown in Figure 3-22 and Figure 3-23. The transmission line and substation construction schedules for the Trans-Island Option are based on the same parameters as those for the Baseline Option.

3.6.1.9.1 Transmission Lines

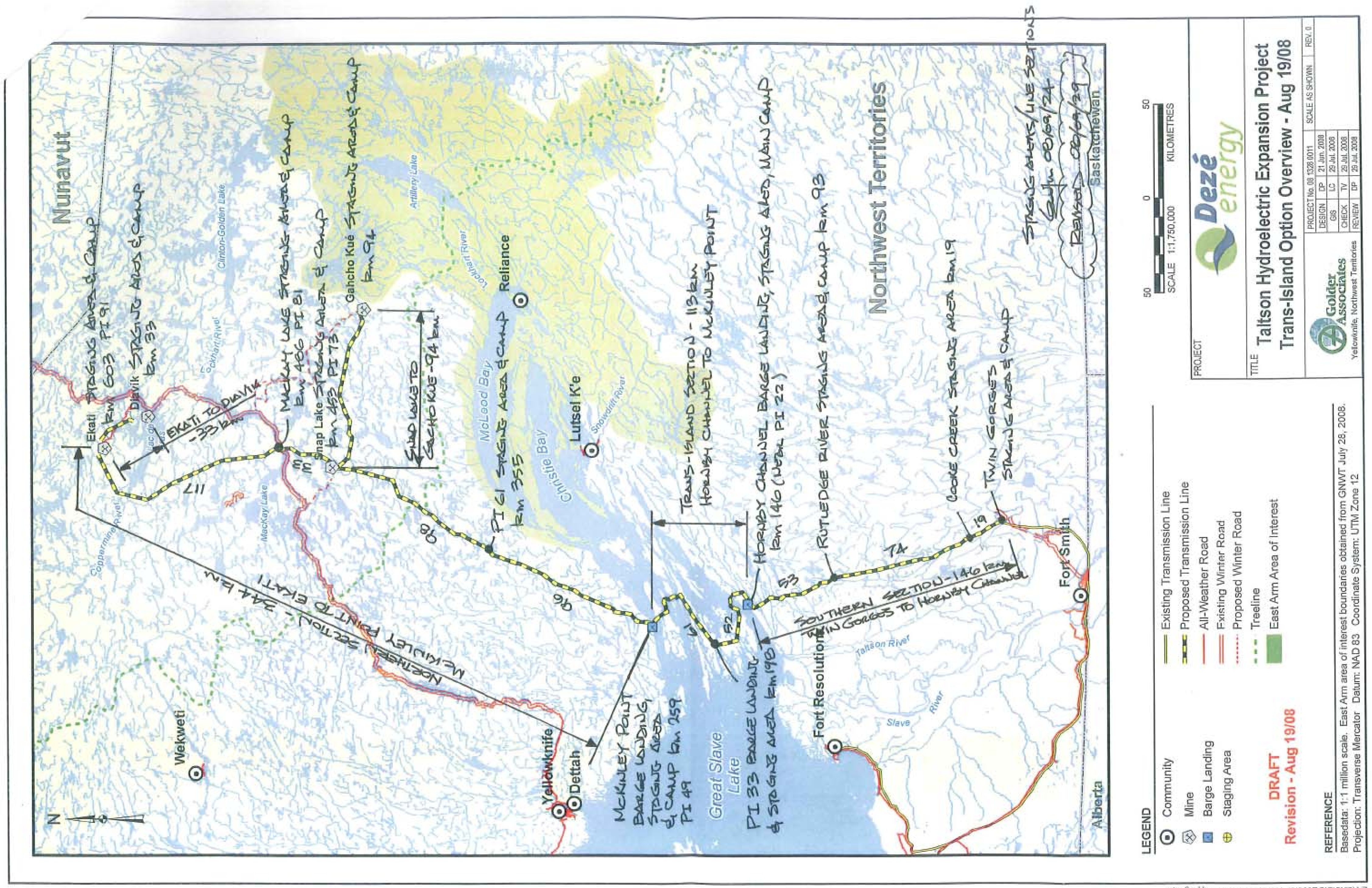
The transmission line schedule for the Trans-Island Option is based on the estimated production rates and construction seasons listed in the construction methodology and the availability of the winter roads as stated above. With a construction start in October 2009, the estimated completion date is November 2011.

3.6.1.9.2 Substations

The schedule for substations in the Trans-Island Option is the same as that for the Baseline Option.

3.6.1.9.3 Material and Construction Cost Estimates

The material and construction cost estimates for the Trans-Island Option are based on the same parameters as those for the Baseline Option, with only the quantities changing.



Staging areas for construction of theTrans-Island option
Figure 3-21

3.7 COST ESTIMATE

The cost estimates developed in this report are high level, with accuracy level in the range of -25% to +40%. Components included in the cost estimate are listed in the Table 2-23.

The cost estimates do not include contingencies and taxes and are based on 2008 prices. Material and construction costs are based on current market conditions and recent bids. Wherever possible, at least two suppliers were contacted for material budget price information. Most of the suppliers validated the price for the period of two to three months. Guyed Y lattice-steel tangent structures and guyed two and three-mast latticed-steel angle and dead-end structures were assumed for this estimate, as proposed in the January 2005 IHI report. A span of 335 m was assumed for calculating the total structure quantity. Based on the geotechnical report, it was assumed that 85% of the structures will be on rock foundations, and the remaining 15% will be on soil foundations.

The cost estimate does not include the cost of bonds, insurances, taxes, land acquisition and easement, environmental assessment and monitoring. The cost of forestry practices such as timber cruises, salvaging merchantable timber, stumpage fees and credit for timber fees is not included. Construction costs include the estimate for the labour including project management, safety personnel, equipment, fuel and camps. Construction cost has been escalated for the remoteness of the region.

The cost of right of way clearing includes labour, equipment and fuel. The clearing assumes the use of mechanized or hand slashing of trees and other vegetation. The average right of way width was assumed to be 20 m.

The cost of access includes the construction and maintenance of temporary trails along the line and to and from the staging areas during the transmission line construction period. Access cost includes the construction and maintenance of the winter roads made exclusively for the purpose of this project.

The cost of Owner's Administration and Allowance for Funds Used During Construction (AFUDC/IDC) are not considered in this cost estimate.

The cost estimate for the land portion of the Trans-Island Alternative is based on per kilometre cost calculated from Baseline Option, for various types of terrain. Assumptions for the terrain type were based on field observations of the Baseline route and Trans-Island route, carried out in July and August 2008, respectively.

Cost estimates for the land portion of the Submarine Cable Alternative and West Route Alternative are based on per kilometre average cost calculated for the full length of the Baseline Option. This average cost was applied over the full length of the two alternatives.

The costs of the submarine cable portions of the Trans-Island and Submarine Cable Alternatives were based on the following assumptions:

a) Cable for the Submarine crossing is 3 conductor, 240 mm^2 alum. conductors, XLPE insulation, lead alloy sheath, PE jacket, single layer armour;
b) Cable for Trans-Island crossings is 3 conductor, 240 mm^2 alum. conductors, XLPE insulation, lead alloy sheath, PE jacket, double layer armour;
c) Submarine crossing is 61 km long, 100 m deep;
d) Trans-Island crossing has two segments of 5 and 2.5 km long, max 320 m deep;
e) Cable is supplied from a cable factory in Asia or Europe and shipped to Tuktoyaktuk by freighter;
f) Cable is transferred from a freighter at anchor offshore Tuktoyaktuk to barge(s) suitable for cable laying;
g) Two barges and two cable lengths are required for submarine crossing to accommodate river navigation; one barge is adequate for Trans-Island crossings;
h) Cable barge(s) taken up McKenzie River and into Great Slave Lake by tugboats and fitted for cable laying;
i) Suitable barges and tugboats are available on Great Slave Lake (Northwest Transportation);
j) For the long crossing, two cable lengths are laid, one from each shore, and joined in the middle, to accommodate limited barge size for river navigation;
k) Shipping and laying can be done in one summer season;
l) Owner's engineering, project management and permitting costs are not included;
m) No contingencies are applied;
n) Interest during construction is not included.

The cost estimate for the Trans Island Alternative is presented in Table 3-15.

The cost estimate for the Submarine Cable Alternative is presented in Table 3-16.

The cost estimate for the West Route Alternative is presented in Table 3-17.

Table 3-15
Trans-Island Alternative Cost Estimate

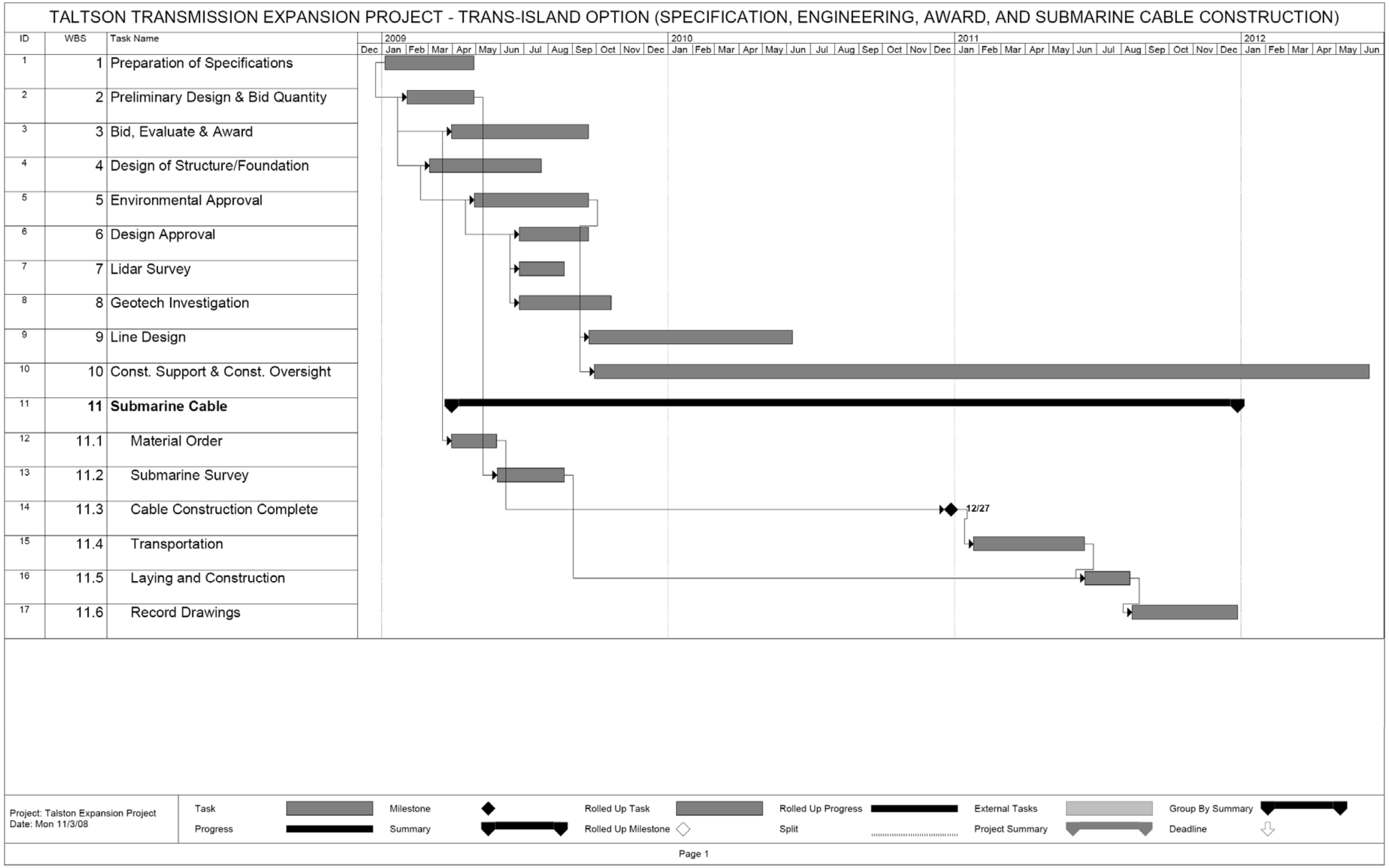
Item	Section	Section Length (km)	Price per km	Total
1	Preparation of specifications			[redacted]
2	Preliminary design & bid quantity			[redacted]
3	Lidar Survey			[redacted]
4	Ground Surveying			[redacted]
5	Geotchnical investigation			[redacted]
6	Southern section – 161 kV (Twin Gorges to Hornby Channel)	152	[redacted]	[redacted]
7	Trans-Island section – 161 kV (Hornby Channel to McKinley point)	107	[redacted]	[redacted]
8	Additional for 7 long spans on Trans-Island section		[redacted]	[redacted]
9	Northern Section – 161 kV (McKinley point to Ekati - below treeline)	145	[redacted]	[redacted]
10	Northern Section – 161 kV (McKinley point to Ekati - above treeline)	196	[redacted]	[redacted]
11	Additional for 3 rock filled steel cofferdams at MacKay Lake crossing		[redacted]	[redacted]
12	Ekati to Diavik – 69 kV (33 km)	32	[redacted]	[redacted]
13	Gahcho Kué to Snap Lake – 69 kV (94 km)	92	[redacted]	[redacted]
14	Material cost for substation			[redacted]
15	Construction cost for substation			[redacted]
16	Material and construction cost of two submarine cables (5 km and 2.5 km)			[redacted]
17	Engineering and line design			[redacted]
18	PLC communication			[redacted]
19	Lightening protection of three spans from substations			[redacted]
20	Construction support			[redacted]
	Total			[redacted]
21	Contingency at 15%			[redacted]
	Total including contingency			[redacted]

Table 3-16
Submarine Cable Alternative Cost Estimate

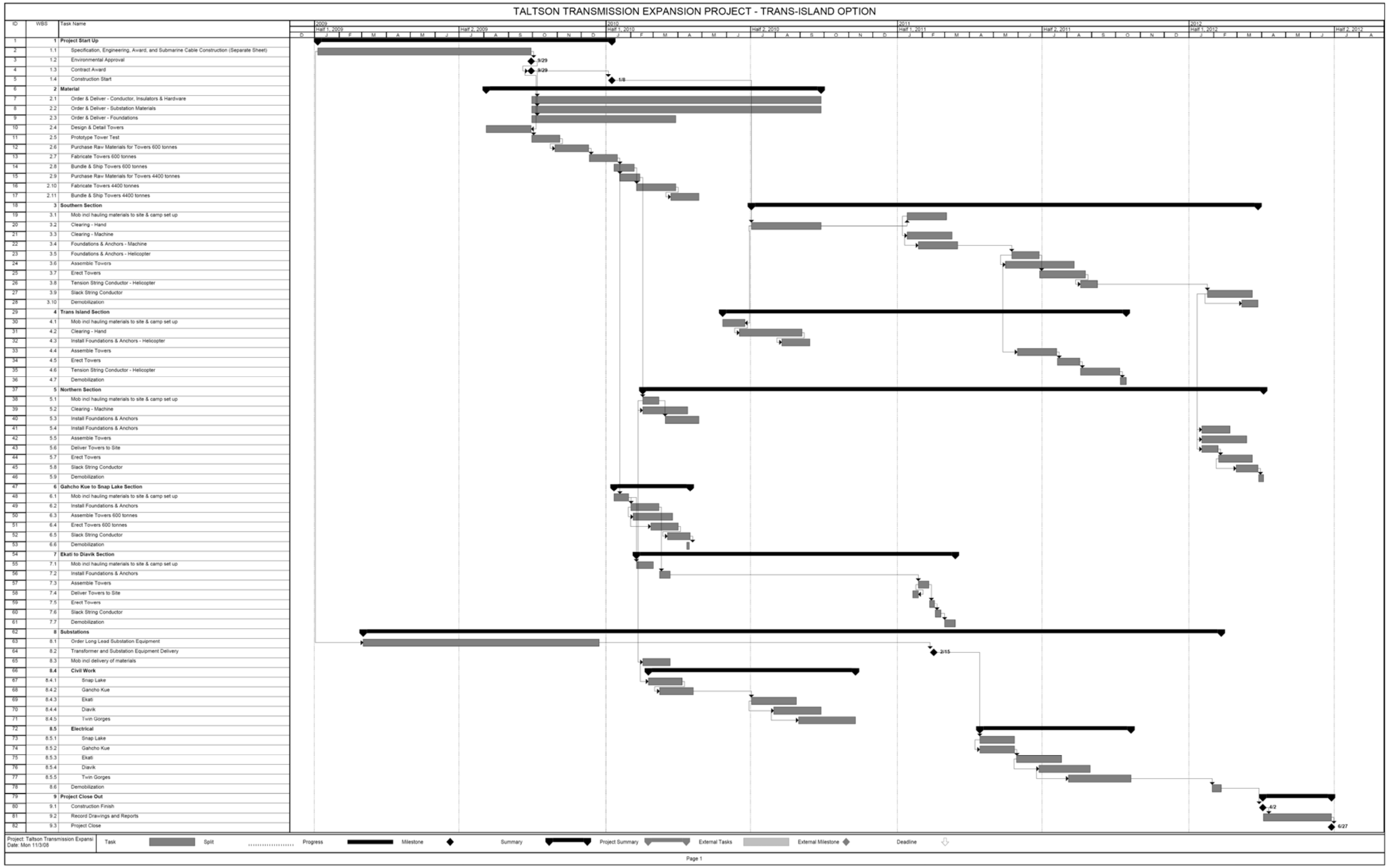
Item	Section	Section Length (km)	Price per km	Total
1	Preparation of specifications			[redacted]
2	Preliminary design and bid quantity			[redacted]
3	Lidar survey			[redacted]
4	Ground surveying			[redacted]
5	Geotchnical investigation			[redacted]
6	Total section of the 161 kV line- (Twin Gorges to Ekati)	541	[redacted]	[redacted]
7	Additional for 7 long spans on Trans-Island section		[redacted]	[redacted]
8	Additional for 3 rock filled steel cofferdams at MacKay Lake crossing		[redacted]	[redacted]
9	Ekati to Diavik – 69 kV (33 km)	32	[redacted]	[redacted]
10	Gahcho Kué to Snap Lake – 69 kV (94 km)	92	[redacted]	[redacted]
11	Material cost for substation			[redacted]
12	Construction cost for substation			[redacted]
13	Material and construction cost for submarine cable (61 km long)			[redacted]
14	Engineering and line design			[redacted]
15	PLC Communication			[redacted]
16	Lightning protection of three spans from substations			[redacted]
17	Construction support			[redacted]
	Total			[redacted]
18	Contingency at 15%			[redacted]
	Total including contingency			[redacted]

Table 3-17
West Route Alternative Cost Estimate

Item	Section	Section Length	Price per km	Total
1	Preparation of specifications			[redacted]
2	Preliminary design and bid quantity			[redacted]
3	Lidar survey			[redacted]
4	Ground surveying			[redacted]
5	Geotchnical investigation			[redacted]
6	Total section of the 161 kV line- (Twin Gorges to Ekati)	1120	[redacted]	[redacted]
7	Additional for 7 long spans on Trans-Island section		[redacted]	[redacted]
8	Additional for 3 rock filled steel cofferdams at MacKay Lake crossing		[redacted]	[redacted]
9	Ekati to Diavik – 69 kV (33 km)	32	[redacted]	[redacted]
10	Gahcho Kué to Snap Lake – 69 kV (94 km)	92	[redacted]	[redacted]
11	Material cost for substation			[redacted]
12	Construction cost for substation			[redacted]
13	Engineering and line design			[redacted]
14	PLC communication			[redacted]
15	Lightning protection of three spans from substation			[redacted]
16	Construction support			[redacted]
	Total			[redacted]
17	Contingency at 15%			[redacted]
	Total including contingency			[redacted]



Schedule Specification, Engineering , Contract Award and Submarine Cable construction for Trans-Island Option
Figure 3-22



Construction Schedule for Trans-Island Option
Figure 3-23

4 RECOMMENDATIONS FOR FUTURE WORK

The proposed transmission alternatives are technically demanding due to the length of the line and extreme climatic conditions. It is recommended that additional investigation is carried out in the following areas before writing the equipment specification, regardless which option is selected as most favourable.

- **Lightning performance:** Lightning performance of the line is the main component of the line and whole system reliability. Due to the length of the line (exposure to lightning) and inability to apply standard lightning protection due to the high ground resistivity, the expected flashover (line-to-ground fault) rate is significant. Measures to limit the number of outages have to be investigated, such as installation of line arresters, and single pole re-closure.

- **Line Insulation Coordination**: A study should be done to assess the parameters that will have an impact on the insulation performance of the lines. This will include an evaluation of the insulation system for steady state conditions, lightning and switching performance. In order to achieve the desired power transfer on the transmission line, it might be compensated with the series capacitors which its insulation should be considered in steady state as well as transient conditions.

- **Station/equipment Insulation Coordination**: Insulation coordination is necessary for the substations and equipment like power transformers, shunt reactors, current and potential transformers, breakers and switches. The insulation coordination and overvoltage protection of series capacitive banks is required as well.

- **Single Pole Reclosing:** Considering the high probability of faults and the fact that a lot of those events are single line to ground faults, having the single pole reclosing will increase the availability of the transmission line. However to have a successful reclosing some components like neutral reactors might be required. EMTP studies are necessary to have an accurate assessment.

- **Transmission Line Energization:** Due to the length of the line, there is a risk of resonance overvoltages at the time of line energization which may result in a flashover. EMTP studies will show the flashover rate and if the value is more than the rates suggested by the standards then mitigation methods should be considered.

- **Switching and resonance studies:** Due to the length of the line, there is a risk of resonance overvoltages during the non-symmetrical operation of the line (single pole re-closure, or stuck breaker pole). The same non-symmetrical operation may impose use of neutral reactors in the neutral points of the shunt reactors.

- **Transient recovery voltage studies (breakers):** Breaker TRV studies will have to be carried out to determine the highest value of TRV and whether mitigation measures are necessary.

- **Series and Shunt Compensation:** More detailed stability and sub-synchronous resonance (SSR) studies have to be carried out to determine interaction between series compensation (if required) and the turbine-generator mass. The location and size of the series and shunt compensation should be optimized.

- **Contingency studies:** System studies that will determine survivability of the system (after-fault condition of the network) are necessary, due to the high expected fault rate. Outage of the highest load or generator should not cause collapse of the whole network. The complexity of the contingency requirements will have to be followed with more extensive communication.

- **Criteria for parallel generation:** Technical criteria for connecting generation at the location of loads (diesel) have to be developed. The interface points between the Utility and the Load must be clearly defined.

- **Impact on the existing load**: Load flow, stability and EMTP studies might be required to evaluate the impact of the new transmission line and mine load on the existing load which is supplied by the generator at Twin George

5 CONCLUSION

Four options for the Taltson Transmission Expansion were evaluated in this report, based on the following criteria. The results of the assessment shown Table 5-2 indicate that the Baseline option is the most favourable.

- **Technical feasibility:** System studies performed show that all four alternatives are technically feasible. The West Route alternative, due to its length, is at the limit of feasibility. Issues with dynamic performance of the series compensation are likely to occur, due to the high expected single fault-to-ground rate. The Baseline Option is the most technically feasible option.

- **Complexity of required equipment:** All of the transmission options require shunt compensation and SVC at the load side. The West Route Option requires three intermediate stations for series compensation and switched capacitor banks. The Submarine Cable and Trans-Island options require cable termination stations, where the shunt reactors can be incorporated. All of the shunt reactor compensation required for the Baseline Option can be placed on the high voltage sides of the mine substations.

- **Constructability:** For the Trans-Island Option there will be two submarine cable crossings required to cross Hearne Channel and the channel between Blanchet and Seaton Islands. Due to the depth of Great Slave Lake, these would be some of the deepest cable crossings in the world. The window for cable crossing construction will be only two to three months per year. The three alternative routes cross over the MacKay crossing using three islands in the lake. This will require construction of rock-filled steel coffer dams around the towers for ice protection.

- **Operational cost (line losses):** Operational cost of the West Route will be the highest among all the alternatives, due to its length. The other three alternatives are equally favourable in terms of losses.

- **Clearing required (footprint of the line):** The West Route Option will require more clearing compared to other options, as about 75% of the line is below the tree line. No need for clearing is foreseen above the tree line.

- **Visual impact of the line:** Crossing the Great Slave Lake over a series of islands with an overhead line creates significant environmental impact in this environmentally sensitive region. Similarly to MacKay Lake crossings, the three alternatives will cause significant visual impact.

- **Terrain and soil variability:** The terrain for all the options considered is mostly rocky, which will enable easier and faster construction. However, the West Route Option passes through many marshy areas that may require special design and heavier foundation types. There is no information available regarding the configuration of the lake bottom which increases the risk for the Trans-Island and Submarine cable options.

- **Construction access:** The transmission lines are located in remote areas, and access for the majority of the transmission line is by winter roads. The West Route Option requires more access roads due to its length, which can stretch the construction schedule.
  The Baseline Option section between the Snowdrift River and the tree line is accessible for construction only by helicopter.

- **Construction schedule:** The main components that define the schedule are the availability of winter roads and electrical equipment (specifically transformers) long delivery time, which could be up to 24 months. The transformers must be ordered in the early months of 2009, so they can be hauled on site and installed in 2011. The schedule of the Trans-Island and Submarine Cable options are additionally constrained by the cable long delivery time, which is in the range of 18 months. The cable must be ordered mid 2009, so it could be shipped in the winter 2010/2011, and then barged through MacKenzie River and installed in the summer 2011. This is realistic schedule for the Trans-Island option, due to the short cable length. Cable installation for the Submarine Cable option will require more vessels to lay the cable. The duration of installation season is generally very short and uncertain. For the Submarine Cable option it would be realistic to expect that the cable installation may not be completed before the end of summer 2012.

- **Construction logistics:** Considering the transmission line length and remoteness of the location, construction of the line will be dependent on availability of winter roads. At some stretches, helicopter construction will be necessary. The staging areas have been selected to suit these requirements. The supply of the material to the site will have to be carefully planned and synchronized with the availability of winter roads. Special consideration will have to be given for shipment of heavier equipment, such as transformers and cables.

- **Cost of the line and substation equipment:** High level cost estimates were developed for all four alternatives based on budgetary prices obtained from the equipment and material suppliers, current market conditions and recent bids. The cost estimates are presented in the Table 5-1. Due to line length and complexity of the equipment, the West Route Alternative is the most expensive. The cost of the cables makes the Submarine Cable and Trans-Island Options more expensive than the Baseline Option.

- **Maintainability of the line and associated equipment:** Maintenance could be a serious issue for a project of this size in northern regions. We think that the maintenance efforts are proportional to the length of the line and complexity of the equipment. Equipment for the West Route is very complex, thus skilled staff will be required for maintenance. There will be additional maintenance requirements for the coffer dams for the three alternative routes that cross MacKay Lake.

- **Reliability of the line and associated equipment:** A significant number of line-to-ground faults is expected due to lightning strikes to the line and climatic conditions. Ground faults are proportional to the length of the overhead portions of the lines. For the West Route, these ground faults will stress the series capacitors' insulation, eventually causing their failure and outage of the whole scheme. Cables will also have significant effect on the reliability of the scheme. Outage of a cable, especially for the Submarine Option, will cause long service outages, possibly exceeding six months, depending on the season when the outage happened. To improve reliability, mitigation measures must be considered for line-to-ground faults. Some of these measures are single phase re-closure, and/or installation of surge arresters along the line. However, more detailed studies must be performed due to the risk of resonant overvoltages.

Table 5-1
Summary of Cost Estimates

Option	Length (km)	Estimated Cost in 2008 CAD
Baseline	693	[redacted] Ø
Trans-Island	731	[redacted] +40 M
Submarine Cable	726	[redacted] +50 M
West	1244	[redacted] +220 M

Table 5-2
Evaluation of the Transmission Alternatives

Criterion	Baseline	Trans-Island	Submarine	West Route
Technical feasibility				
Number of substations and equipment required				
Footprint of line (clearing required)				
Visual impact of line				
Terrain variability (foundations)				
Construction access issues				

Table 5-2
Evaluation of the Transmission Alternatives

Criterion	Baseline	Trans-Island	Submarine	West Route
Construction schedule/duration				
Logistics and logistical risk in construction				
Basic cost of line				
Contingencies				
Operation cost (line losses)				
Maintainability				
Reliability				

Legend:

Not Recommended
The Least Favorable Option
Less Favorable Option
Favorable Option

6 APPENDICES

The following appendices are part of this document:

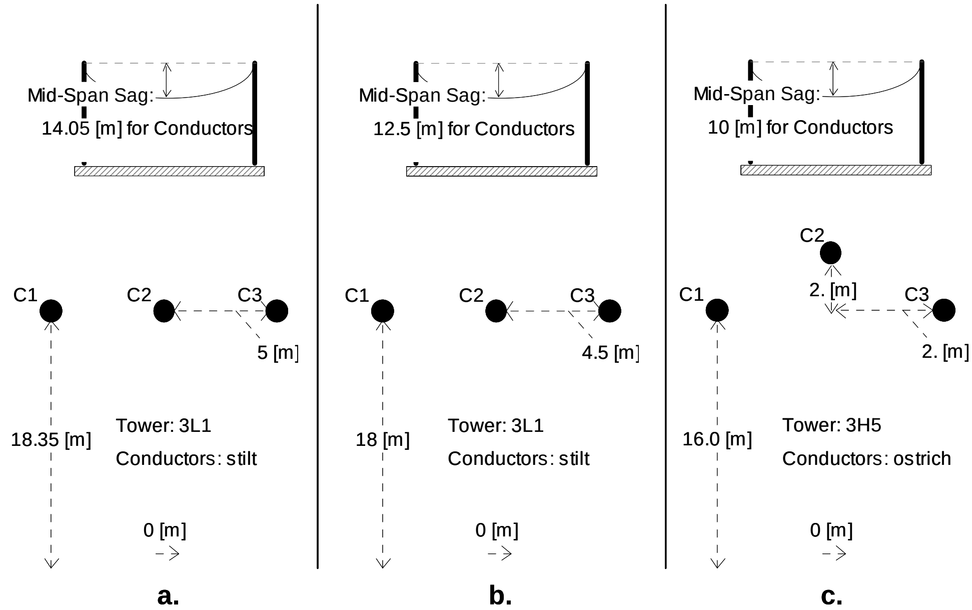
APPENDIX A:	POWER-FLOW AND DYNAMIC DATA
APPENDIX B:	PSS/E SIMULATION RESULTS
Appendix C:	FOUNDATION TYPES
Appendix D:	ELECTROMAGNETIC FIELD EFFECTS
Appendix E:	BASELINE SUBSTATION LAYOUTS, OPTION 1
Appendix F:	BASELINE SUBSTATION LAYOUTS, OPTION 2
Appendix G:	BASELINE SUBSTATION LAYOUTS, OPTION 3
Appendix H:	TRANS-ISLAND OPTION SUBSTATION LAYOUTS
Appendix I:	LIDAR SURVEY SPECIFICATION

VOLUME 2

Appendix J:	ROUTE MAPS – BASELINE OPTION (Volume 2)
Appendix K:	ROUTE MAPS – TRANS-ISLAND OPTION (Volume 2)
Appendix L:	ROUTE MAPS – SUBMARINE CROSSING OPTION (Volume 2)
Appendix M:	ROUTE MAPS – WEST ROUTE OPTION (Volume 2))

APPENDIX A

POWER-FLOW AND DYNAMIC DATA



Towerhead Configuration for: (a) 161 kV lines, (b) 115 kV lines, (c) 69 kV and 72 kV lines
Figure 6-1

Table 6-1
Existing Transmission System Voltage Rating and Length

Transmission line	Line voltage (kV)(1)	Line length (km) (1)	Line resistance (pu)	Line reactance (pu)	Line susceptance (pu)
Twin Gorges - Fort Smith	115	30	0.0187	0.1079	0.0085
Fort Smith - Pine Point	115	140	0.0866	0.5009	0.0397
Fort Smith - Fort Fitzgerald	115	30	0.0187	0.1079	0.0085
Pine Point - Hay River	72	90	0.4666	0.8040	0.0086
Pine Point - Fort Resolution	72	70	0.3636	0.6257	0.0067

Note:
(1) According to the Dezé Energy report except for Fort Smith - Fort Fitzgerald line for which the data assumed.

Table 6-2
New transmission system calculated parameters

Transmission Line	Line voltages (kV)	Line resistance(1) (pu)	Line reactance(1) (pu)	Line susceptance(1) (pu)
Twin Gorges - Lockhart River	161	0.0936	0.5635	0.2799
Lockhart River - Gahcho Kué	161	0.0232	0.1360	0.0651
Gahcho Kué - Snap Lake	161	0.0305	0.1787	0.0856
	69	0.5416	0.9336	0.0163
Gahcho Kué - Diavik	161	0.0537	0.3165	0.1530
Snap Lake - Ekati	161	0.0469	0.2763	0.1332
Ekati - Diavik	69	0.2266	0.3895	0.0068
Note: (1) pu values 100 MVA base				

Table 6-3
Conductor Characteristic

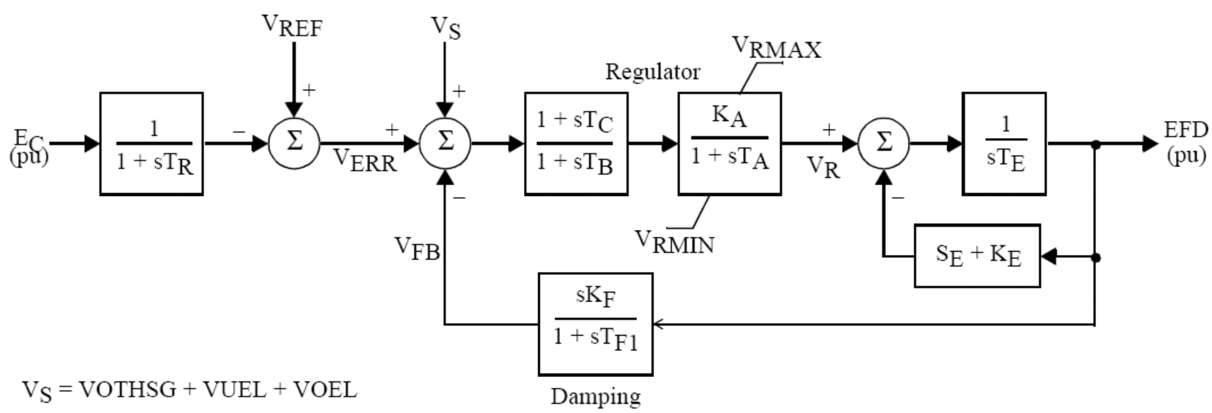
Conductor Type	Cross Section (kcmil)	DC resistance (ohm/km)	Conductor overall radius (m)
Stilt	716.0	0.08146	0.013157
Ostrich	300.0	0.269595	0.008636

Table 6-4
Generator Power Flow Data

Generator	Pmax (MW)	Pmin (MW)	Qmax (Mvar)	Qmin (Mvar)	Mbase (MVA)	R source (pu)	Xsource (pu)
Existing	18.0	0.0	0.0	-2.0	18.0	0.001	0.28
New	18.0	0.0	13.5	-7.0	22.5	0.001	0.28

Table 6-5
Generator Dynamic Data

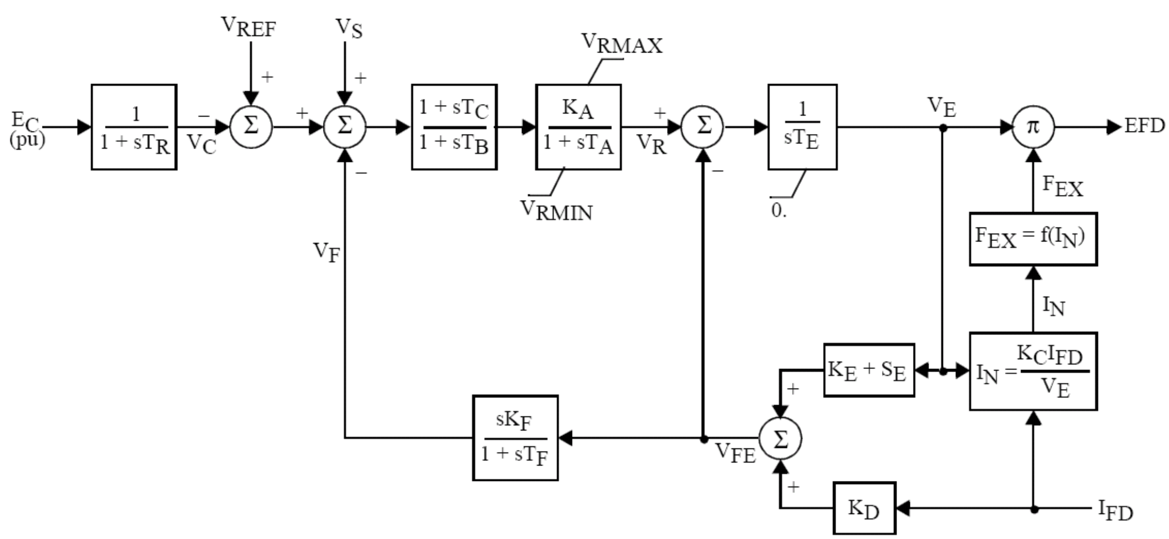
Description	Variable	Value
D-axis transient rotor time constant	T'do (>0) (sec)	1.67
D-axis sub-transient rotor time constant	T"do (>0) (sec)	0.035
Q-axis sub-transient rotor time constant	T"qo (>0) (sec)	0.035
Inertia constant, sec	Inertia, H	4.06
Damping factor, pu	Speed damping, D	2.0
D-axis synchronous reactance	Xd	0.91
Q-axis synchronous reactance	Xq	0.6
D-axis transient reactance	X'd	0.32
D-axis transient reactance	X"d = X"q	0.28
Stator leakage reactance, pu	Xl	0.188
Saturation factor at 1 pu flux	S(1.0)	0.064
Saturation factor at 1.2 pu flux	S(1.2)	1.018



Existing Exciter: PSS/E Excitation System Model IEEEX1
Figure 6-2

Table 6-6
Existing Exciter: IEEEX1 Model Data

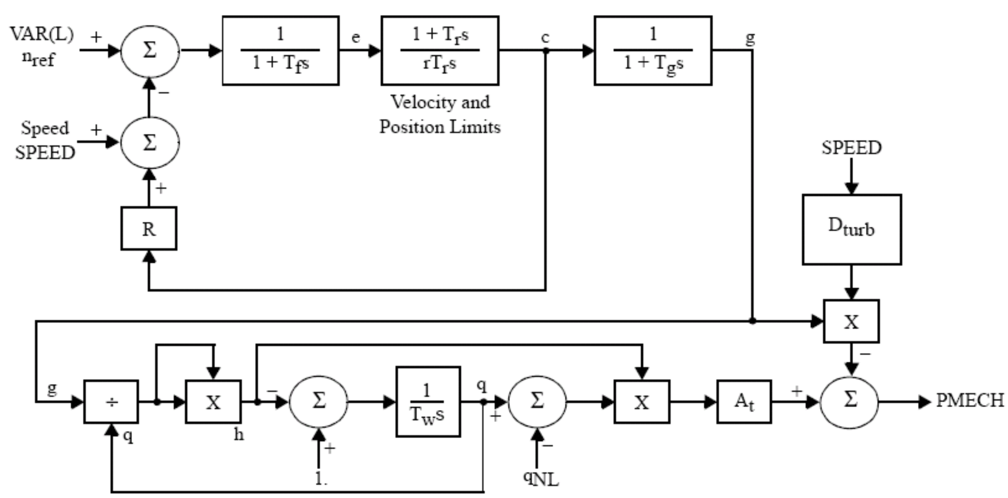
Description	Variable	Value
Filter time constant, sec.	TR	0.0
Gain, p.u.	KA	40
Time constant, sec.	TA	0.05
Lag time constant, sec.	TB	0.0
Lead time constant, sec.	TC	0.0
Maximum controller output, p.u.	VRMAX	4.12
Minimum controller output, p.u.	VRMIN	-4.112
Exciter field resistance line slope margin, p.u.	KE	-0.243
Exciter time constant, sec.	TE	0.95
Rate feedback gain	KF	0.04
Rate feedback time constant, sec.	TF1	10.0
Not used	0.	0.0
Field voltage value, 1	E1	2.25
Saturation factor at E1	SE(E1)	0.484
Field voltage value, 2	E2	3.0
Saturation factor at E2	SE(E2)	1.308



New Generation: PSS/E Excitation System Model EXAC1
Figure 6-3

Table 6-7
New Exciter: EXAC1 Model Data

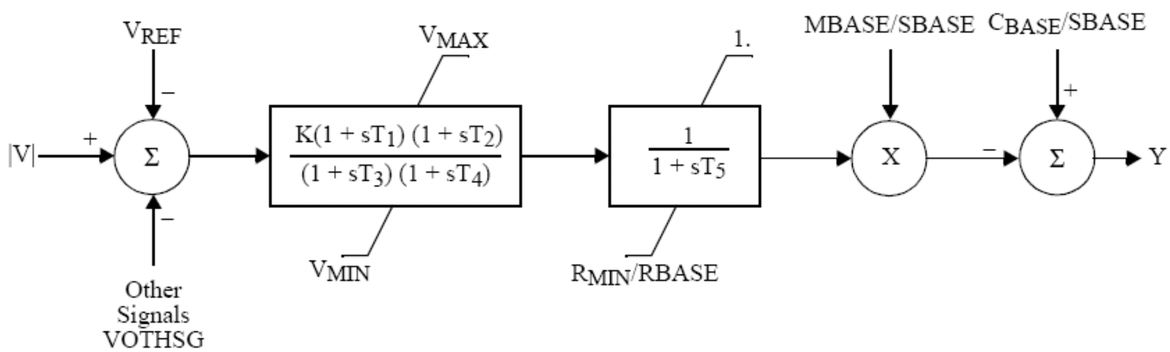
Description	Variable	Value
Filter time constant, sec.	Tr	0
Time constant, sec.	Tb	0
Time constant, sec.	Tc	0
Voltage regulator gain	Ka	400
Time constant, sec.	Ta	0.02
Maximum control element output, p.u.	Vrmax	8
Minimum control element output, p.u.	Vrmin	-8
Exciter time constant, sec.	Te	0.8
Rate feedback gain, p.u.	Kf	0.06
Rate feedback time constant, sec	Tf	1
Rectifier regulation factor, p.u.	Kc	0.2
Exciter internal reactance, p.u.	Kd	0.38
Exciter field resistance constant, p.u.	Ke	1
Field voltage value, 1	E1	3.62
Saturation factor at E1	S(E1)	0.46
Field voltage value, 2	E2	4.82
Saturation factor at E2	S(E2)	0.656



PSS/E Hydro Turbine-Governor Model HYGOV
Figure 6-4

Table 6-8
HYGOV Model Data

Description	Variable	Value
Permanent droop, p.u.	R	0.04
Temporary droop, p.u.	r	0.30
Washout time constant, sec.	Tr	5.00
Filter time constant, sec.	Tf	0.05
Gate servo time constant, sec.	Tg	0.50
Maximum gate velocity, p.u./sec.	VELM	0.20
Maximum gate opening, p.u.	GMAX	1.00
Minimum gate opening, p.u.	GMIN	0.00
Water inertia time constant, sec.	TW	1.00
Turbine gain, p.u.	At	1.20
Turbine damping factor, p.u.	Dturb	0.50
No-load flow at nominal head, p.u.	qNL	0.08



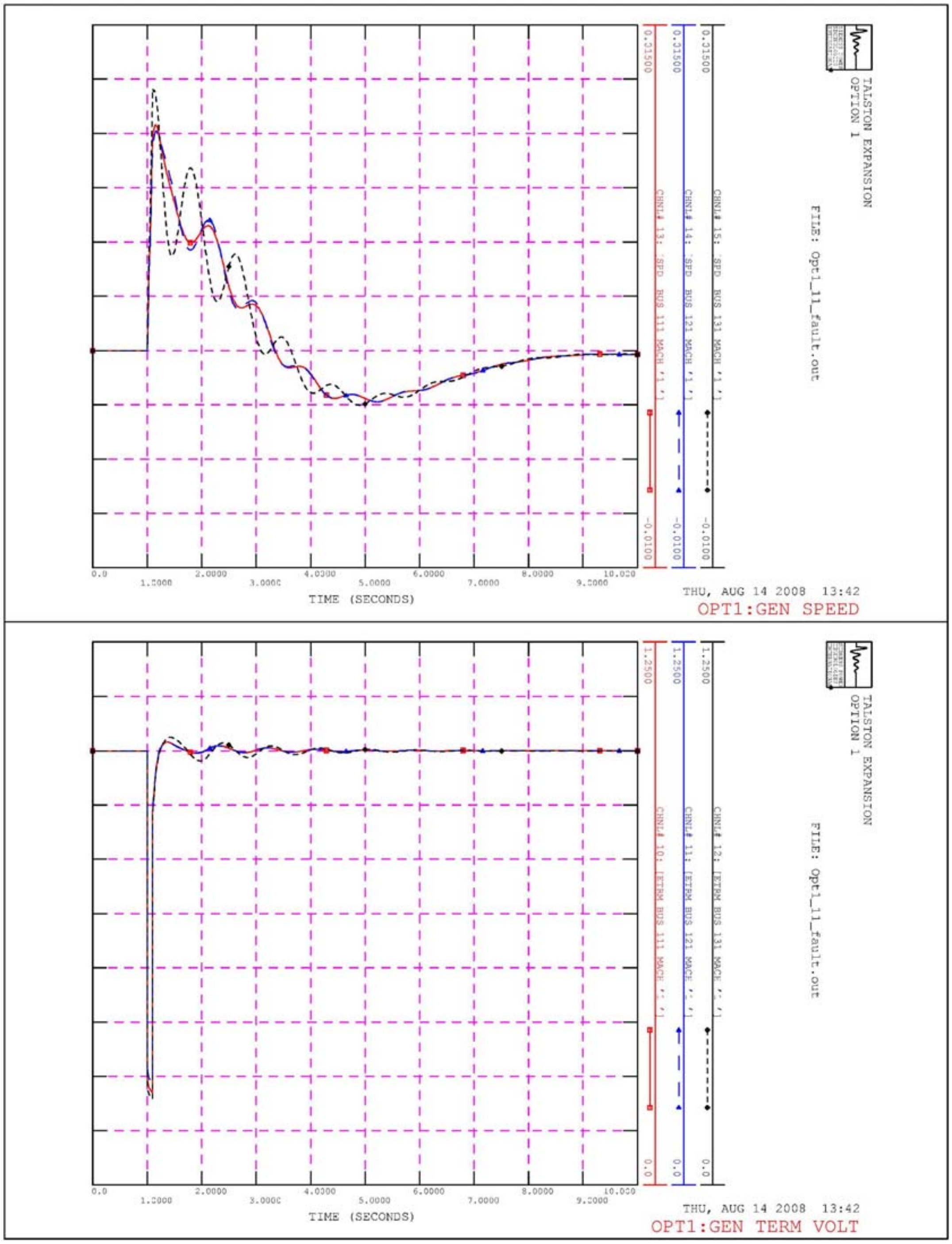
PSS/E SVC Model CSVGN1
Figure 6-5

Table 6-9
CSVGN1 Parameters

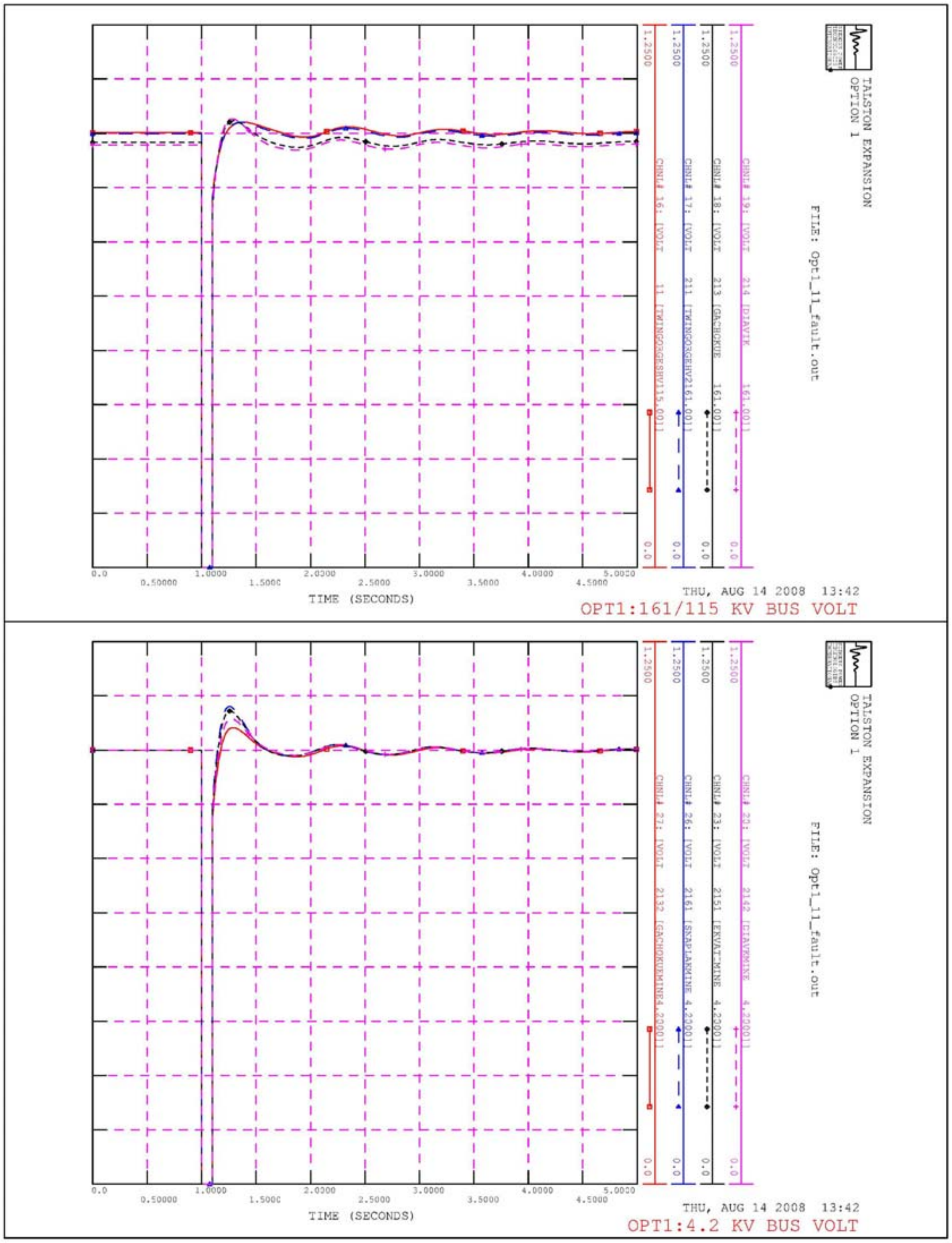
Description	Variable	Value
Steady state gain	K	100.00
Lead-lag compensator	T1	0.00
	T2	0.00
	T3 (>0)	10.00
	T4	0.00
SVC response time constant	T5	0.05
Reactor mInimum var	RMIN	0.00
Upper limit of active range	VMAX	1.00
Lower limit of active range	VMIN	0.00
Capacitor Mvar	CBASE	15.00

APPENDIX B

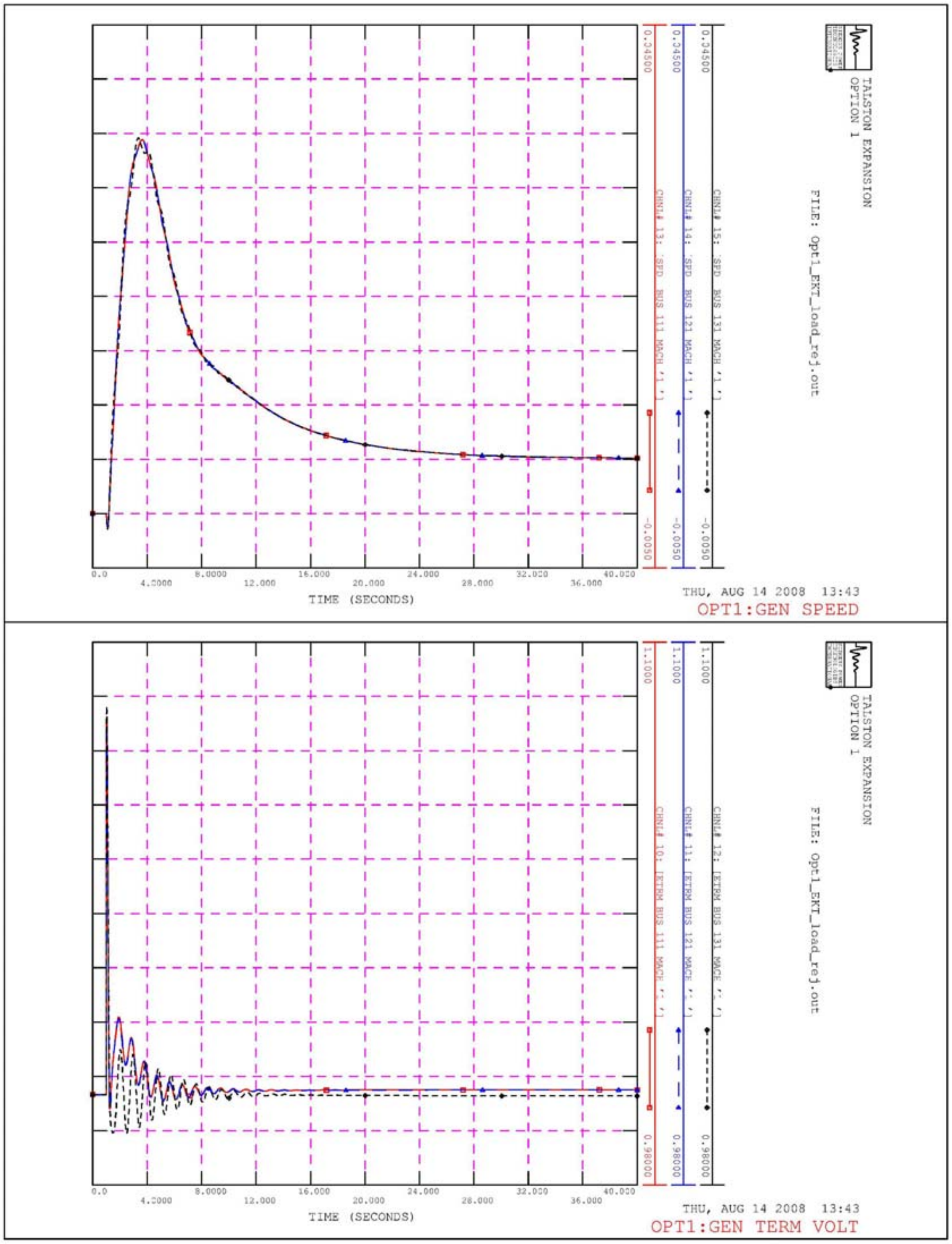
PSS/E SIMULATION RESULTS



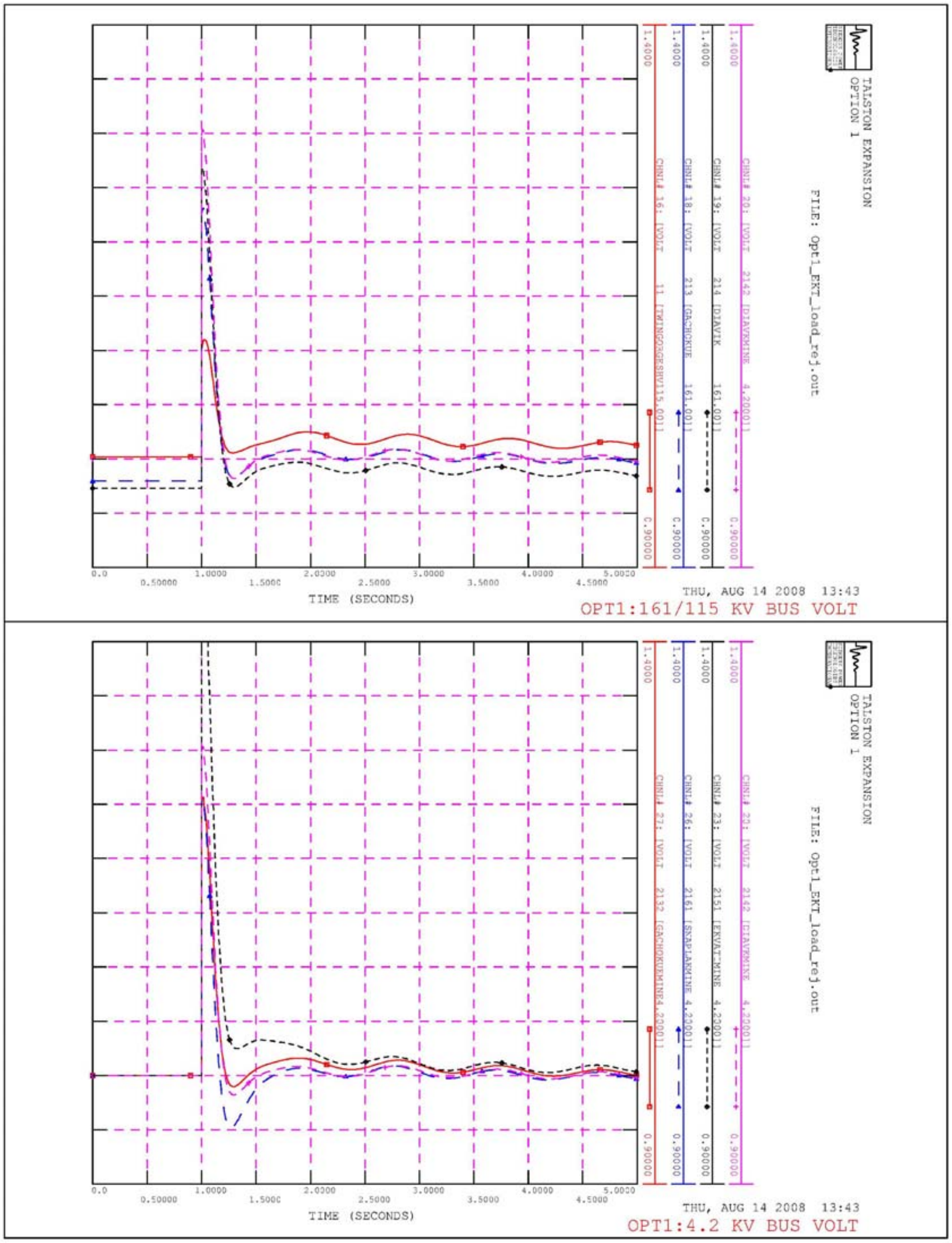
Option 1-Three Phase Fault at Twin Gorges 115 kV Bus
Figure 6-6



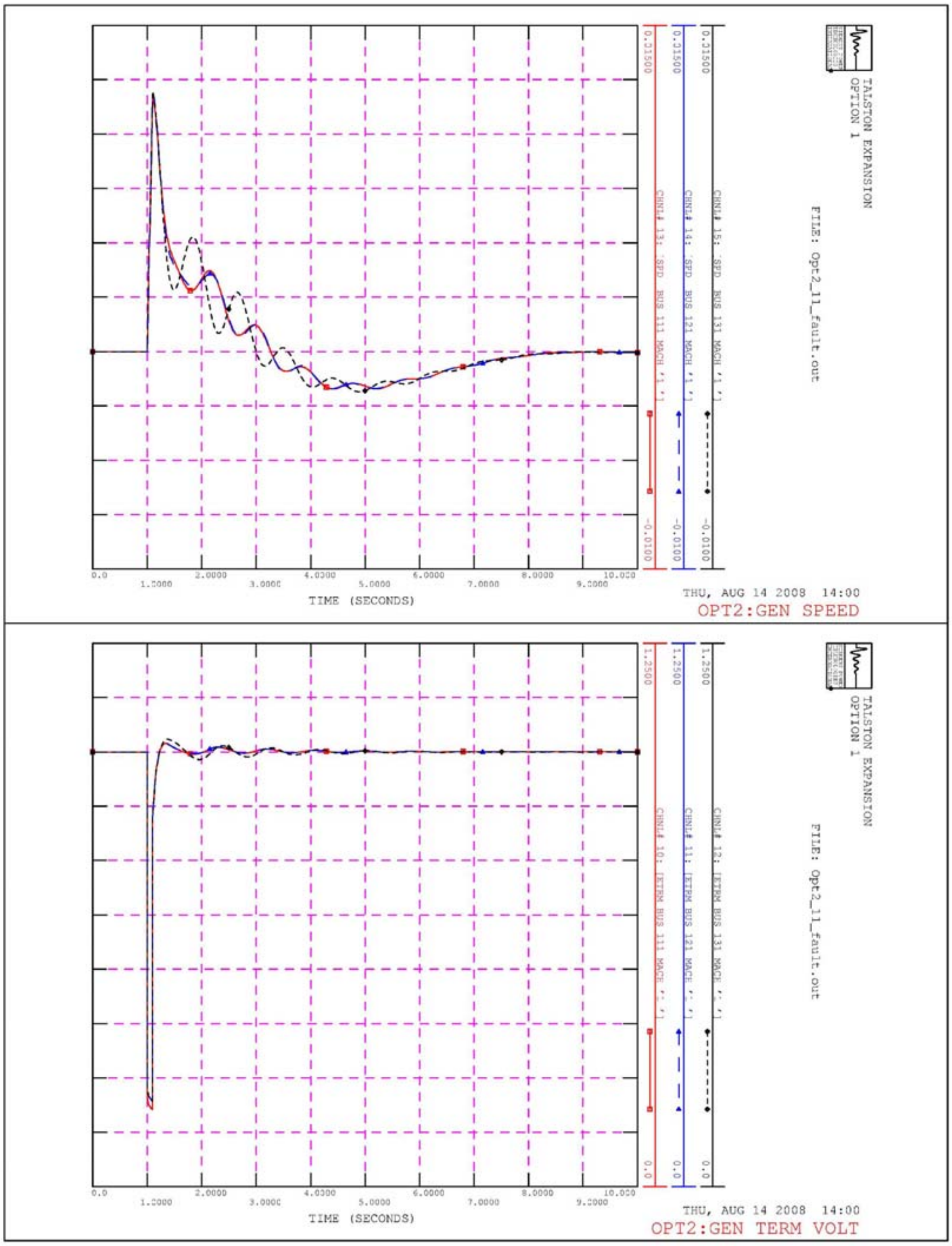
Option 1-Three Phase Fault at Twin Gorges 115 Kv Bus
Figure 6-7



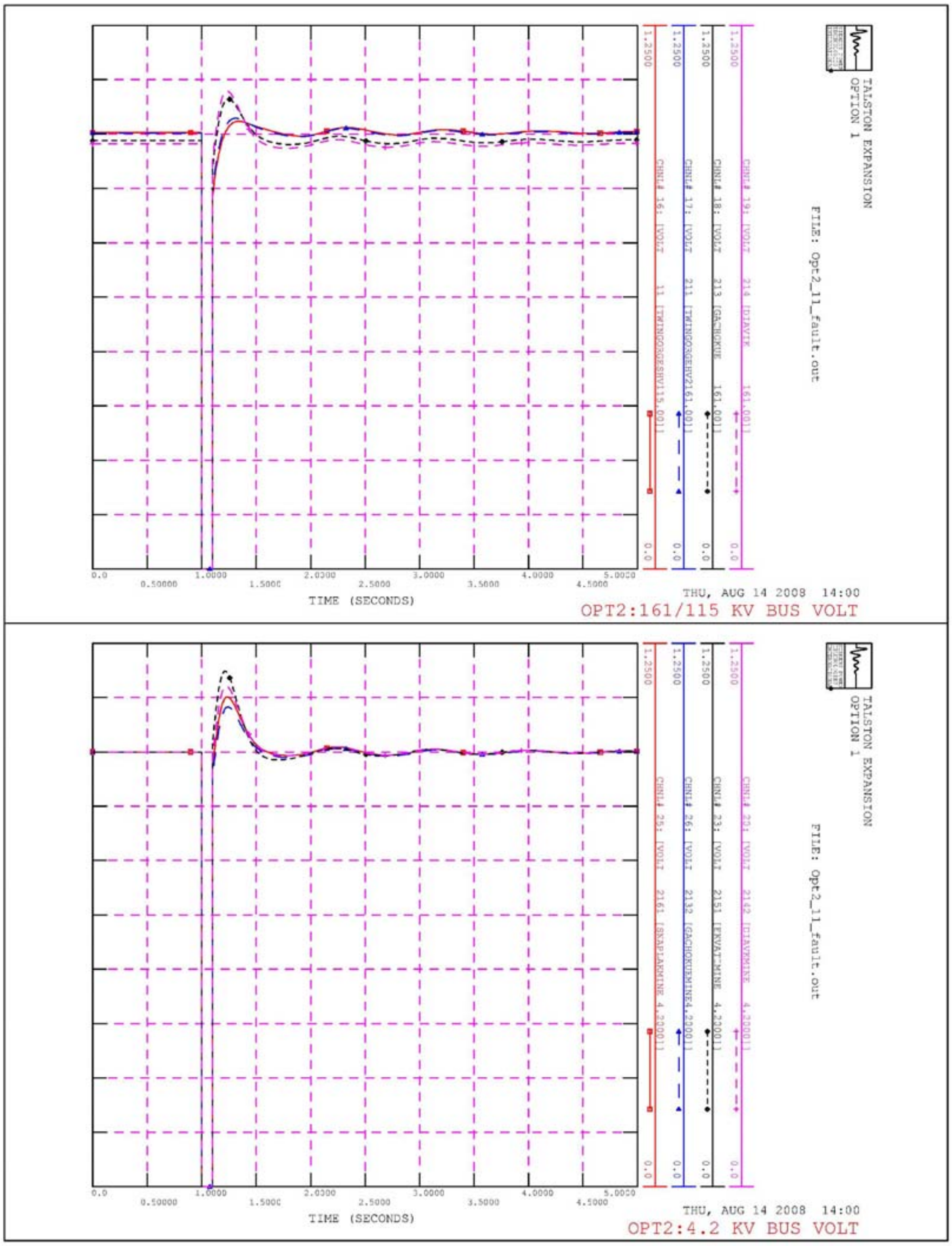
Option 1-Ekati Mine 100% Load Rejection
Figure 6-8



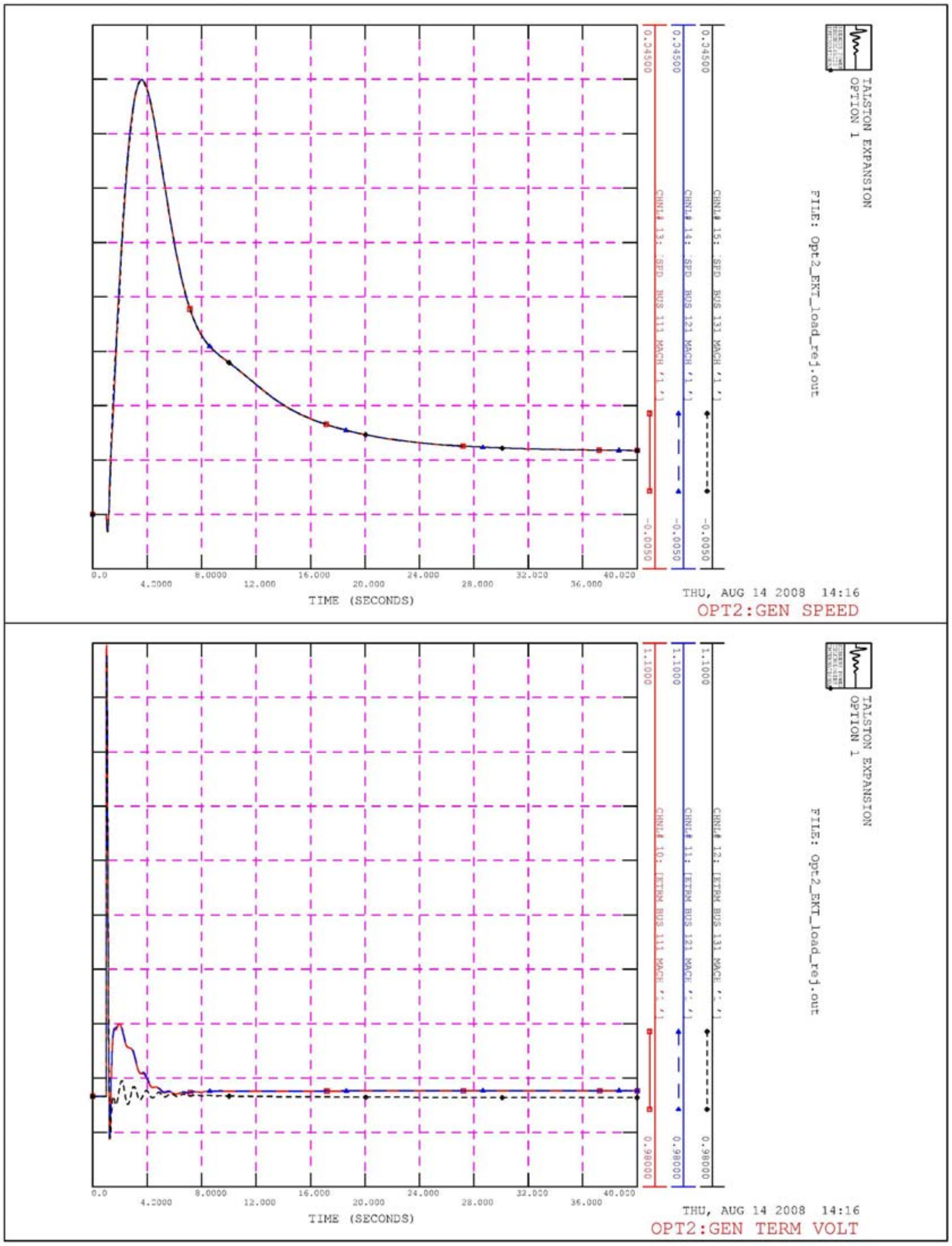
Option 1-Ekati Mine 100% Load Rejection
Figure 6-9



Option 2-Three Phase Fault At Twin Gorges 115 Kv Bus
Figure 6-10



Option 2-Three Phase Fault at Twin Gorges 115 kV Bus
Figure 6-11



Option 2-Ekati Mine 100% Load Rejection
Figure 6-12

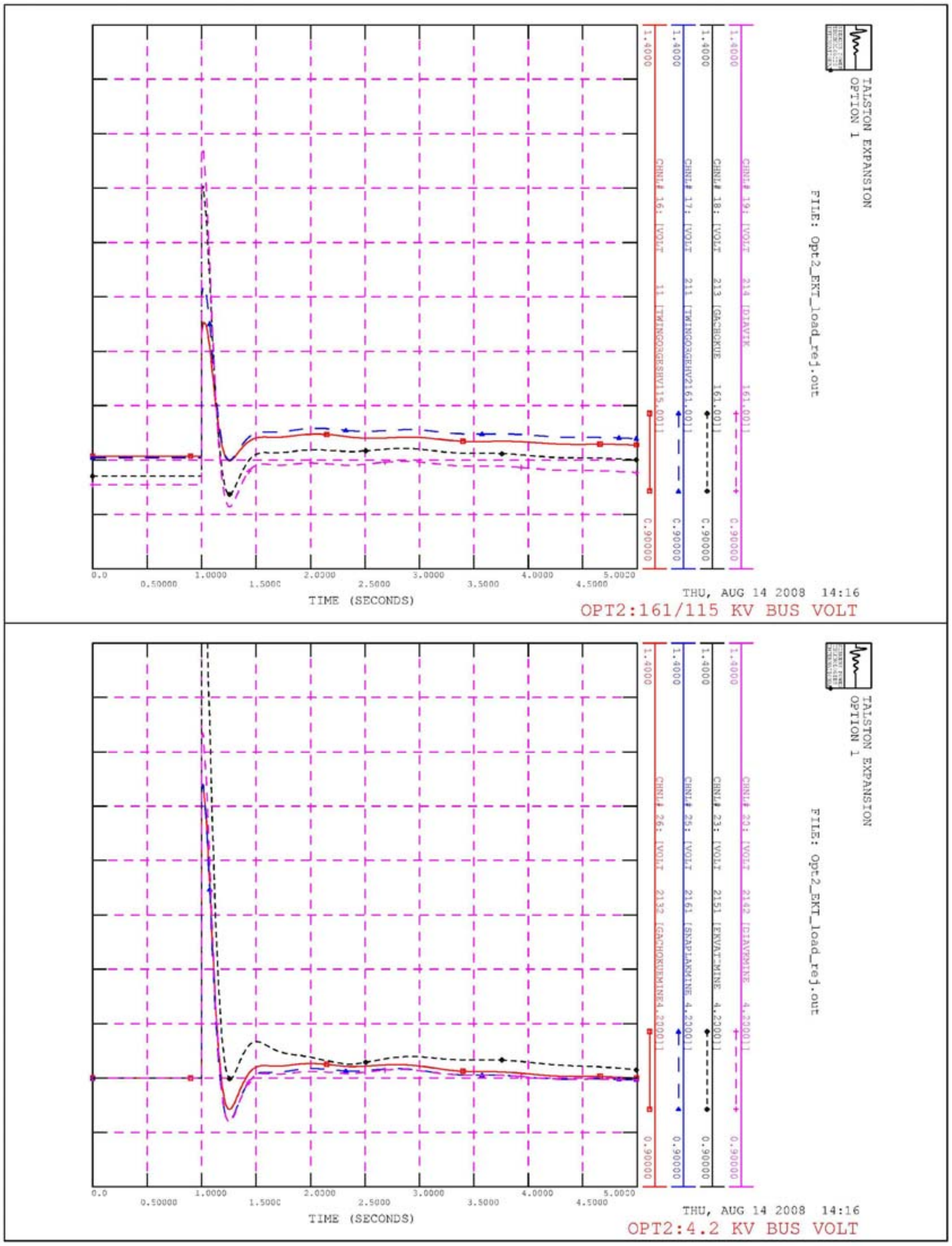
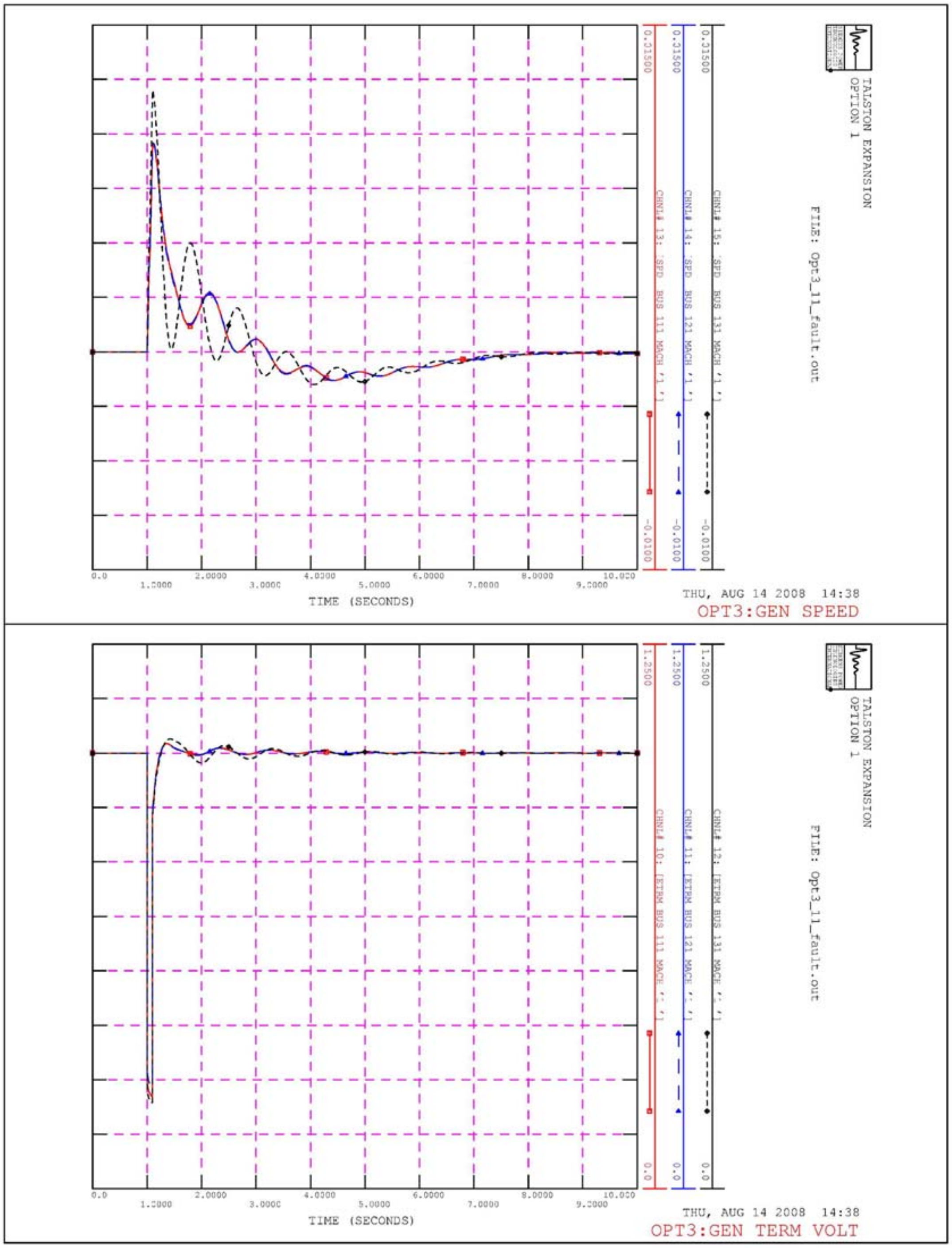
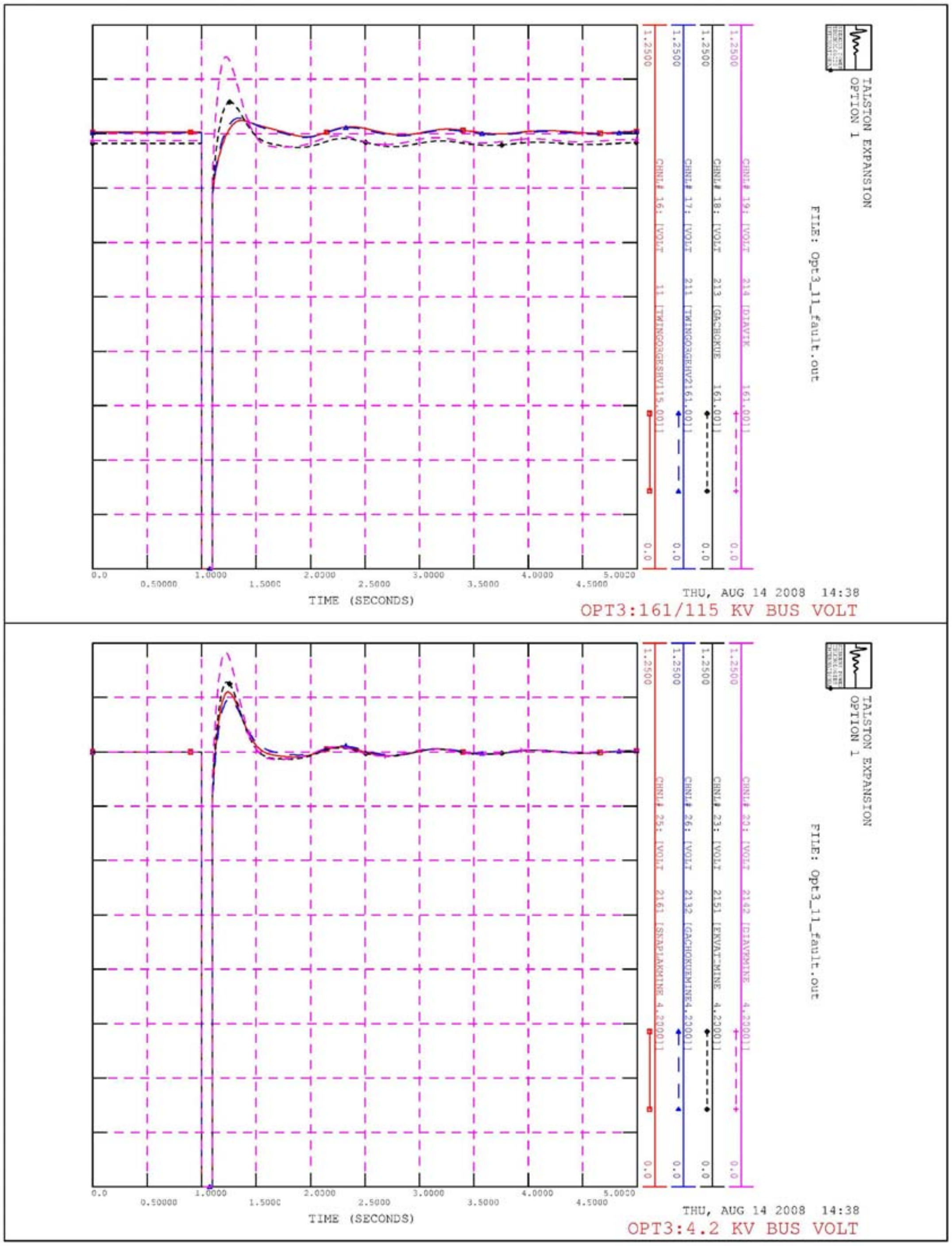


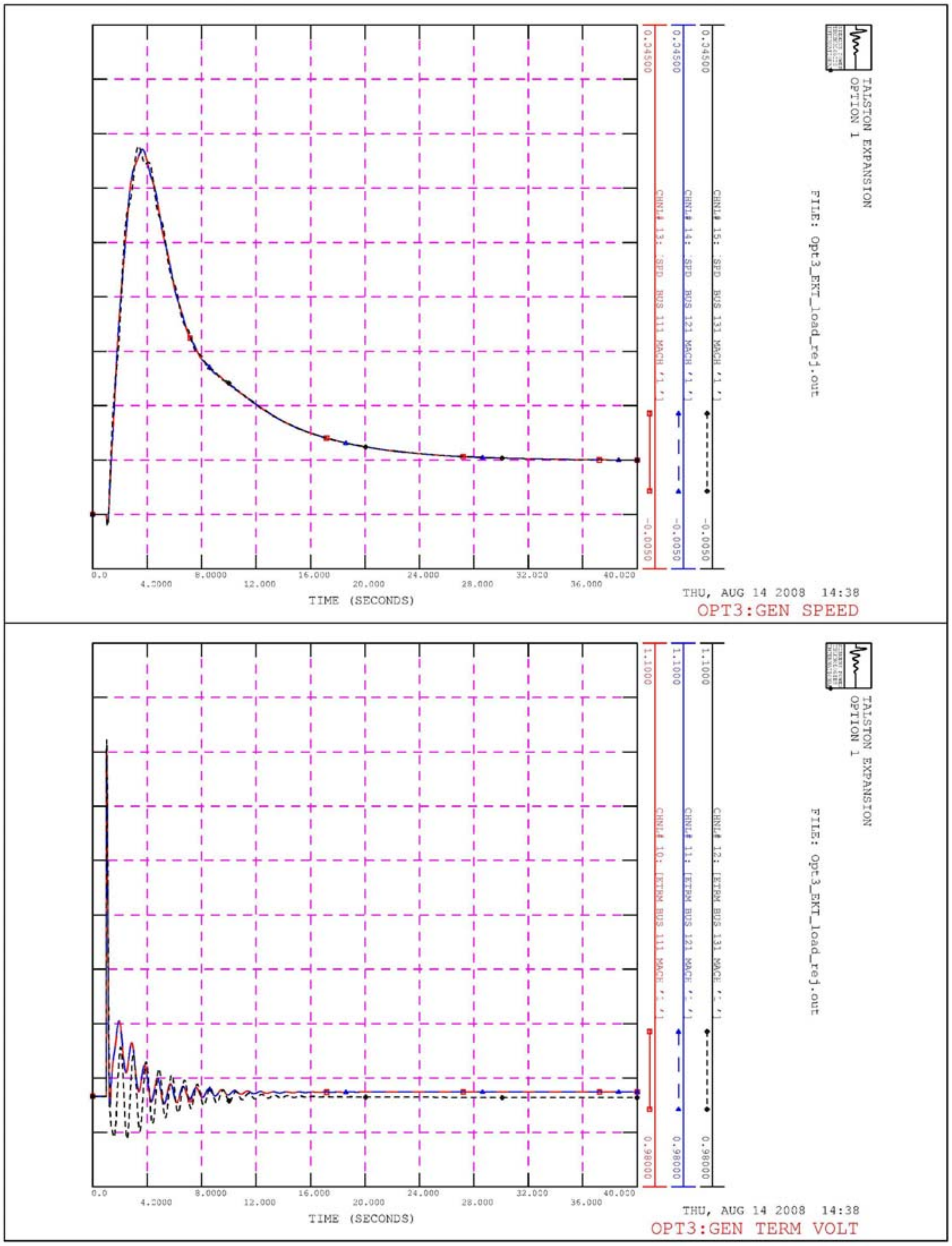
Figure 6-13
Option 2-Ekati Mine 100% Load Rejection



Option 3-Three Phase Fault At Twin Gorges 115 Kv Bus
Figure 6-14



Option 3-Three Phase Fault at Twin Gorges 115 kV Bus
Figure 6-15



Option 3-Ekati Mine 100% Load Rejection
Figure 6-16

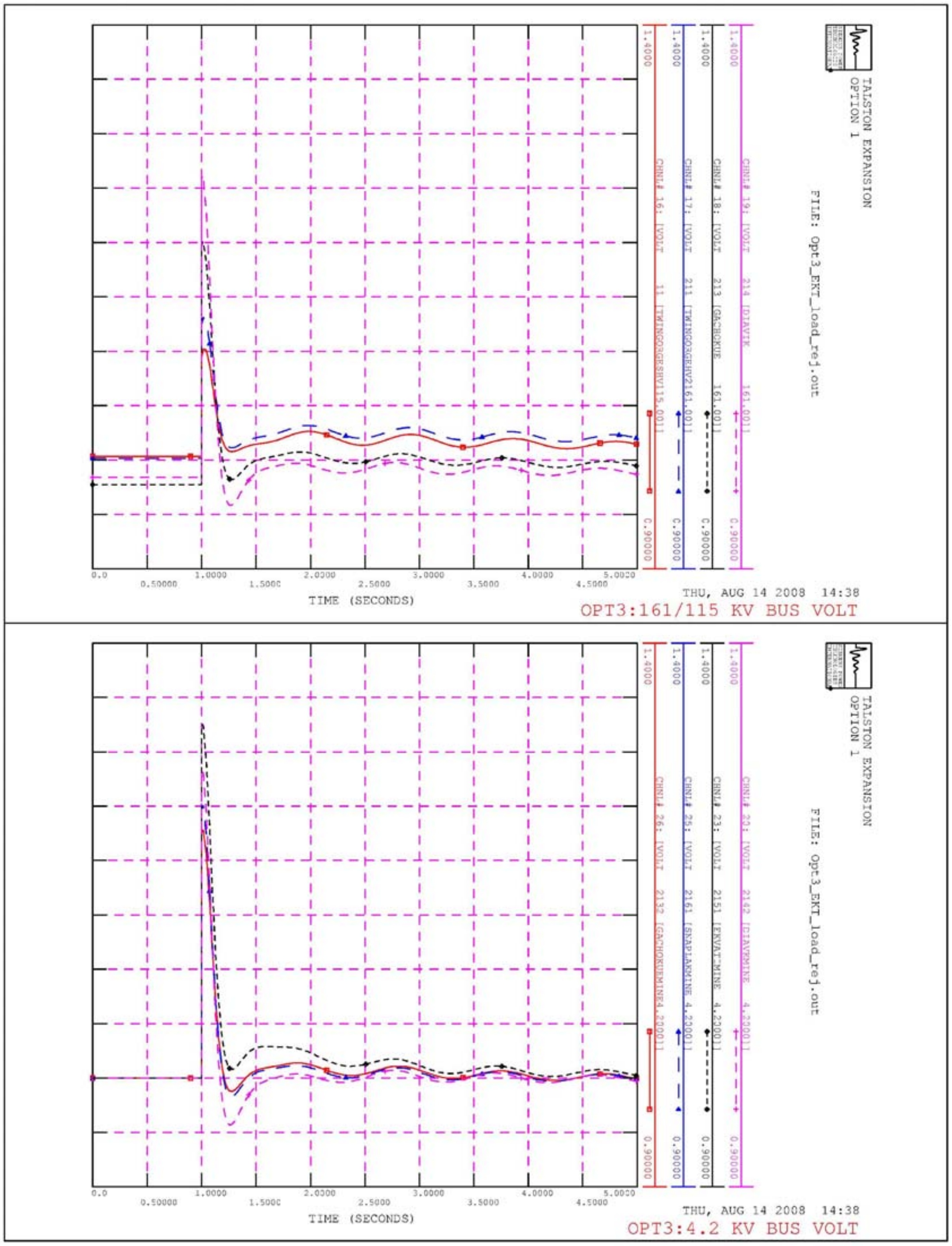


Figure 6-17
Figure 6-18

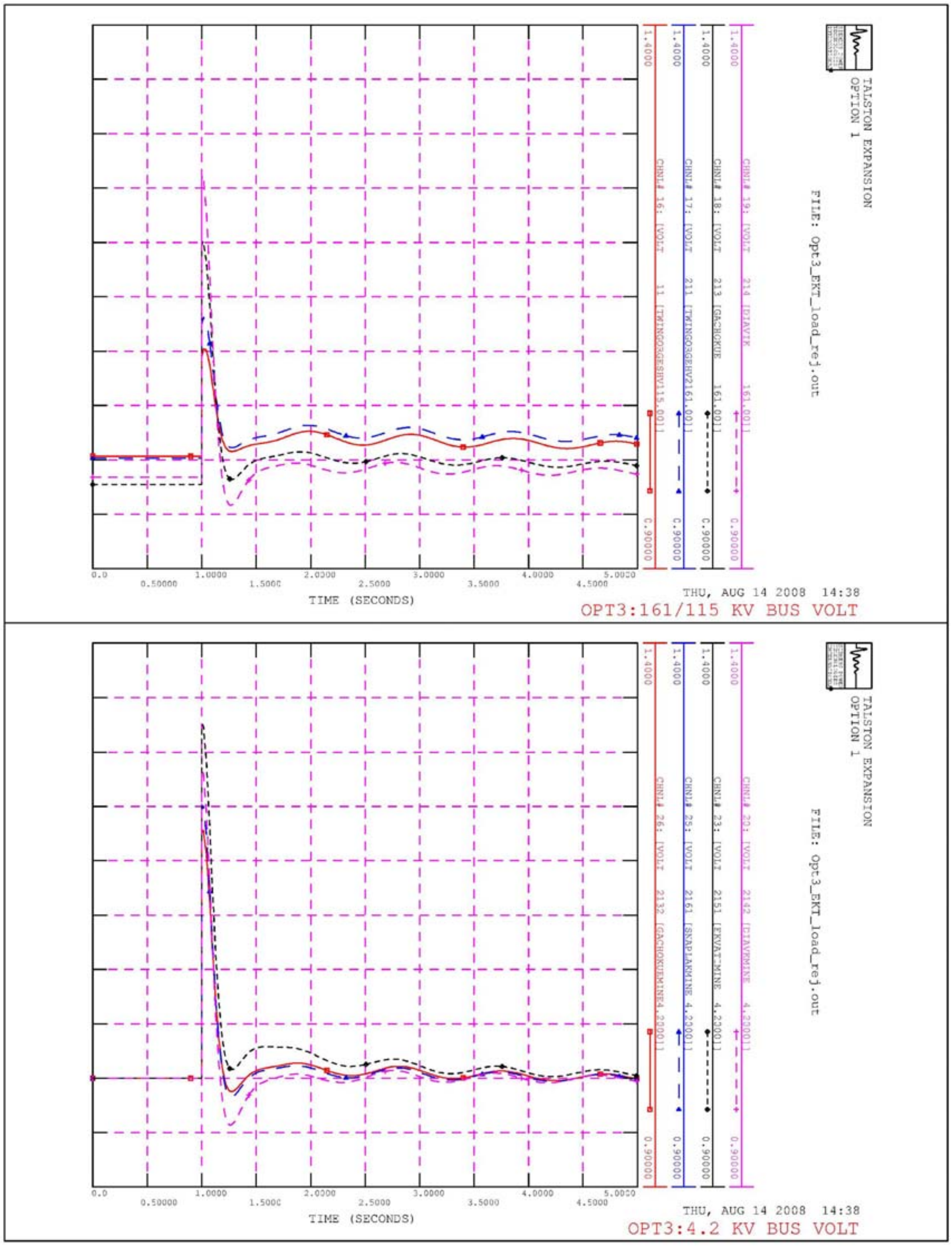

TALSTON EXPANSION
OPTION 1
FILE: Opt3_EKT_load_rej.out
TIME (SECONDS)
THU, AUG 14 2008 14:38
OPT3:161/115 KV BUS VOLT
TALSTON EXPANSION
OPTION 1
FILE: Opt3_EKT_load_rej.out
TIME (SECONDS)
THU, AUG 14 2008 14:38
OPT3:4.2 KV BUS VOLT

Figure 6-19

Appendix C

FOUNDATION TYPES

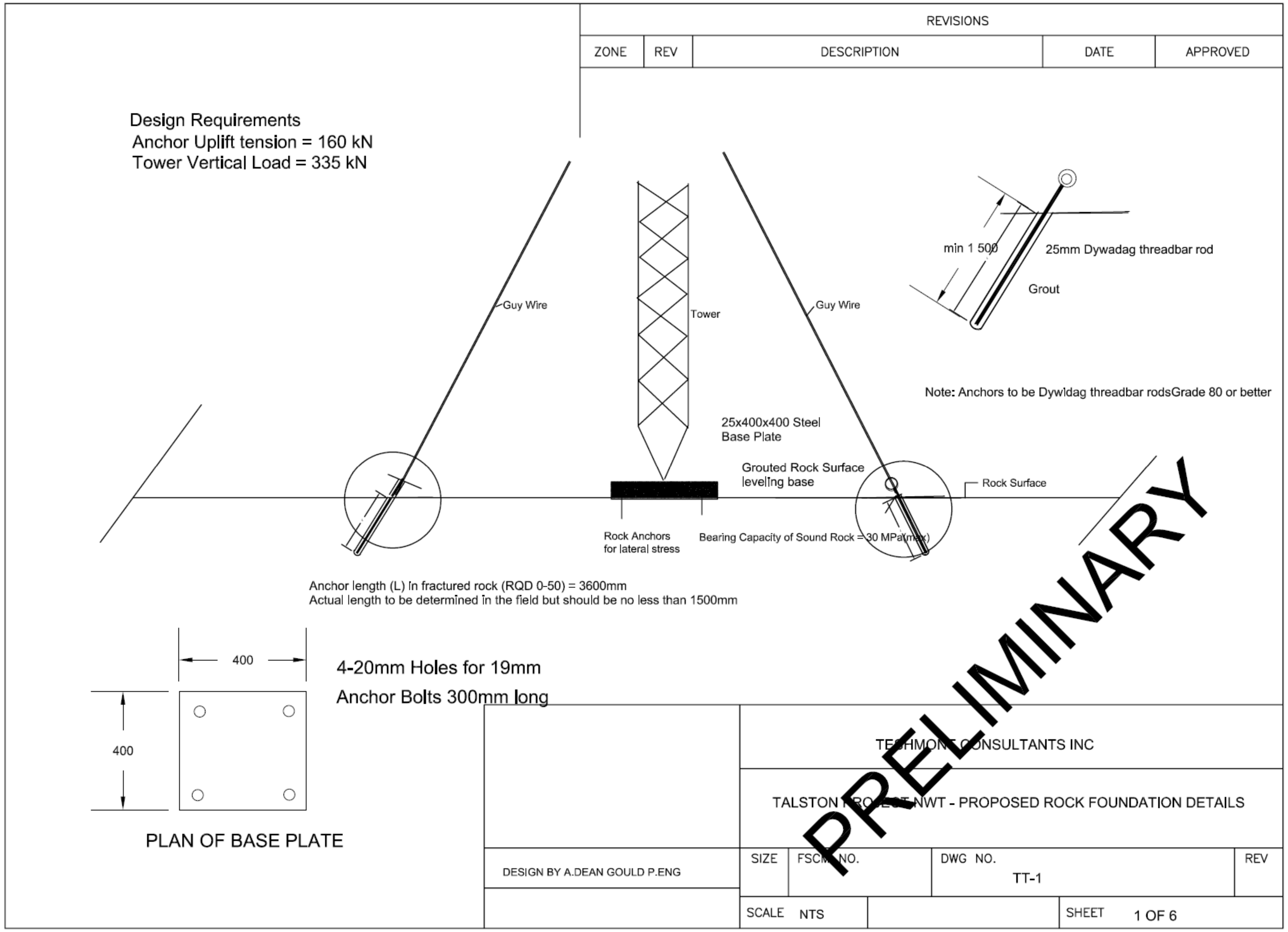

REVISIONS
ZONE
REV
DESCRIPTION
DATE
APPROVED
Design Requirements
Anchor Uplift tension = 160 kN
Tower Vertical Load = 335 kN
Guy Wire
Tower
Guy Wire
min 1 500
25mm Dywadag threadbar rod
Grout
Note: Anchors to be Dywidag threadbar rodsGrade 80 or better
25x400x400 Steel
Base Plate
Grouted Rock Surface
leveling base
Rock Surface
Rock Anchors
for lateral stress
Bearing Capacity of Sound Rock = 30 MPa(max)
Anchor length (L) in fractured rock (RQD 0-50) = 3600mm
Actual length to be determined in the field but should be no less than 1500mm
400
400
4-20mm Holes for 19mm
Anchor Bolts 300mm long
PLAN OF BASE PLATE
PRELIMINARY
TESHMONT CONSULTANTS INC
TALSTON PROJECT NWT - PROPOSED ROCK FOUNDATION DETAILS
DESIGN BY A.DEAN GOULD P.ENG
SIZE
FSCM NO.
DWG NO.
TT-1
REV
SCALE
NTS
SHEET
1 OF 6

Figure 6-20

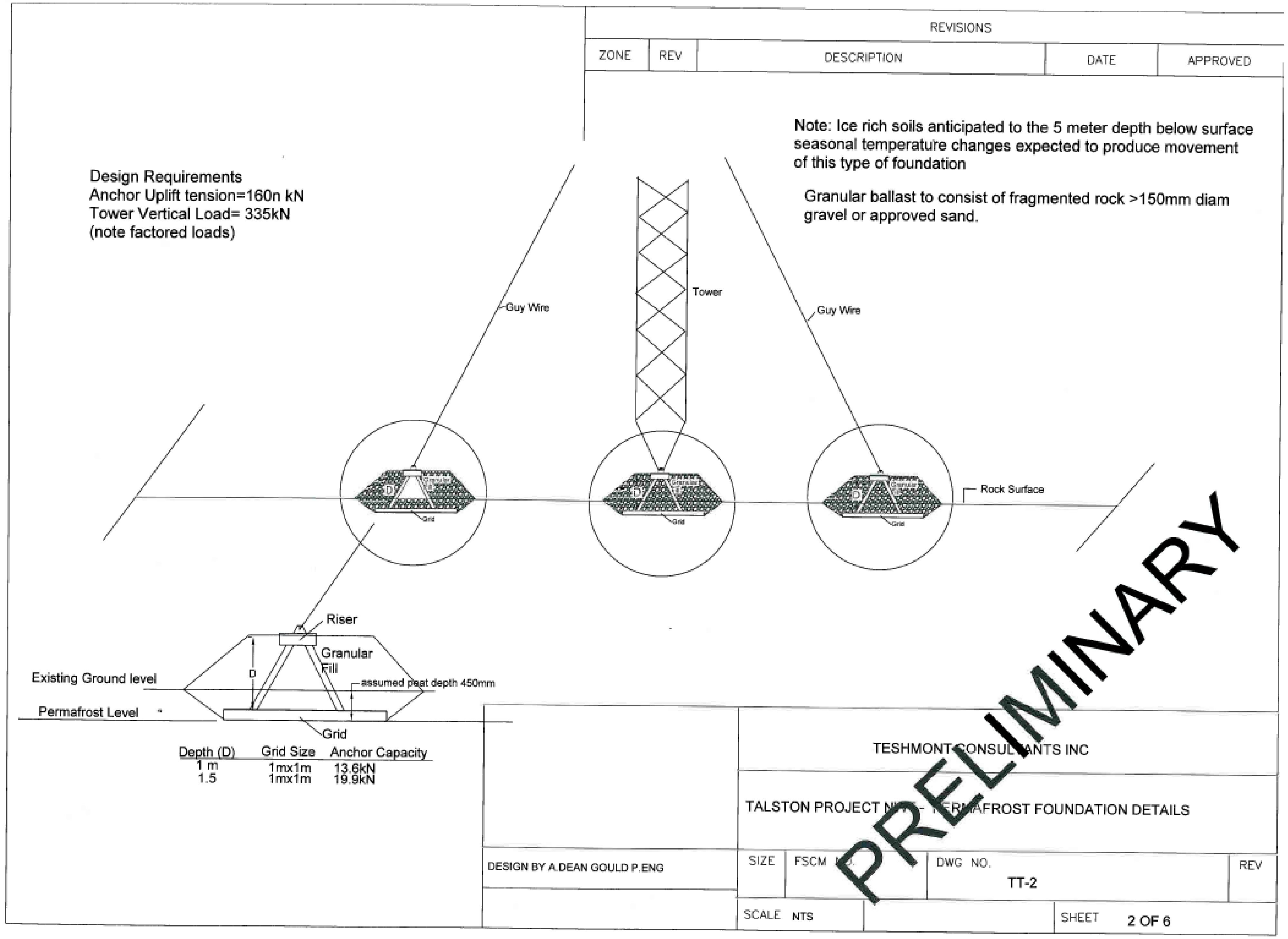

REVISIONS
ZONE
REV
DESCRIPTION
DATE
APPROVED
Note: Ice rich soils anticipated to the 5 meter depth below surface seasonal temperature changes expected to produce movement of this type of foundation
Granular ballast to consist of fragmented rock >150mm diam gravel or approved sand.
Design Requirements
Anchor Uplift tension=160n kN
Tower Vertical Load= 335kN
(note factored loads)
Guy Wire
Tower
Guy Wire
Rock Surface
Riser
Granular Fill
D
assumed peat depth 450mm
Existing Ground level
Permafrost Level
Grid
Depth (D) Grid Size Anchor Capacity
1 m 1mx1m 13.6kN
1.5 1mx1m 19.9kN
PRELIMINARY
TESHMONT CONSULTANTS INC
TALSTON PROJECT
FOUNDATION DETAILS
DESIGN BY A.DEAN GOULD P.ENG
SIZE
FSCM
DWG NO.
TT-2
REV
SCALE NTS
SHEET 2 OF 6

Figure 6-21

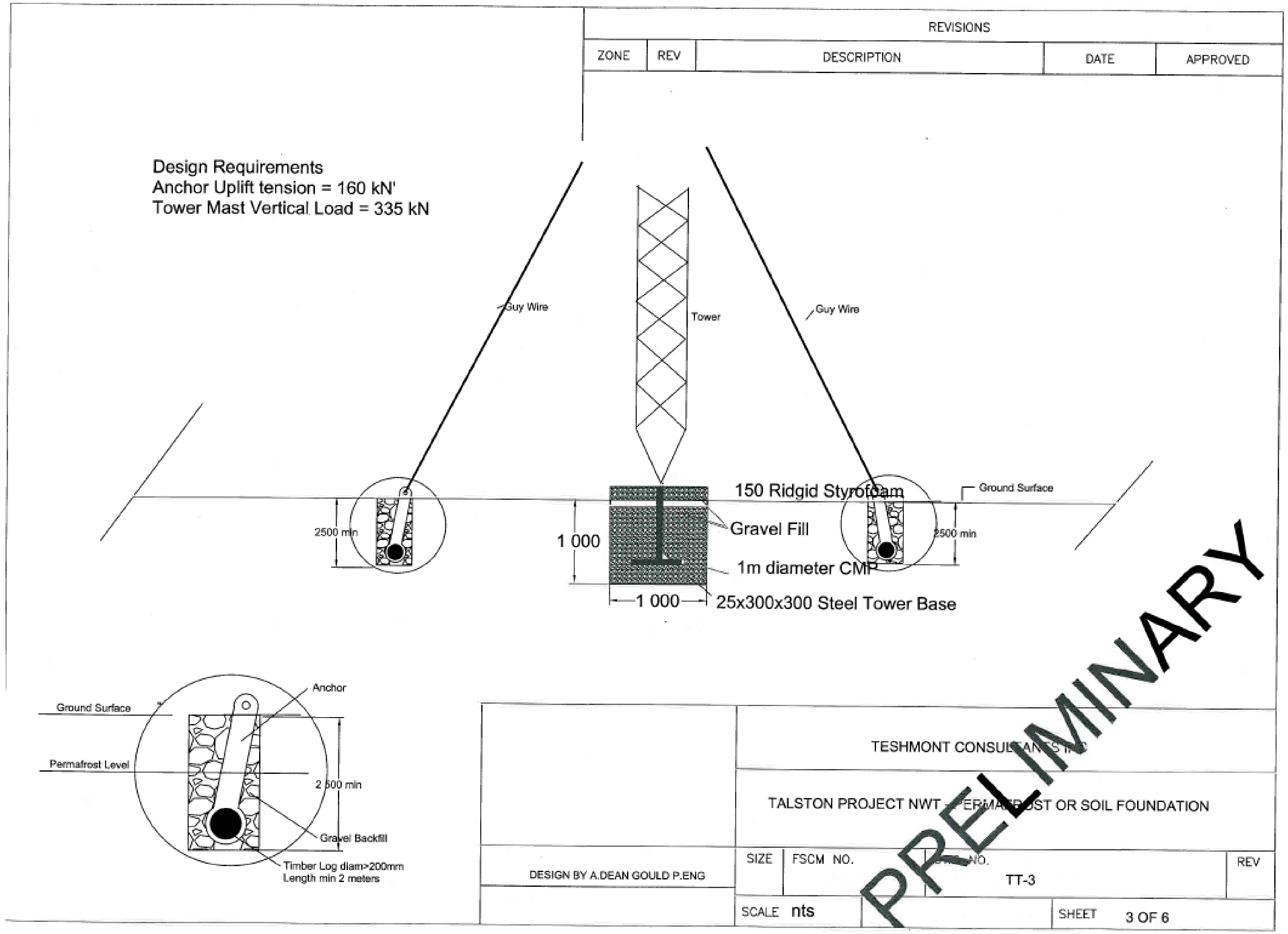

REVISIONS
ZONE
REV
DESCRIPTION
DATE
APPROVED
Design Requirements
Anchor Uplift tension = 160 kN'
Tower Mast Vertical Load = 335 kN
Guy Wire
Tower
Guy Wire
150 Ridgid Styrofoam
Ground Surface
2500 min
Gravel Fill
1 000
1m diameter CMP
2500 min
1 000
25x300x300 Steel Tower Base
Anchor
Ground Surface
Permafrost Level
2 500 min
Gravel Backfill
Timber Log diam>200mm
Length min 2 meters
TESHMONT CONSULTANTS INC
TALSTON PROJECT NWT - PERMAFROST OR SOIL FOUNDATION
DESIGN BY A.DEAN GOULD P.ENG
SIZE
FSCM NO.
DWG NO.
TT-3
REV
SCALE nts
SHEET 3 OF 6
PRELIMINARY

Figure 6-22

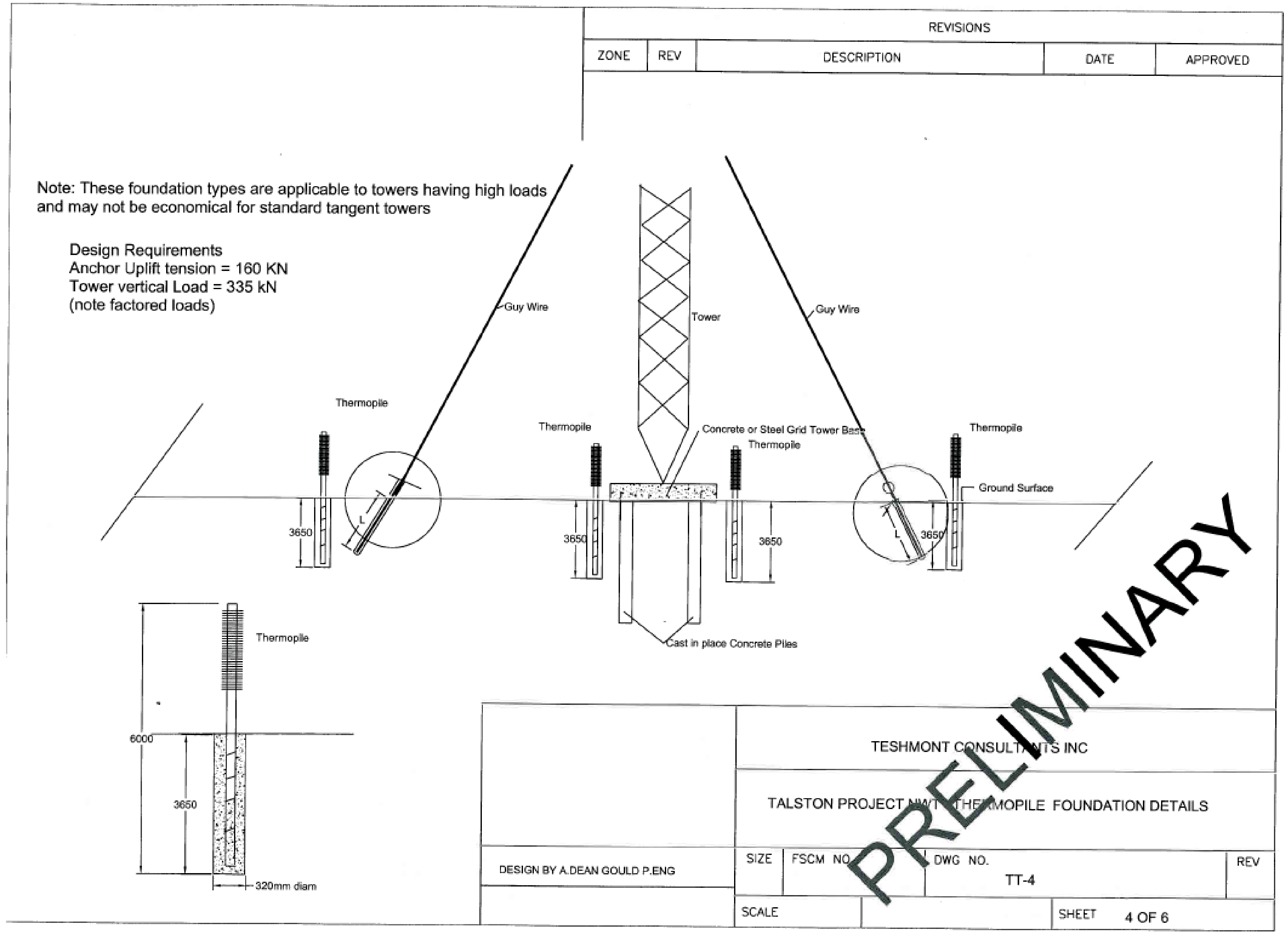

REVISIONS
ZONE
REV
DESCRIPTION
DATE
APPROVED
Note: These foundation types are applicable to towers having high loads and may not be economical for standard tangent towers
Design Requirements
Anchor Uplift tension = 160 KN
Tower vertical Load = 335 kN
(note factored loads)
Guy Wire
Tower
Guy Wire
Thermopile
Thermopile
Concrete or Steel Grid Tower Base
Thermopile
Thermopile
Ground Surface
3650
3650
3650
3650
L
L
Cast in place Concrete Piles
Thermopile
6000
3650
320mm diam
PRELIMINARY
TESHMONT CONSULTANTS INC
TALSTON PROJECT NWT THERMOPILE FOUNDATION DETAILS
DESIGN BY A.DEAN GOULD P.ENG
SIZE
FSCM NO
DWG NO.
TT-4
REV
SCALE
SHEET
4 OF 6

Figure 6-23

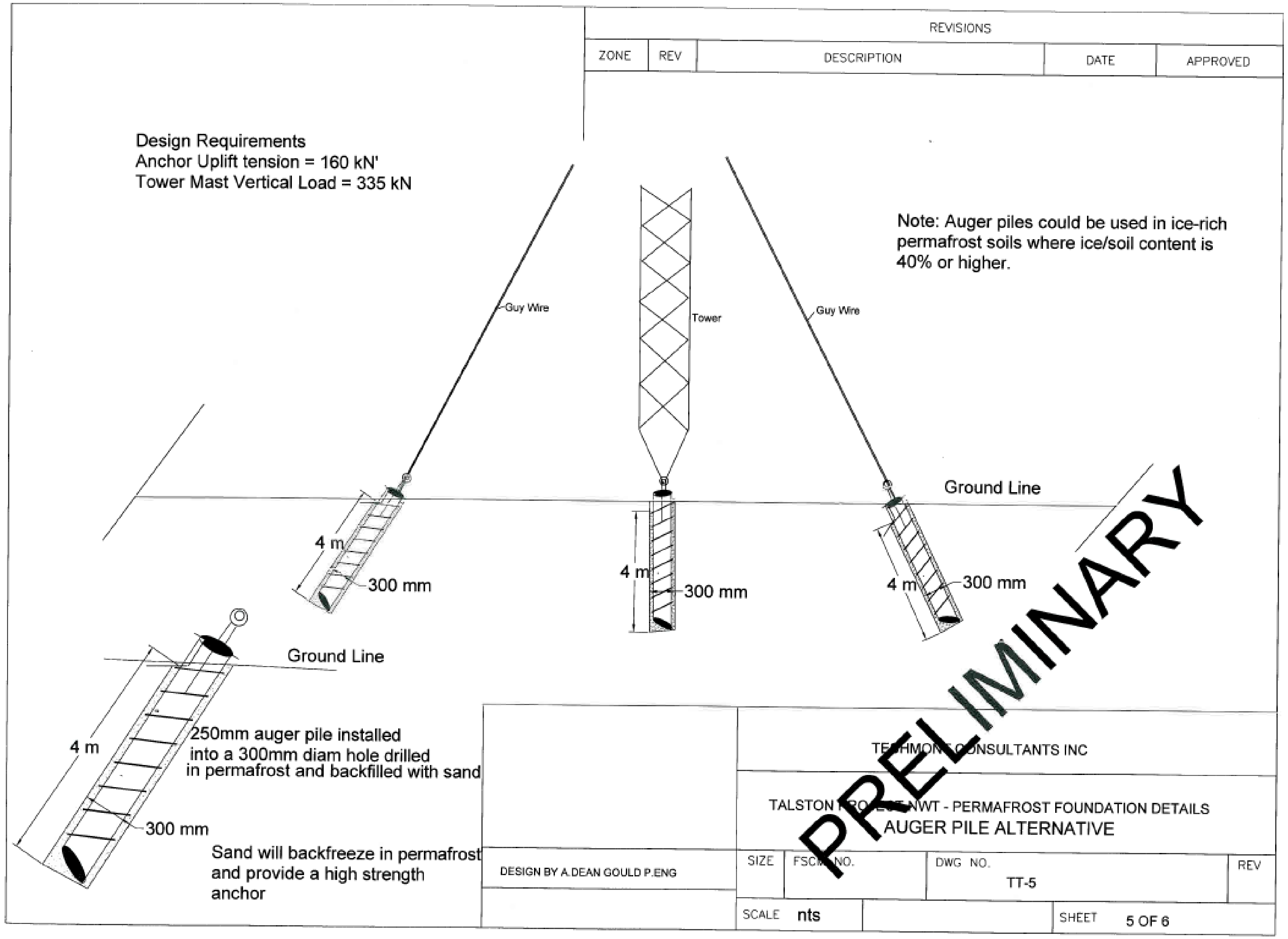

REVISIONS
ZONE
REV
DESCRIPTION
DATE
APPROVED
Design Requirements
Anchor Uplift tension = 160 kN'
Tower Mast Vertical Load = 335 kN
Note: Auger piles could be used in ice-rich permafrost soils where ice/soil content is 40% or higher.
Guy Wire
Tower
Guy Wire
Ground Line
4 m
300 mm
4 m
300 mm
4 m
300 mm
Ground Line
4 m
250mm auger pile installed into a 300mm diam hole drilled in permafrost and backfilled with sand
300 mm
Sand will backfreeze in permafrost and provide a high strength anchor
PRELIMINARY
TESHMONT CONSULTANTS INC
TALSTON PROJECT NWT - PERMAFROST FOUNDATION DETAILS
AUGER PILE ALTERNATIVE
DESIGN BY A.DEAN GOULD P.ENG
SIZE
FSCM NO.
DWG NO.
TT-5
REV
SCALE nts
SHEET 5 OF 6

Figure 6-24

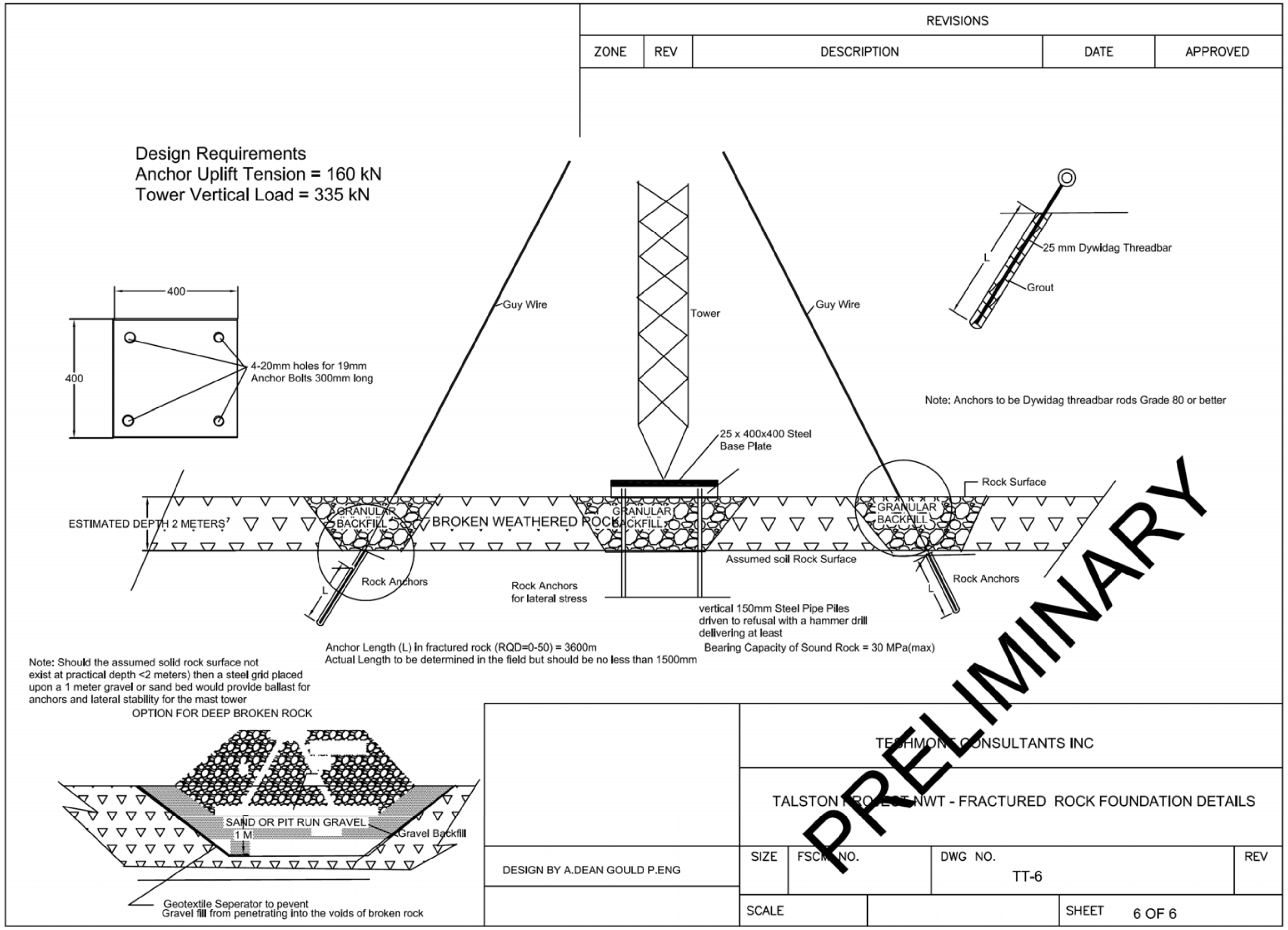
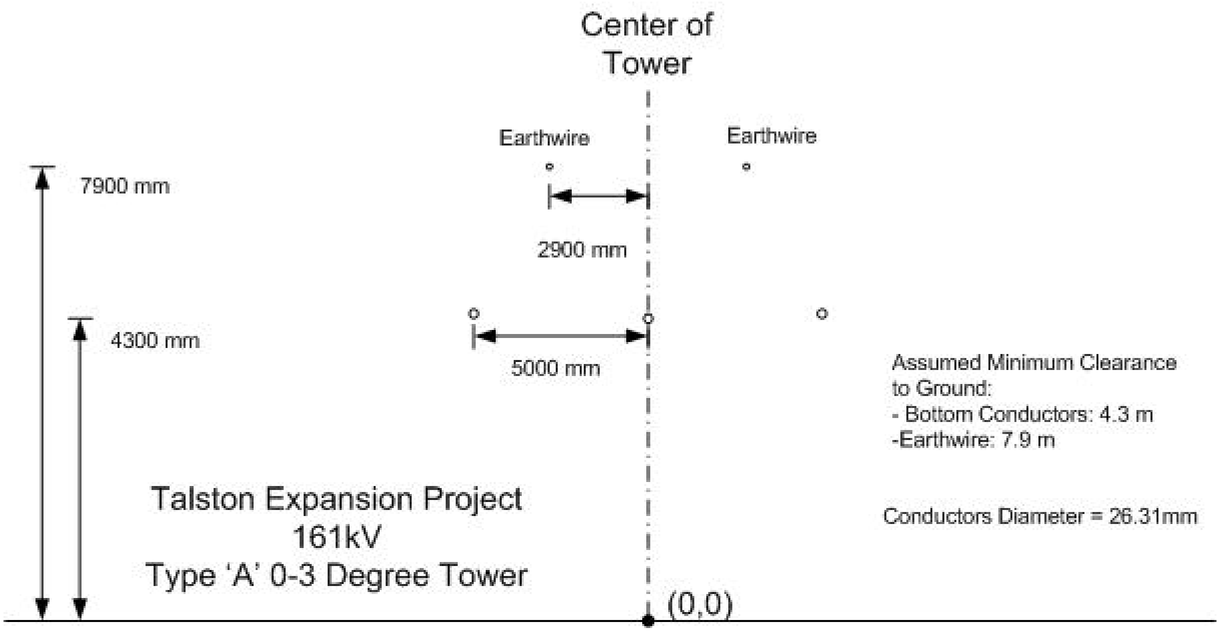
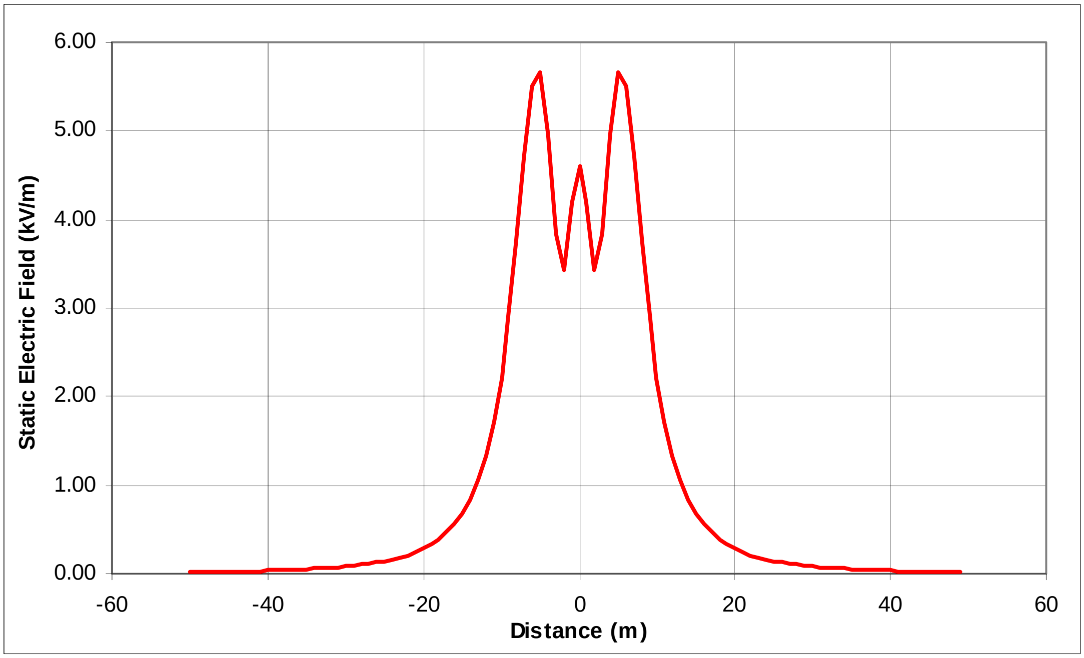

REVISIONS
ZONE
REV
DESCRIPTION
DATE
APPROVED
Design Requirements
Anchor Uplift Tension = 160 kN
Tower Vertical Load = 335 kN
400
400
4-20mm holes for 19mm
Anchor Bolts 300mm long
Guy Wire
Tower
Guy Wire
25 mm Dywidag Threadbar
Grout
L
Note: Anchors to be Dywidag threadbar rods Grade 80 or better
25 x 400x400 Steel
Base Plate
Rock Surface
ESTIMATED DEPTH 2 METERS
GRANULAR
BACKFILL
BROKEN WEATHERED ROCK
GRANULAR
BACKFILL
GRANULAR
BACKFILL
Assumed soil Rock Surface
Rock Anchors
Rock Anchors
for lateral stress
Rock Anchors
vertical 150mm Steel Pipe Piles
driven to refusal with a hammer drill
delivering at least
Bearing Capacity of Sound Rock = 30 MPa(max)
Anchor Length (L) in fractured rock (RQD=0-50) = 3600m
Actual Length to be determined in the field but should be no less than 1500mm
Note: Should the assumed solid rock surface not
exist at practical depth <2 meters) then a steel grid placed
upon a 1 meter gravel or sand bed would provide ballast for
anchors and lateral stability for the mast tower
OPTION FOR DEEP BROKEN ROCK
SAND OR PIT RUN GRAVEL
1 M
Gravel Backfill
Geotextile Seperator to pevent
Gravel fill from penetrating into the voids of broken rock
PRELIMINARY
TESHMONT CONSULTANTS INC
TALSTON PROJECT NWT - FRACTURED ROCK FOUNDATION DETAILS
DESIGN BY A.DEAN GOULD P.ENG
SIZE
FSCM NO.
DWG NO.
TT-6
REV
SCALE
SHEET
6 OF 6

Figure 6-25

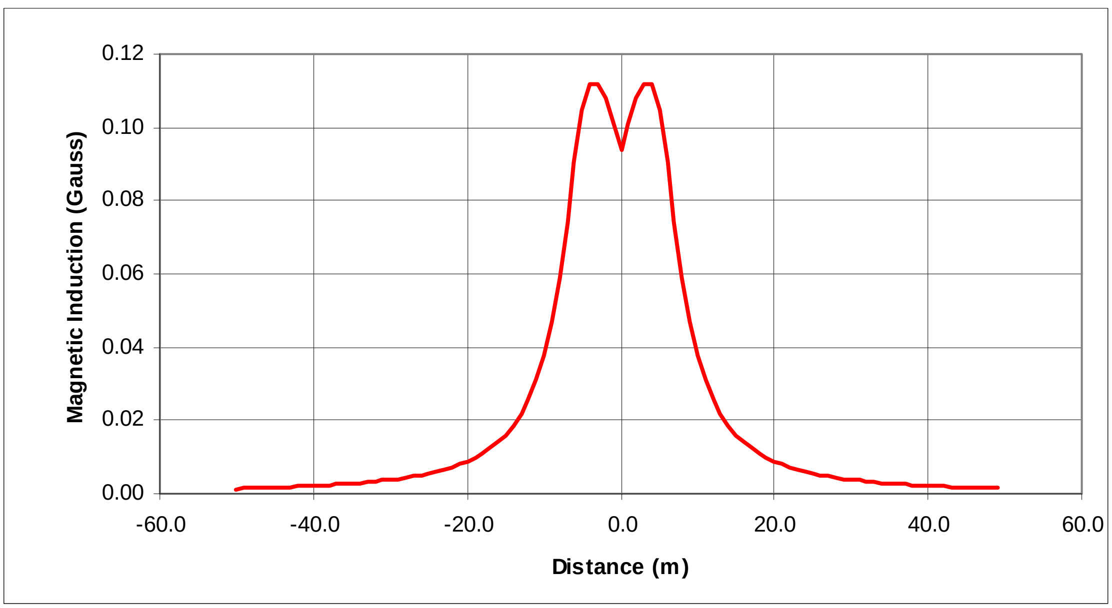
Appendix D
ELECTROMAGNETIC FIELD EFFECTS



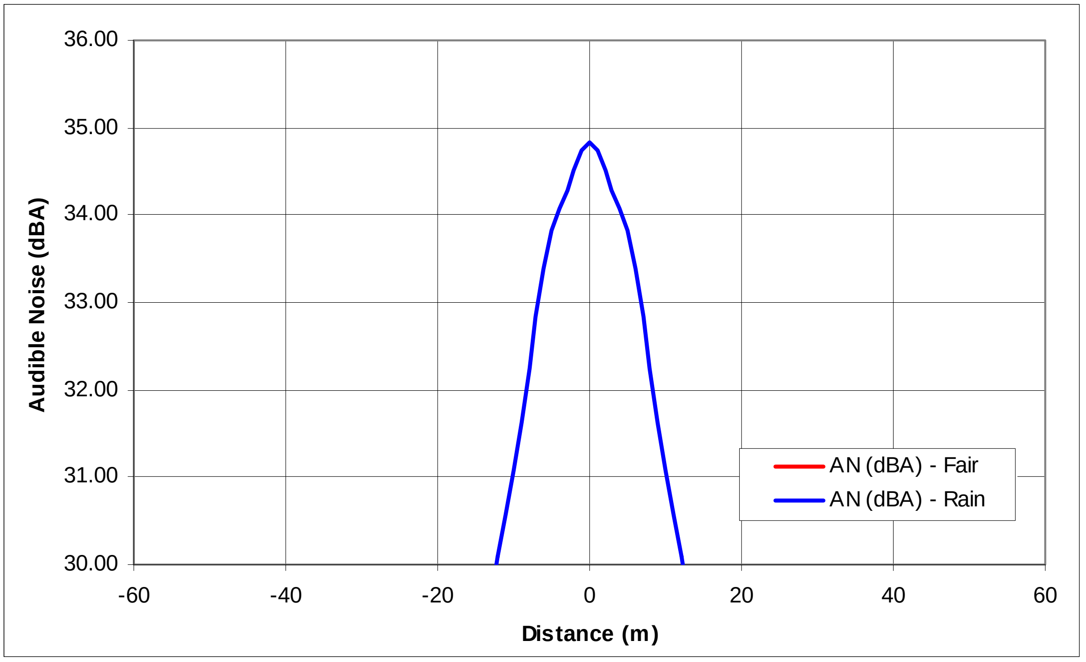
Type 'A' Conductor Configuration
Figure 6-26



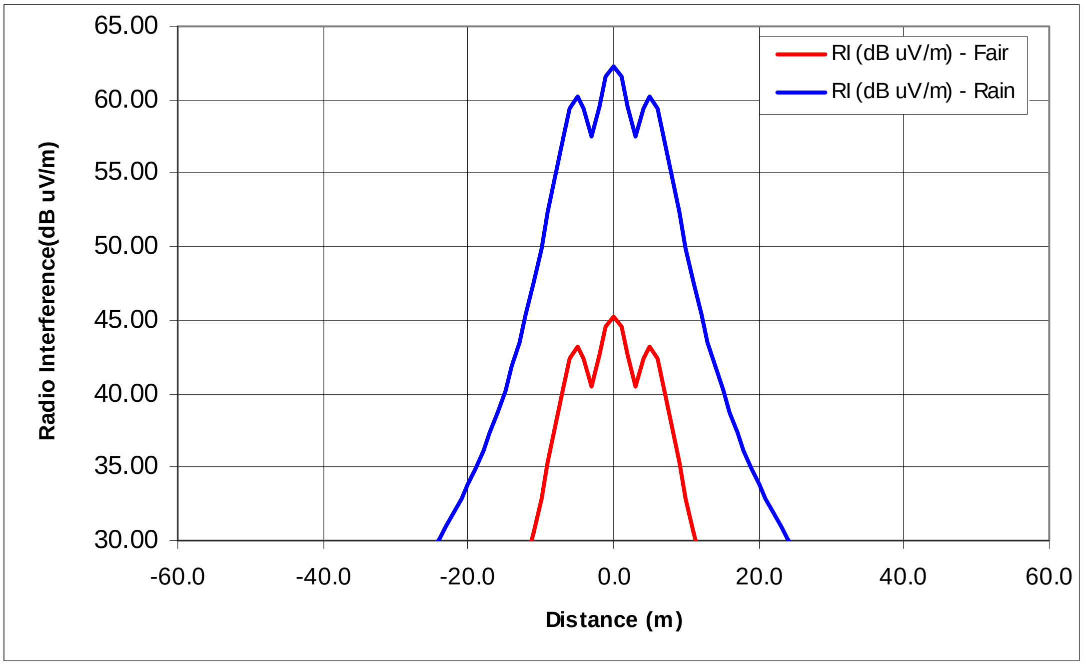
Electric Field Profile for the Type 'A' Tower
Figure 6-27



Magnetic Flux Density Profile for the Type 'A' Tower (0.194 kA)
Figure 6-28

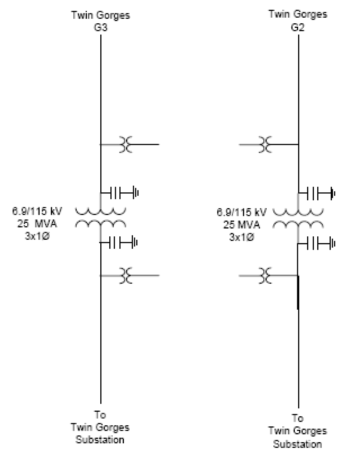


Audible Noise Profile for the Type 'A' Tower
(Fair Weather AN Profile is below 30 dBA)
Figure 6-29

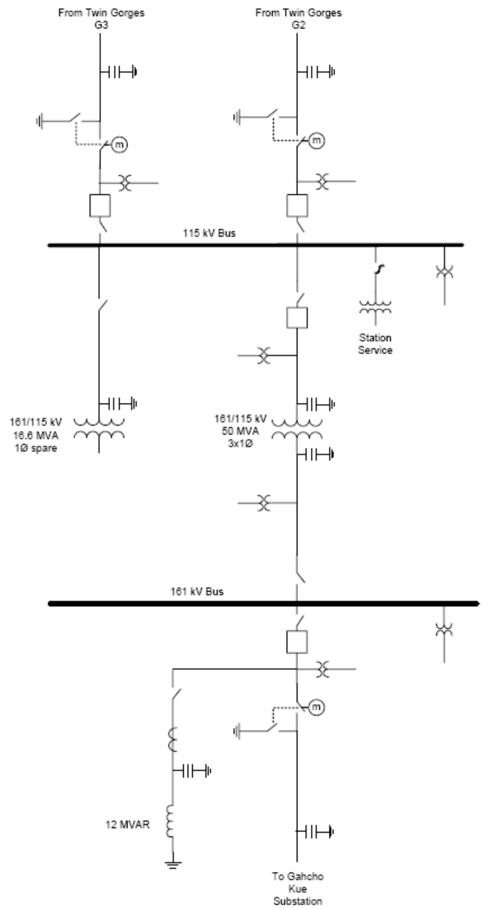


Radio Interference Profile for the Type 'A' Tower
Figure 6-30

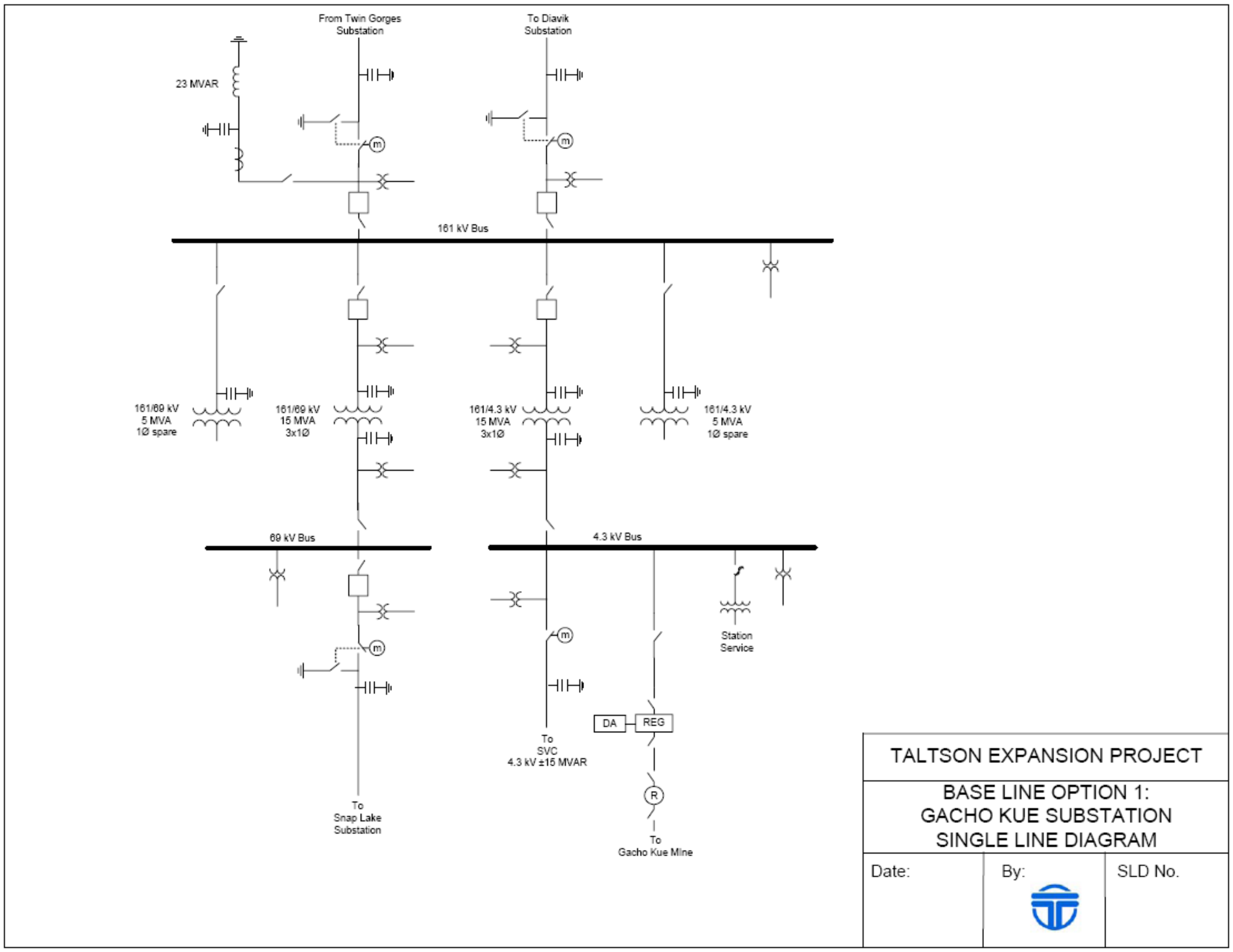
Appendix E
BASELINE SUBSTATION LAYOUTS
OPTION 1

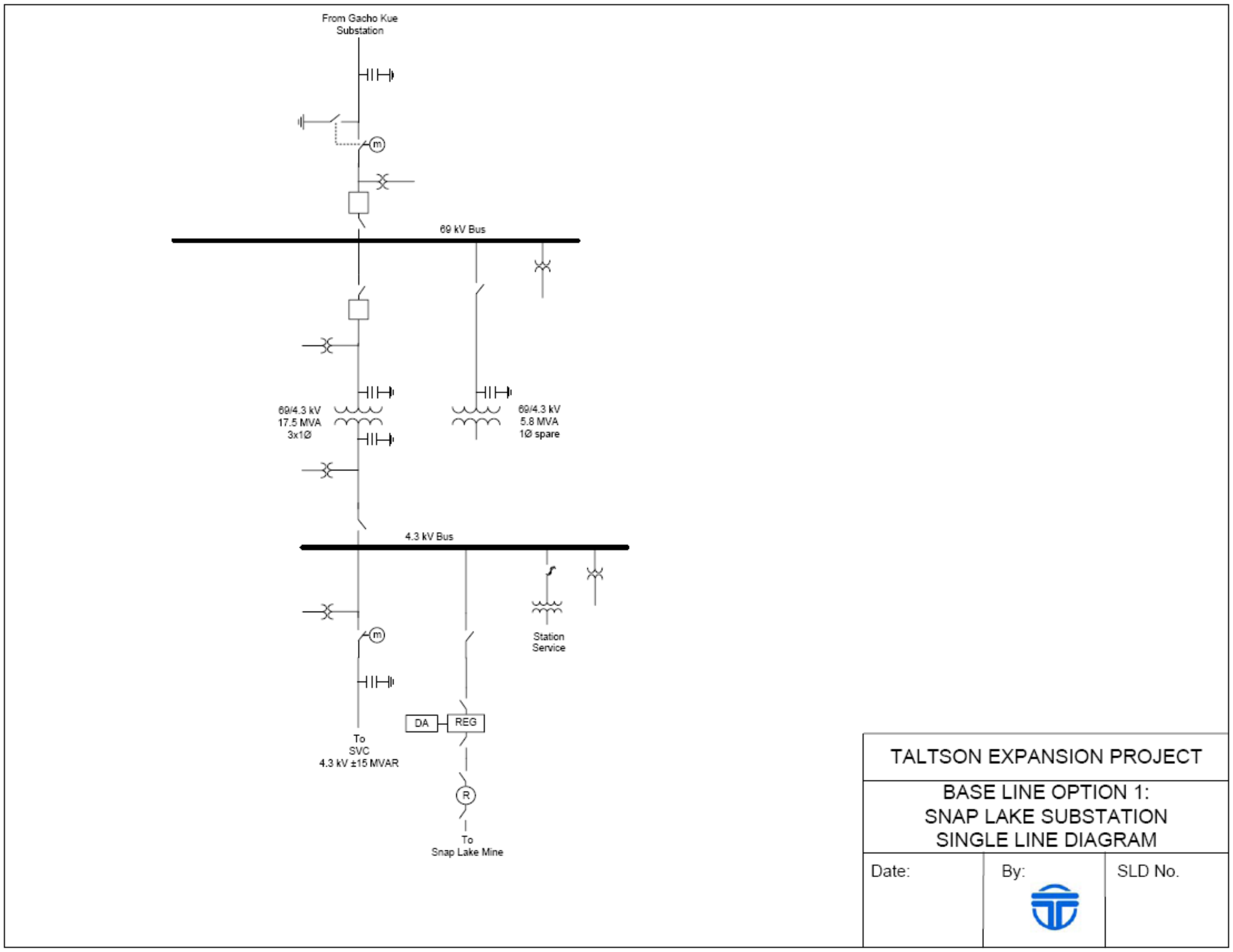


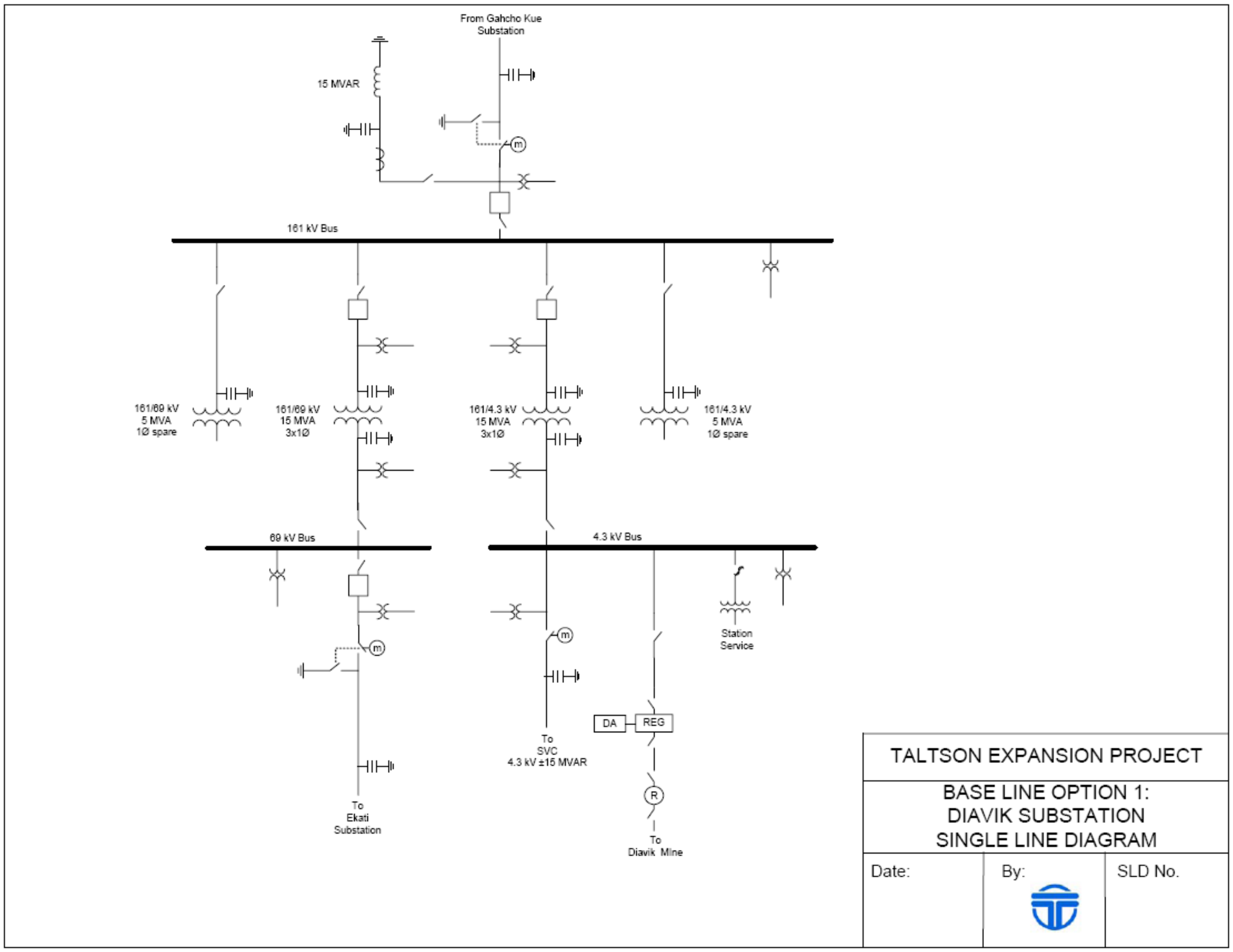
TALTSON EXPANSION PROJECT		
BASE LINE OPTION 1: TWIN GORGES POWERHOUSE SINGLE LINE DIAGRAM		
Date:	By:	SLD No.

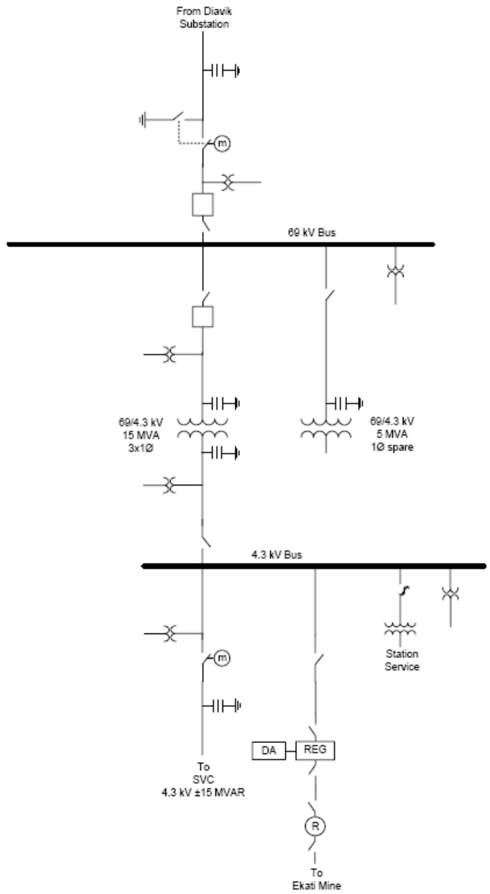


TALTSON EXPANSION PROJECT		
BASE LINE OPTION 1: TWIN GORGES SUBSTATION SINGLE LINE DIAGRAM		
Date:	By:	SLD No.


From Twin Gorges Substation
To Diavik Substation
23 MVAR
161 kV Bus
161/69 kV
5 MVA
1Ø spare
161/69 kV
15 MVA
3x1Ø
161/4.3 kV
15 MVA
3x1Ø
161/4.3 kV
5 MVA
1Ø spare
69 kV Bus
4.3 kV Bus
Station Service
DA
REG
To SVC 4.3 kV ±15 MVAR
To Snap Lake Substation
To Gacho Kue Mine
TALTSON EXPANSION PROJECT
BASE LINE OPTION 1:
GACHO KUE SUBSTATION
SINGLE LINE DIAGRAM
Date:
By:
SLD No.

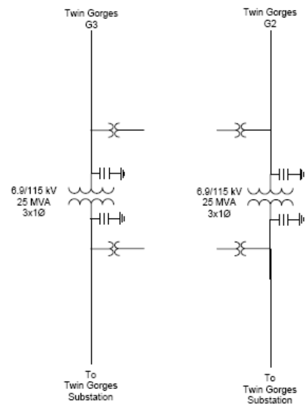

From Gacho Kue Substation
69 kV Bus
69/4.3 kV
17.5 MVA
3x1Ø
69/4.3 kV
5.8 MVA
1Ø spare
4.3 kV Bus
Station Service
DA
REG
To
SVC
4.3 kV ±15 MVAR
R
To
Snap Lake Mine
TALTSON EXPANSION PROJECT
BASE LINE OPTION 1:
SNAP LAKE SUBSTATION
SINGLE LINE DIAGRAM
Date:
By:
SLD No.


From Gahcho Kue Substation
15 MVAR
161 kV Bus
161/69 kV
5 MVA
1Ø spare
161/69 kV
15 MVA
3x1Ø
161/4.3 kV
15 MVA
3x1Ø
161/4.3 kV
5 MVA
1Ø spare
69 kV Bus
4.3 kV Bus
Station Service
DA
REG
To Ekati Substation
To SVC 4.3 kV ±15 MVAR
To Diavik Mine
TALTSON EXPANSION PROJECT
BASE LINE OPTION 1:
DIAVIK SUBSTATION
SINGLE LINE DIAGRAM
Date:
By:
SLD No.



TALTSON EXPANSION PROJECT		
BASE LINE OPTION 1: EKATI SUBSTATION SINGLE LINE DIAGRAM		
Date:	By:	SLD No.

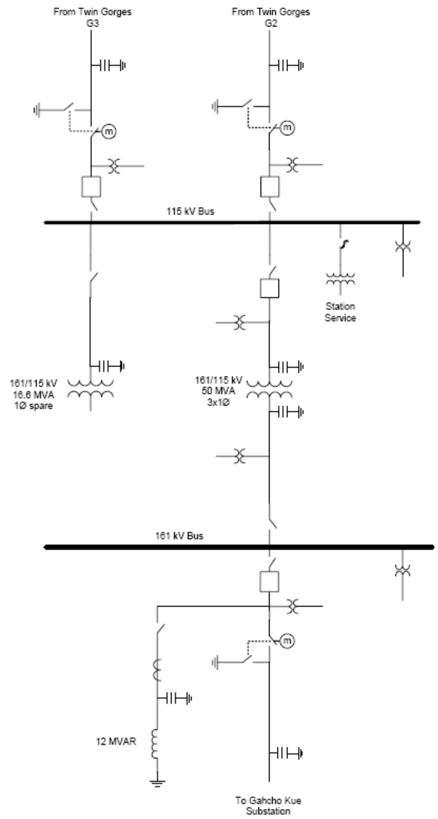
Appendix F
BASELINE SUBSTATION LAYOUTS
OPTION 2



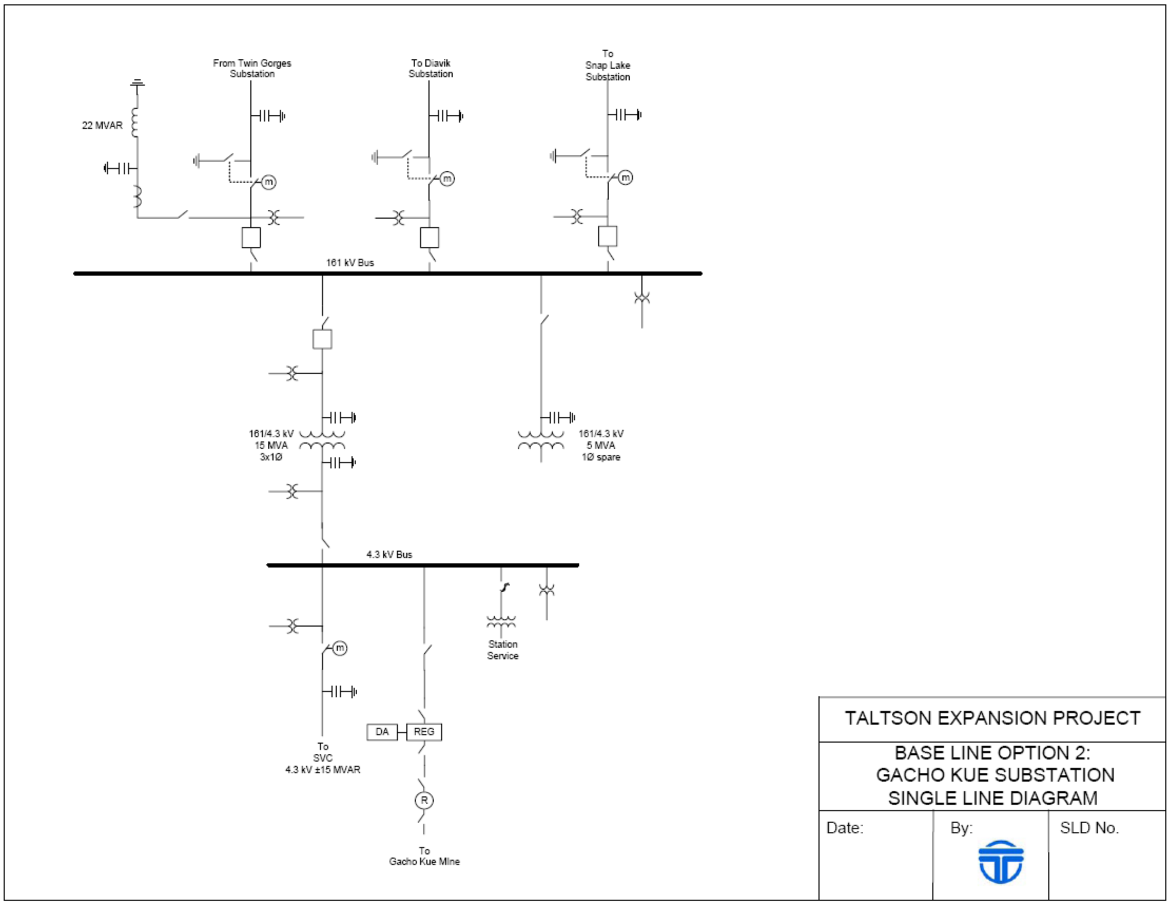
TALTSON EXPANSION PROJECT

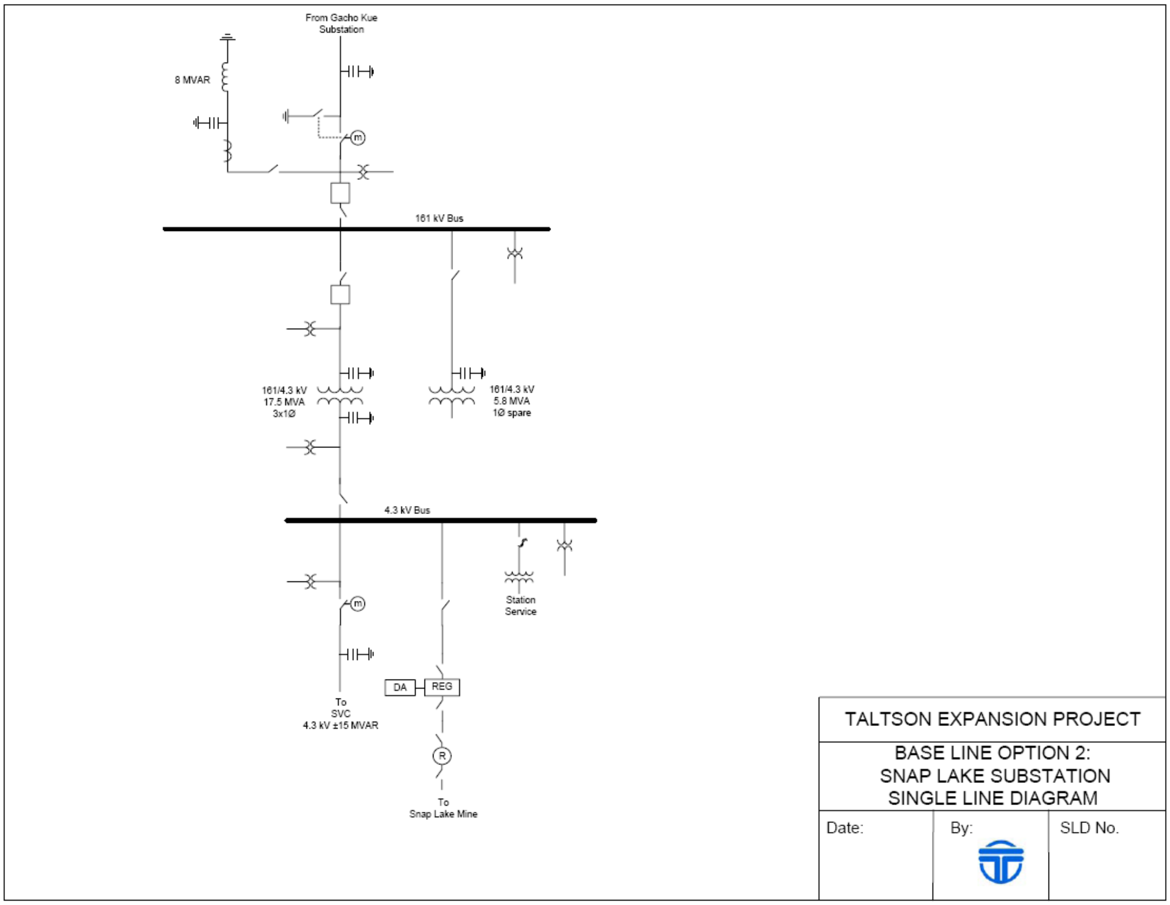
BASE LINE OPTION 2:
TWIN GORGES POWERHOUSE
SINGLE LINE DIAGRAM

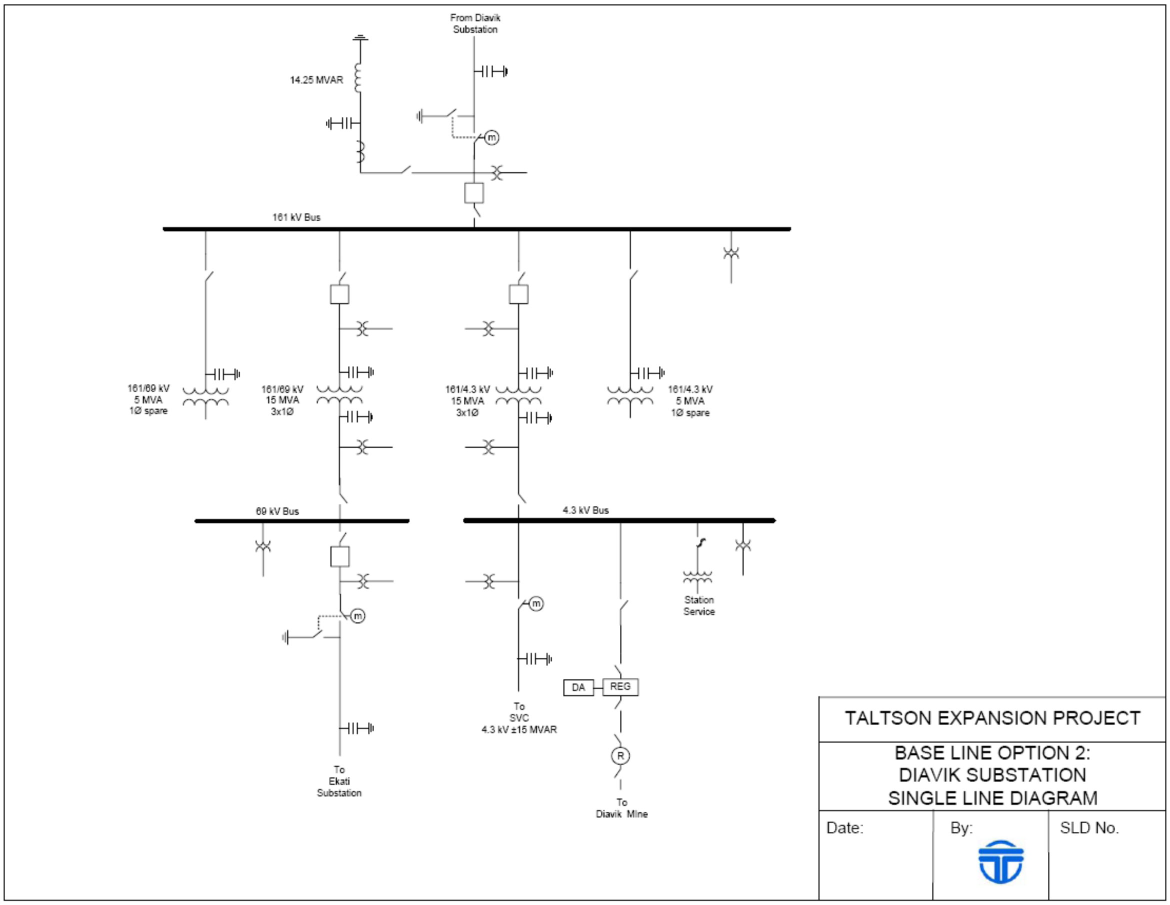
Date:	By:	SLD No.

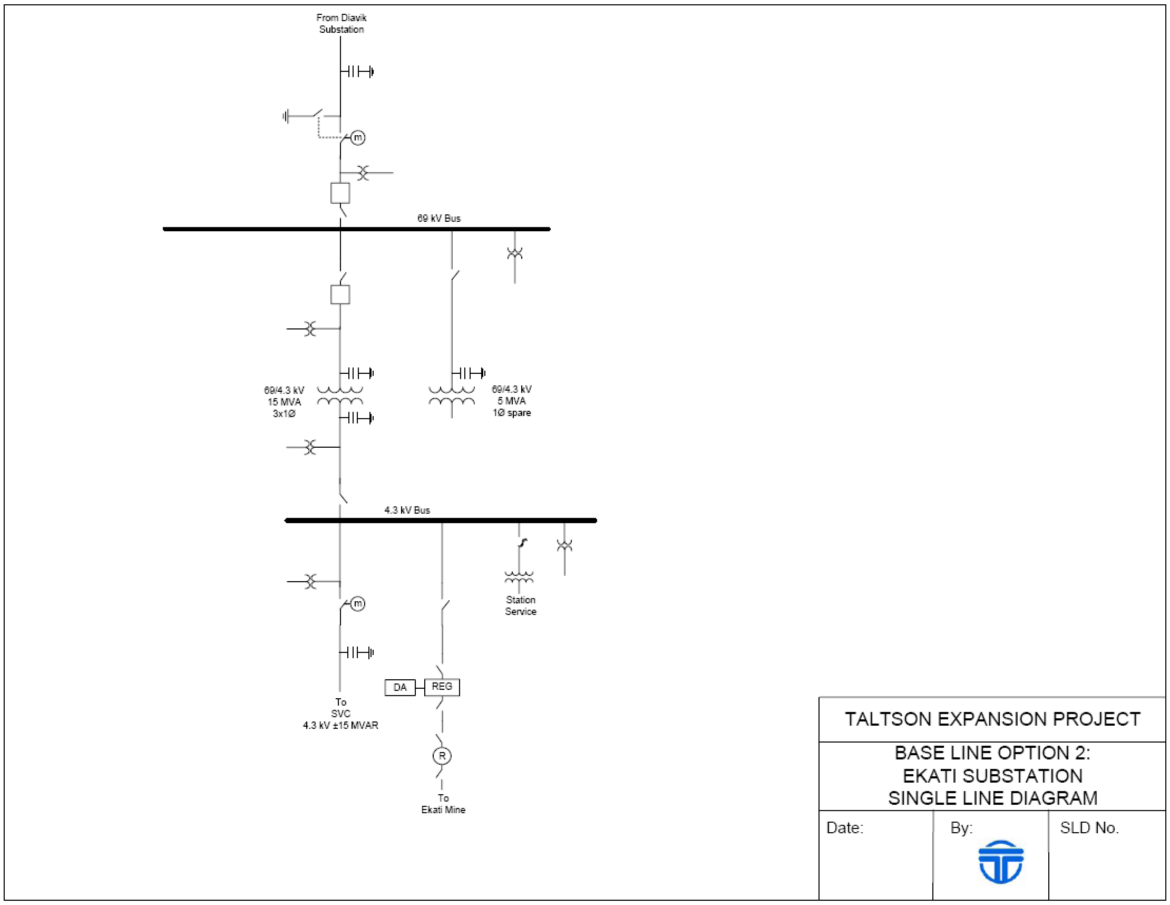


TALTSON EXPANSION PROJECT		
BASE LINE OPTION 2: TWIN GORGES SUBSTATION SINGLE LINE DIAGRAM		
Date:	By:	SLD No.

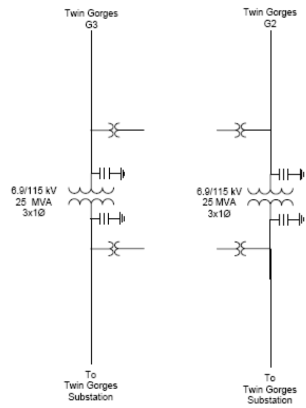

From Twin Gorges Substation
To Diavik Substation
To Snap Lake Substation
22 MVAR
161 kV Bus
161/4.3 kV
15 MVA
3x1Ø
161/4.3 kV
5 MVA
1Ø spare
4.3 kV Bus
Station Service
To SVC
4.3 kV ±15 MVAR
DA
REG
R
To Gacho Kue Mine
TALTSON EXPANSION PROJECT
BASE LINE OPTION 2:
GACHO KUE SUBSTATION
SINGLE LINE DIAGRAM
Date:
By:
SLD No.


From Gacho Kue Substation
8 MVAR
161 kV Bus
161/4.3 kV
17.5 MVA
3x1Ø
161/4.3 kV
5.8 MVA
1Ø spare
4.3 kV Bus
Station Service
DA
REG
To
SVC
4.3 kV ±15 MVAR
R
To
Snap Lake Mine
TALTSON EXPANSION PROJECT
BASE LINE OPTION 2:
SNAP LAKE SUBSTATION
SINGLE LINE DIAGRAM
Date:
By:
SLD No.


From Diavik Substation
14.25 MVAR
161 kV Bus
161/69 kV
5 MVA
1Ø spare
161/69 kV
15 MVA
3x1Ø
161/4.3 kV
15 MVA
3x1Ø
161/4.3 kV
5 MVA
1Ø spare
69 kV Bus
4.3 kV Bus
Station Service
DA
REG
To Ekati Substation
To SVC 4.3 kV ±15 MVAR
To Diavik Mine
TALTSON EXPANSION PROJECT
BASE LINE OPTION 2:
DIAVIK SUBSTATION
SINGLE LINE DIAGRAM
Date:
By:
SLD No.


From Diavik Substation
69 kV Bus
69/4.3 kV
15 MVA
3x1Ø
69/4.3 kV
5 MVA
1Ø spare
4.3 kV Bus
Station Service
DA
REG
To
SVC
4.3 kV ±15 MVAR
R
To
Ekati Mine
TALTSON EXPANSION PROJECT
BASE LINE OPTION 2:
EKATI SUBSTATION
SINGLE LINE DIAGRAM
Date:
By:
SLD No.

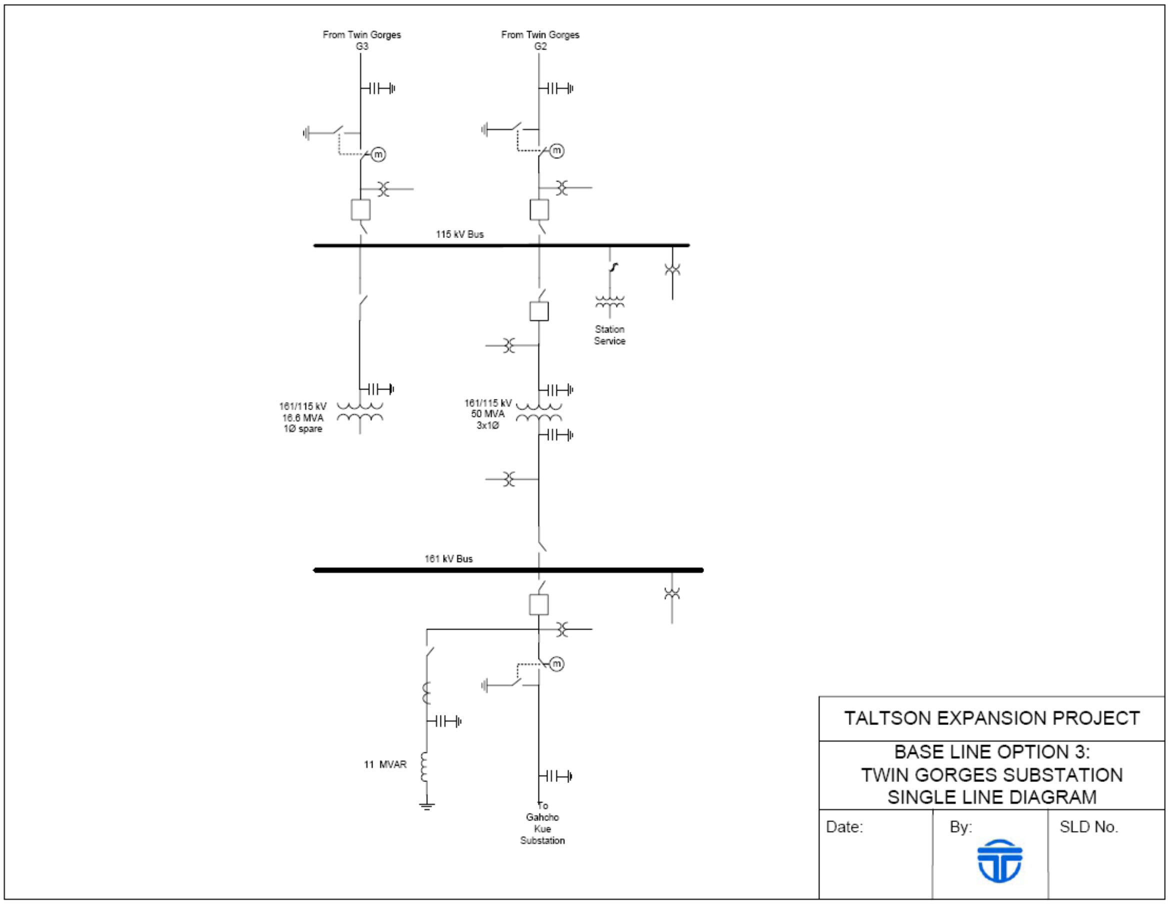
Appendix G
BASELINE SUBSTATION LAYOUTS
OPTION 3

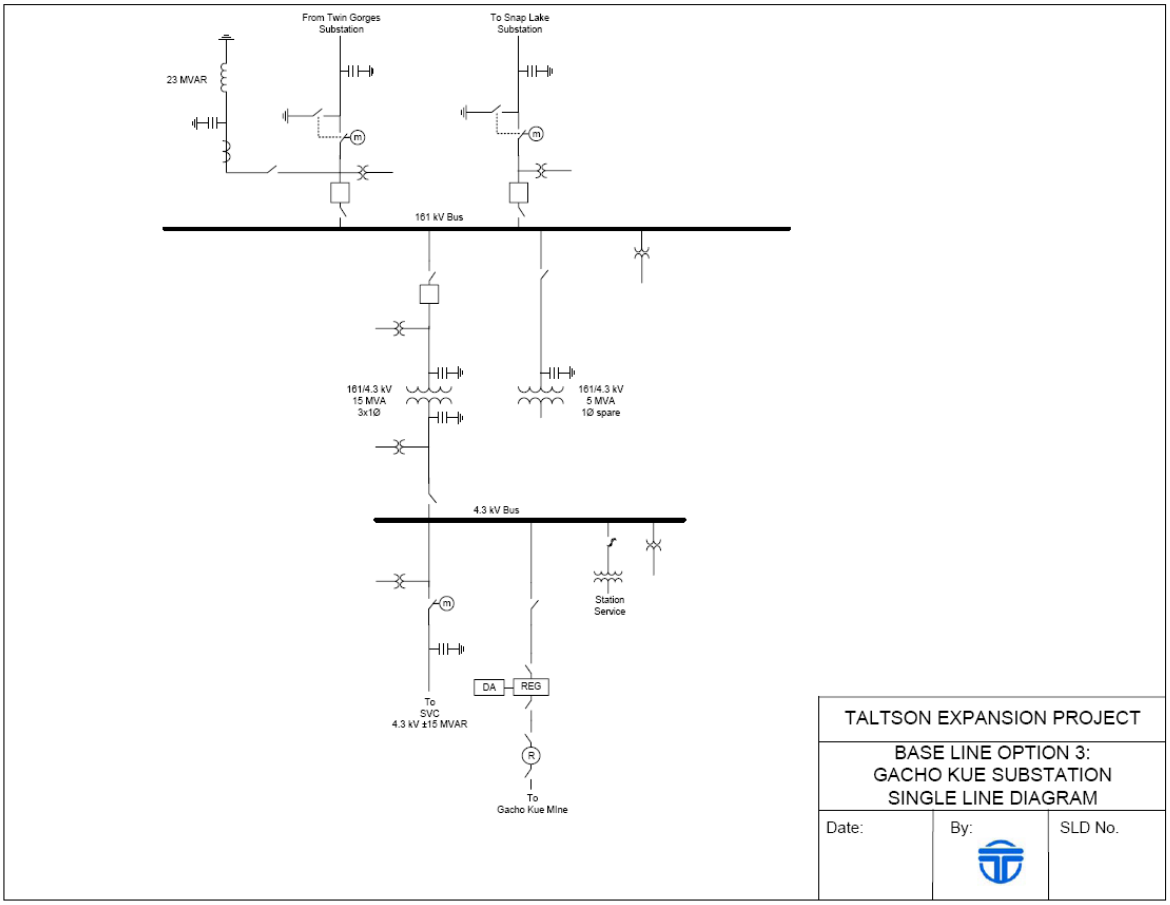


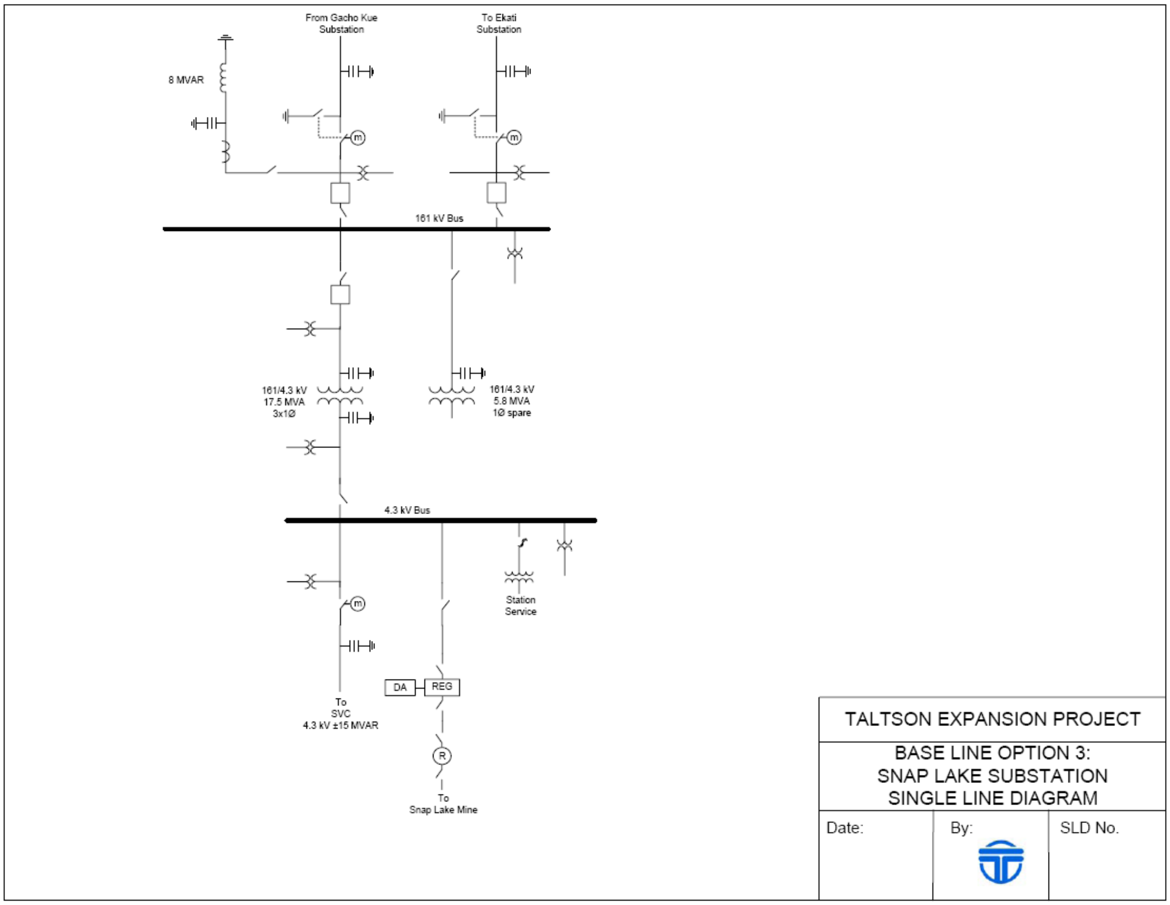
TALTSON EXPANSION PROJECT

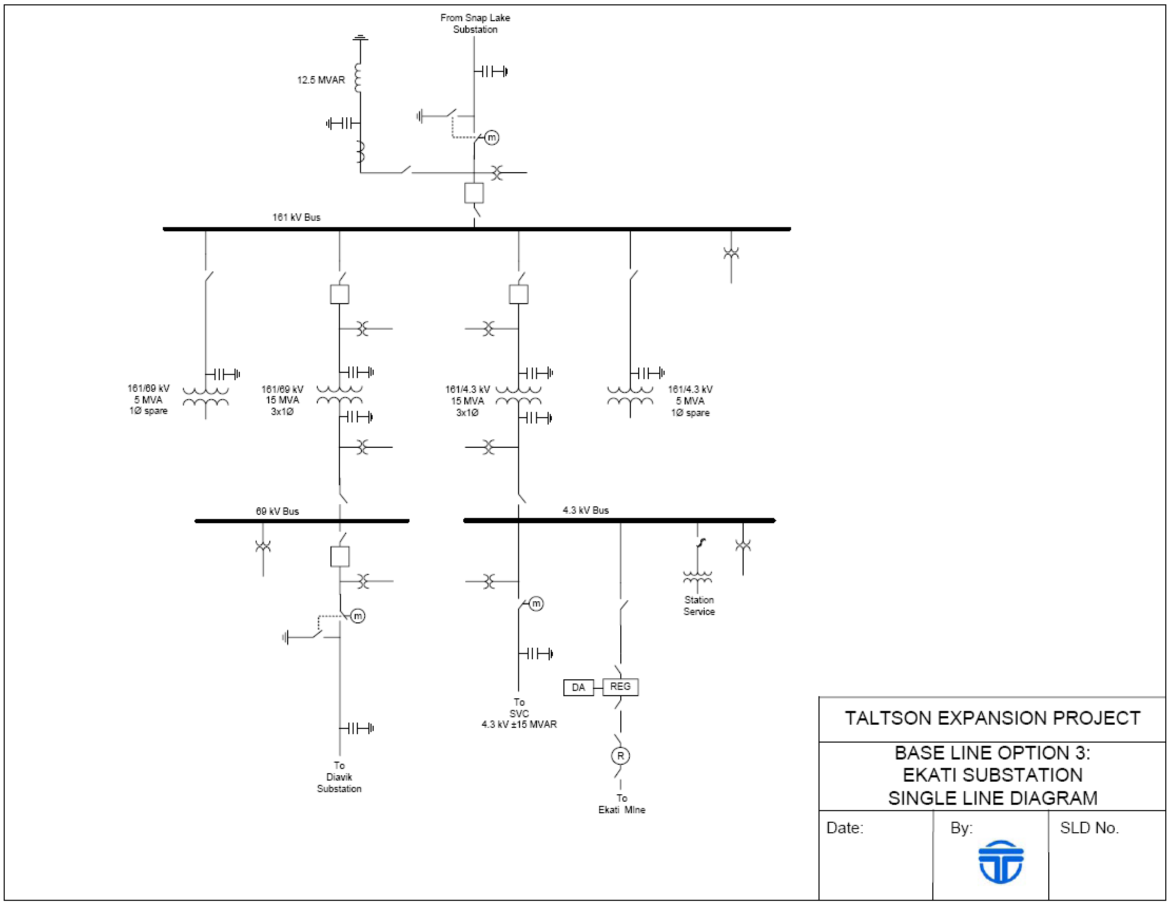
BASE LINE OPTION 3:
TWIN GORGES POWERHOUSE
SINGLE LINE DIAGRAM

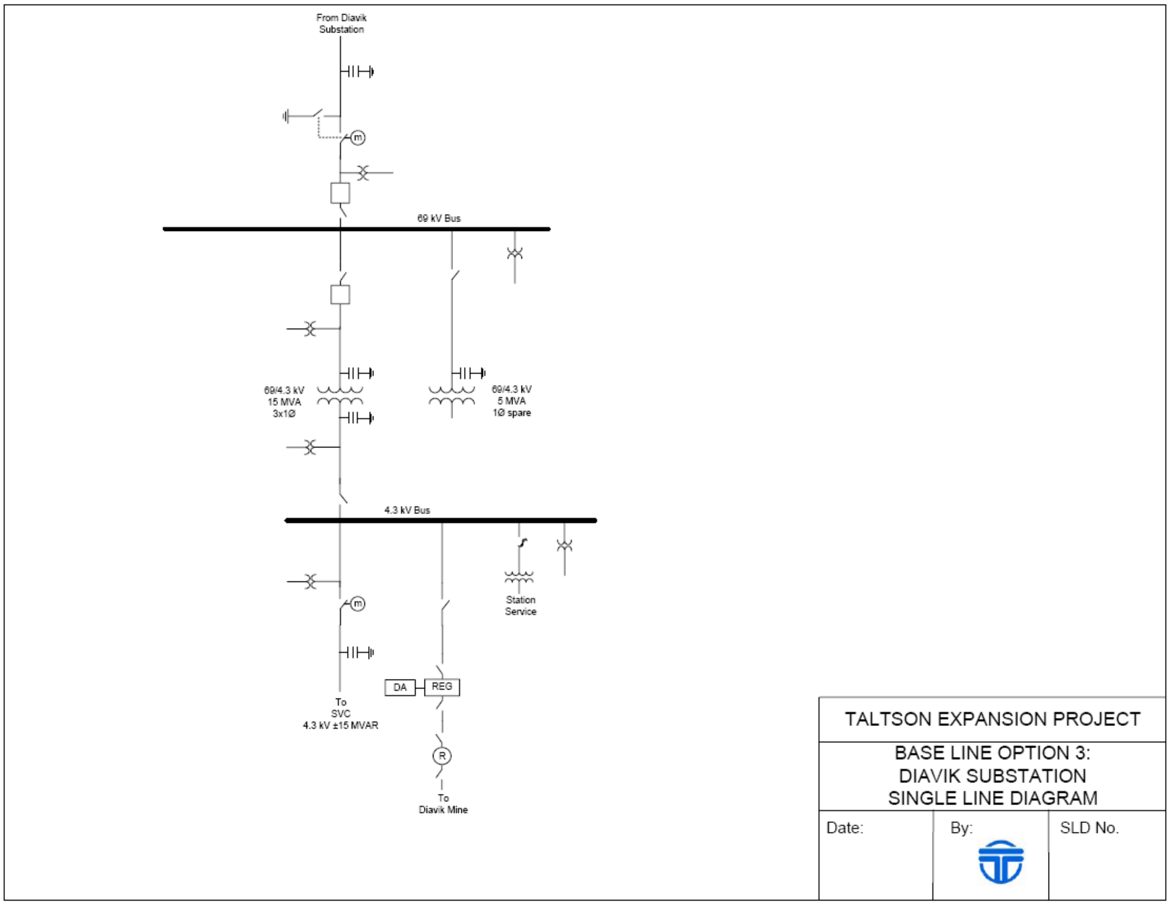
Date:	By:	SLD No.


From Twin Gorges G3
From Twin Gorges G2
115 kV Bus
Station Service
161/115 kV 16.6 MVA 1Ø spare
161/115 kV 50 MVA 3x1Ø
161 kV Bus
11 MVAR
To Gahcho Kue Substation
TALTSON EXPANSION PROJECT
BASE LINE OPTION 3:
TWIN GORGES SUBSTATION
SINGLE LINE DIAGRAM
Date:
By:
SLD No.

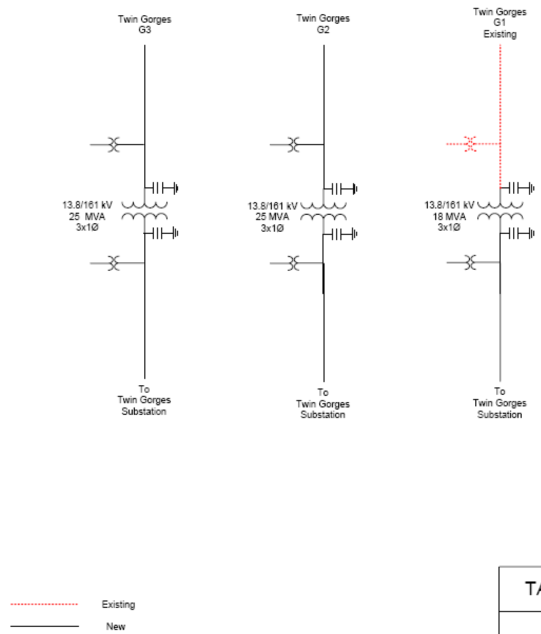

From Twin Gorges Substation
To Snap Lake Substation
23 MVAR
161 kV Bus
161/4.3 kV
15 MVA
3x1Ø
161/4.3 kV
5 MVA
1Ø spare
4.3 kV Bus
Station Service
To SVC 4.3 kV ±15 MVAR
DA
REG
R
To Gacho Kue Mine
TALTSON EXPANSION PROJECT
BASE LINE OPTION 3:
GACHO KUE SUBSTATION
SINGLE LINE DIAGRAM
Date:
By:
SLD No.


From Gacho Kue Substation
To Ekati Substation
8 MVAR
161 kV Bus
161/4.3 kV
17.5 MVA
3x1Ø
161/4.3 kV
5.8 MVA
1Ø spare
4.3 kV Bus
Station Service
DA
REG
To SVC 4.3 kV ±15 MVAR
R
To Snap Lake Mine
TALTSON EXPANSION PROJECT
BASE LINE OPTION 3:
SNAP LAKE SUBSTATION
SINGLE LINE DIAGRAM
Date:
By:
SLD No.


From Snap Lake Substation
12.5 MVAR
161 kV Bus
161/69 kV
5 MVA
1Ø spare
161/69 kV
15 MVA
3x1Ø
161/4.3 kV
15 MVA
3x1Ø
161/4.3 kV
5 MVA
1Ø spare
69 kV Bus
4.3 kV Bus
Station Service
DA
REG
R
To Diavik Substation
To SVC 4.3 kV ±15 MVAR
To Ekati Mine
TALTSON EXPANSION PROJECT
BASE LINE OPTION 3:
EKATI SUBSTATION
SINGLE LINE DIAGRAM
Date:
By:
SLD No.


From Diavik Substation
69 kV Bus
69/4.3 kV
15 MVA
3x1Ø
69/4.3 kV
5 MVA
1Ø spare
4.3 kV Bus
Station Service
DA
REG
To
SVC
4.3 kV ±15 MVAR
R
To
Diavik Mine
TALTSON EXPANSION PROJECT
BASE LINE OPTION 3:
DIAVIK SUBSTATION
SINGLE LINE DIAGRAM
Date:
By:
SLD No.

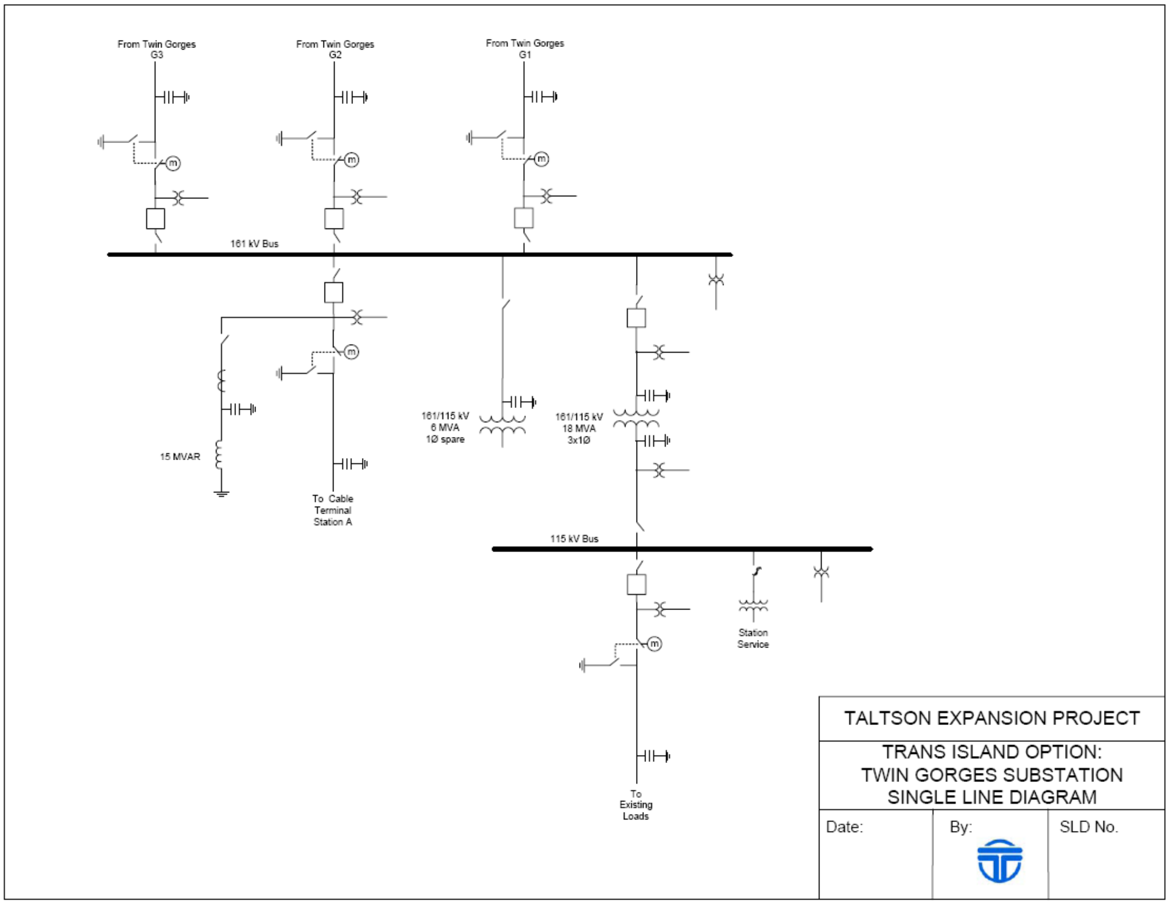
Appendix H
TRANS-ISLAND OPTION SUBSTATION LAYOUTS

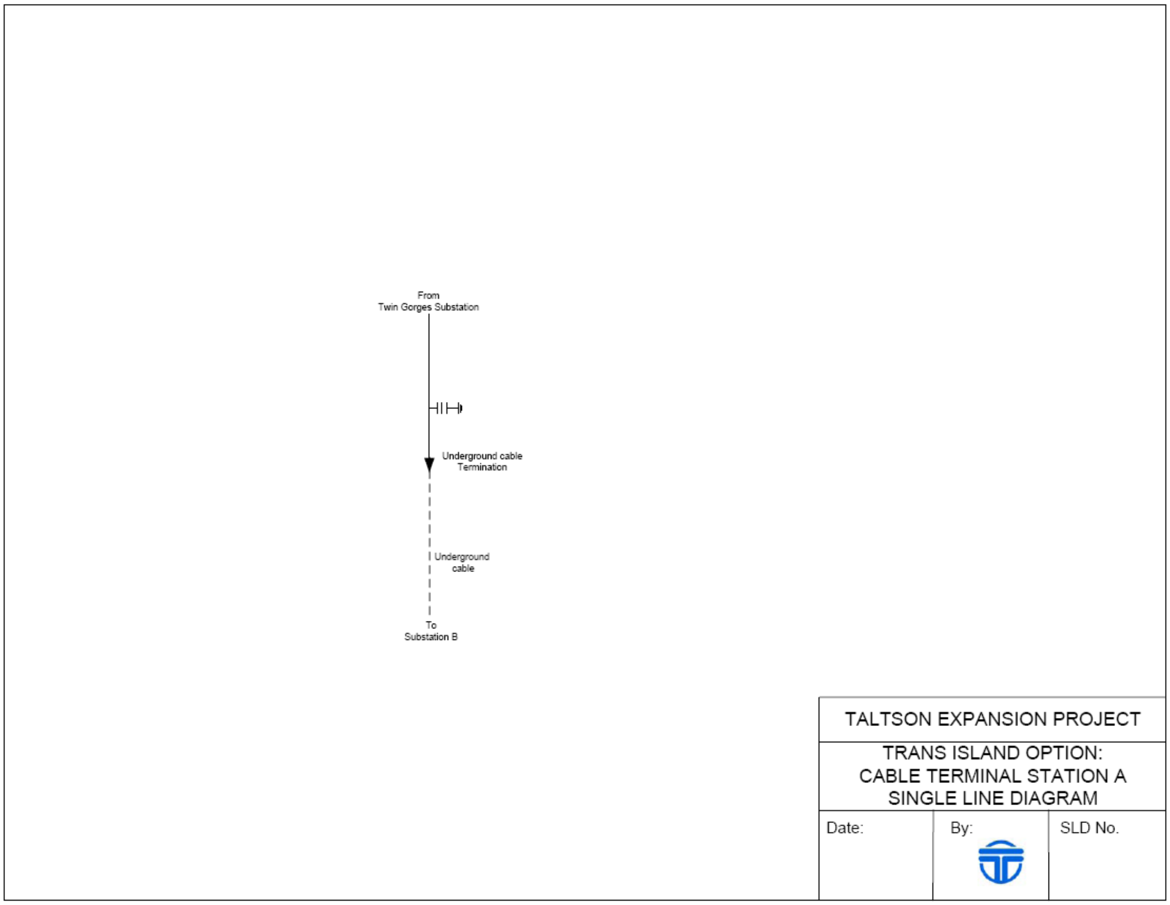


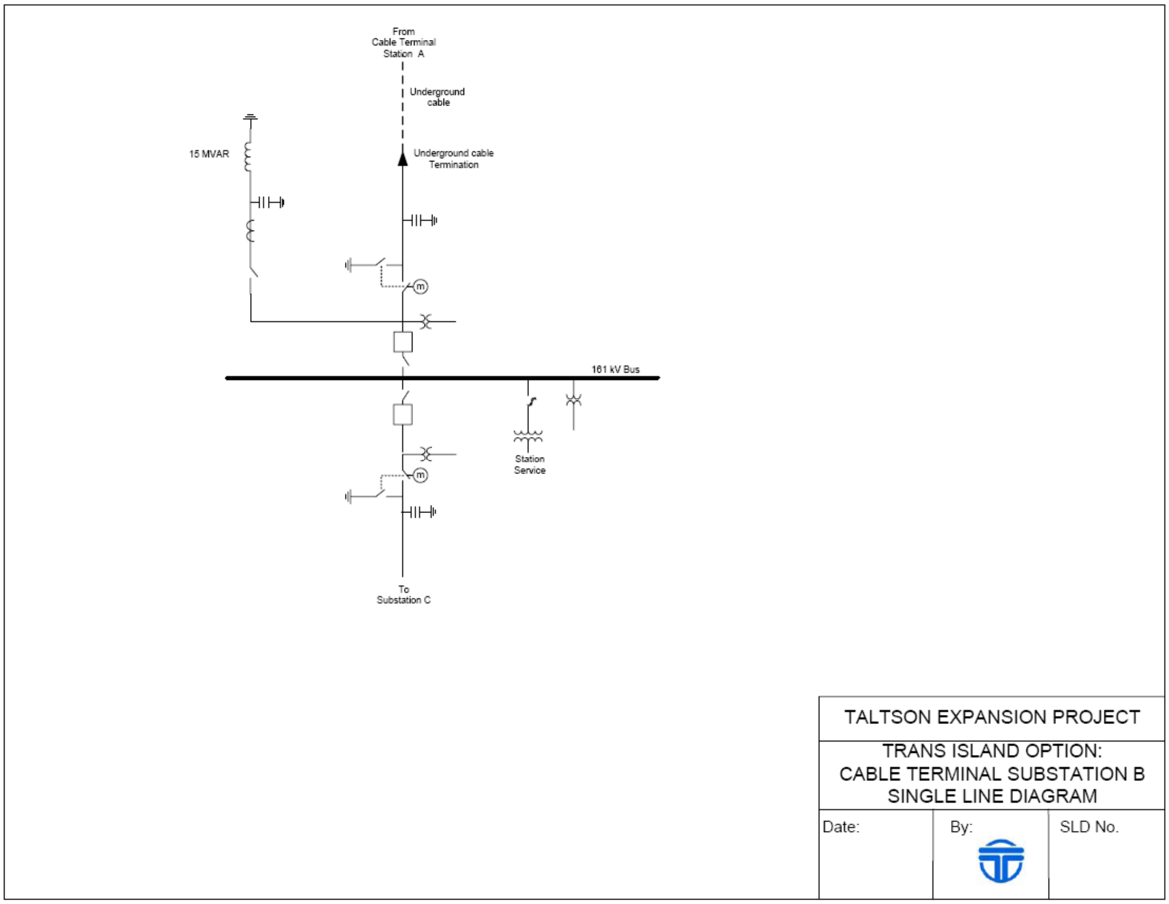
TALTSON EXPANSION PROJECT

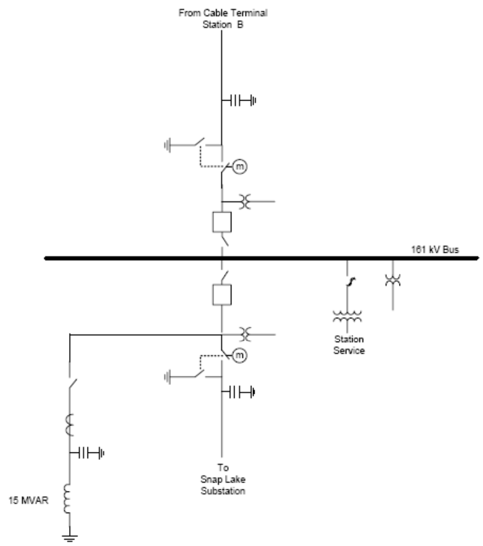
TRANS ISLAND OPTION:
TWIN GORGES POWERHOUSE
SINGLE LINE DIAGRAM

Date:	By:	SLD No.

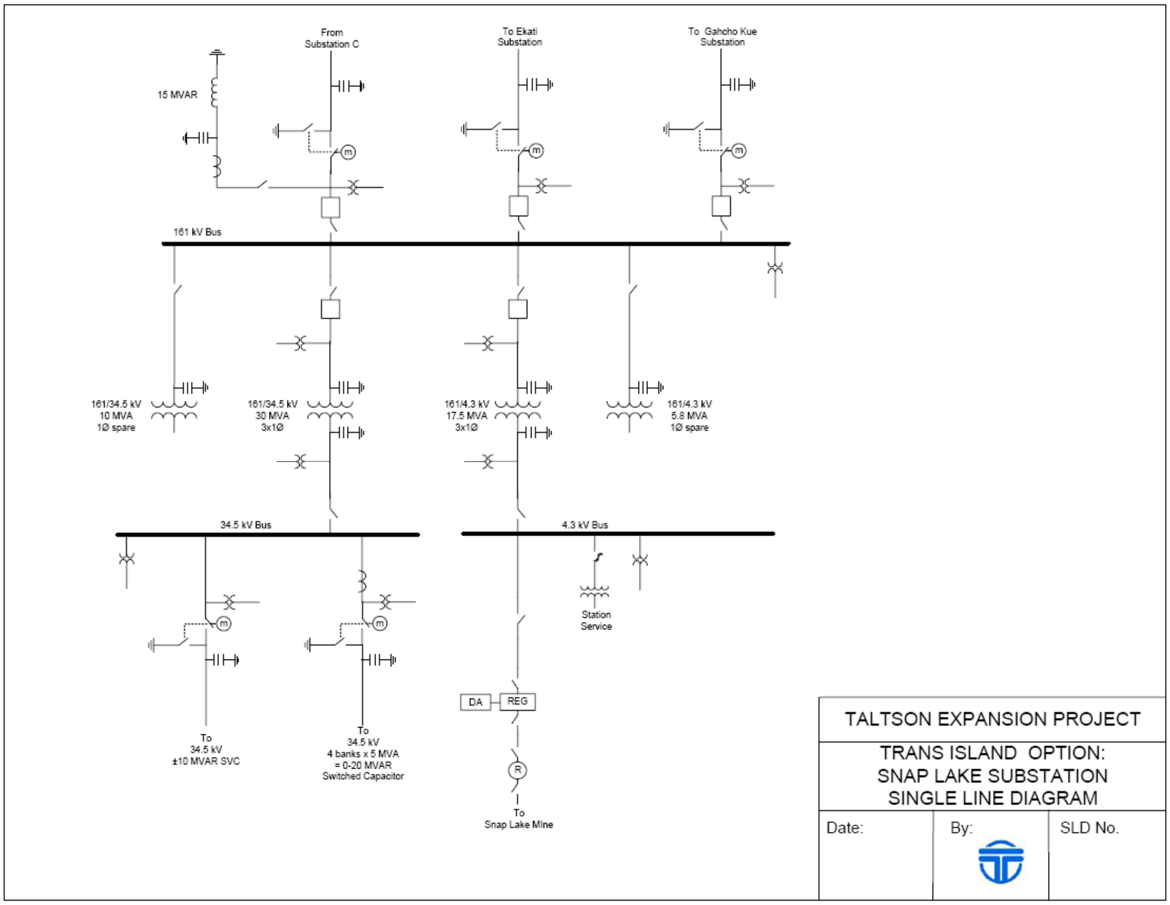

From Twin Gorges G3
From Twin Gorges G2
From Twin Gorges G1
161 kV Bus
15 MVAR
To Cable Terminal Station A
161/115 kV 6 MVA 1Ø spare
161/115 kV 18 MVA 3x1Ø
115 kV Bus
Station Service
To Existing Loads
TALTSON EXPANSION PROJECT
TRANS ISLAND OPTION:
TWIN GORGES SUBSTATION
SINGLE LINE DIAGRAM
Date:
By:
SLD No.

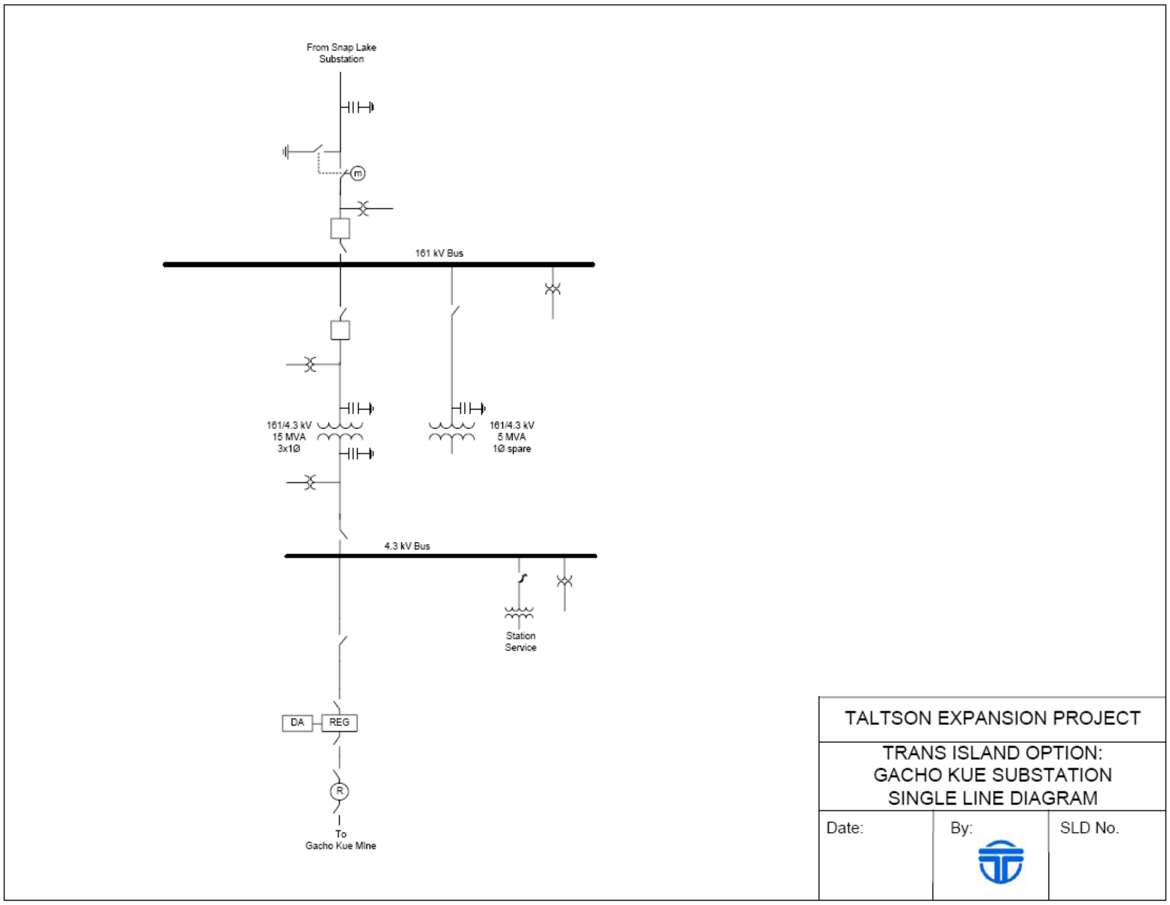

From
Twin Gorges Substation
Underground cable
Termination
Underground
cable
To
Substation B
TALTSON EXPANSION PROJECT
TRANS ISLAND OPTION:
CABLE TERMINAL STATION A
SINGLE LINE DIAGRAM
Date:
By:
SLD No.

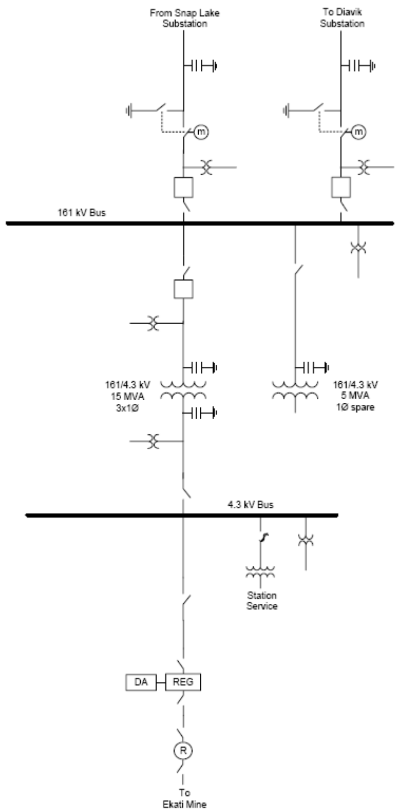

From
Cable Terminal
Station A
Underground
cable
15 MVAR
Underground cable
Termination
161 kV Bus
Station
Service
To
Substation C
TALTSON EXPANSION PROJECT
TRANS ISLAND OPTION:
CABLE TERMINAL SUBSTATION B
SINGLE LINE DIAGRAM
Date:
By:
SLD No.



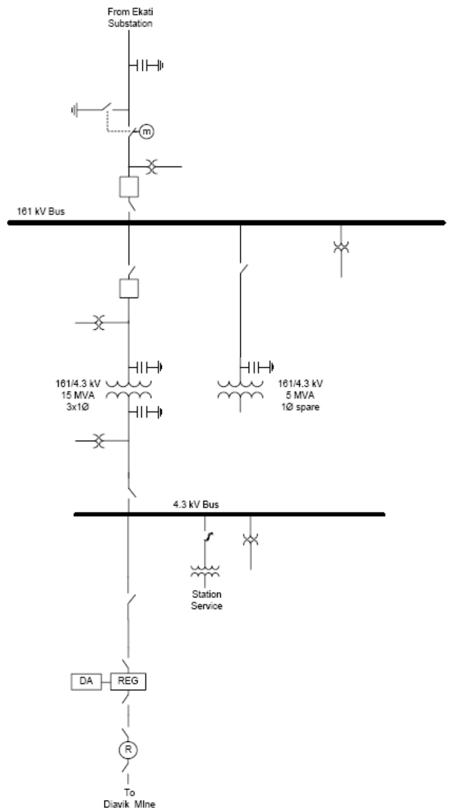
TALTSON EXPANSION PROJECT		
TRANS ISLAND OPTION: SUBSTATION C SINGLE LINE DIAGRAM		
Date:	By:	SLD No.


From
Substation C
To Ekati
Substation
To Gahcho Kue
Substation
15 MVAR
161 kV Bus
161/34.5 kV
10 MVA
1Ø spare
161/34.5 kV
30 MVA
3x1Ø
161/4.3 kV
17.5 MVA
3x1Ø
161/4.3 kV
5.8 MVA
1Ø spare
34.5 kV Bus
4.3 kV Bus
Station
Service
To
34.5 kV
±10 MVAR SVC
To
34.5 kV
4 banks x 5 MVA
= 0-20 MVAR
Switched Capacitor
DA
REG
R
To
Snap Lake Mine
TALTSON EXPANSION PROJECT
TRANS ISLAND OPTION:
SNAP LAKE SUBSTATION
SINGLE LINE DIAGRAM
Date:
By:
SLD No.


From Snap Lake Substation
161 kV Bus
161/4.3 kV
15 MVA
3x1Ø
161/4.3 kV
5 MVA
1Ø spare
4.3 kV Bus
Station Service
DA
REG
R
To Gacho Kue Mine
TALTSON EXPANSION PROJECT
TRANS ISLAND OPTION:
GACHO KUE SUBSTATION
SINGLE LINE DIAGRAM
Date:
By:
SLD No.



TALTSON EXPANSION PROJECT		
TRANS ISLAND OPTION: EKATI SUBSTATION SINGLE LINE DIAGRAM		
Date:	By:	SLD No.



TALTSON EXPANSION PROJECT		
TRANS ISLAND OPTION: DIAVIK SUBSTATION SINGLE LINE DIAGRAM		
Date:	By:	SLD No.

Appendix I
LiDAR SURVEY SPECIFICATION

DEZÉ ENERGY CORPORATION
TALTSON TRANSMISSION EXPANSION PROJECT
TRANSMISSION ALTERNATIVES STUDY

LiDAR Survey Specification

Introduction

This Specification covers the airborne LiDAR terrain survey which shall be carried out along the centre line of Taltson transmission line system.

The line routes have been established by the Owner and will be presented to the Contractor in the form of full size line routes maps as shown in Appendices. The line route covers a total length of about _____ km.

The final collected LiDAR data given to the Contractor to the Owner shall be ready to be imported into PLS-CADD software for the development of a highly accurate three-dimensional digital terrain model. Each LiDAR point shall have a distinct coordinates Latitude, Longitude and Height or x, y, z values.

LiDAR Survey

The required laser swath width of the route for LiDAR survey along the line corridor shall be at least 500 m. For the LiDAR survey the Contractor shall use the state of the art equipments, qualified and experienced personnel. The Contractor shall employ HELIX airborne LiDAR System for this project. The equipments used for LiDAR survey shall be certified from Federal Aviation Administration (FAA) and Transport Canada to install on the aircraft which is going to be use in the project.

The Contractor shall be responsible for horizontal coordinate system and vertical datum required for the bare earth Digital Terrain Model (DTM). Prior to start of LiDAR survey, the Contractor shall establish all GPS ground control stations that will be required to perform the LiDAR survey. The physical requirement for each station is that it shall be monumented by a permanent and stable marker, and GPS observable with an unobstructed view of the sky to 10 degrees above the horizon. These stations shall also be located in unobstructed areas free from electrical and physical interference. To obtain the best possible accuracy of the LiDAR HELIX system, there should be a control point every 30 – 35 km down the survey corridor. The Contractor shall ensure that the locations of the stations along the line corridor shall be coordinated such a way that the best possible quality of GPS reference data is obtained.

During the airborne LiDAR survey, the Contractor shall also use digital camera to collect high resolution downward and forward looking color digital imagery. The downward collected imagery should be orthorectified and geo referenced to the co-ordinate system. This orthorectification process is required to remove any image distortion due to height changes and handles the overlap of images so that the entire corridor is delivered as a continuous strip mosaic suitable for PLS-CADD importing.

Following the LiDAR survey, the Contractor shall process all the collected raw data such that each laser point will have a three dimensional coordinate. The Contractor shall also be responsible to thin the ground points to only key ground points which will accurately reflects the ground surface with a minimum number of points.

Not less than 15 days prior to the commencement of the LiDAR survey, the Contractor shall submit the following to the Owner for review:

- Qualifications of all survey personnel,
- Work program,
- GPS ground control stations including their coordinated locations
- List of all survey equipment including their specifications e.g. LiDAR system, profile laser, GPS ground stations, digital camera etc.

Deliverables

The Contractor shall deliver to the Owner the following deliverables:

- The Aerial Laser Digital Ground Profile, DTM, on CD in a binary format. A binary to ASCII conversion program shall also be provided so that the data could be use in PLS-CADD software.
- Digital orthorectified images on CD or DVD in 24-bit colour Geo Tiff format or better.

Volume 2

Appendix J

ROUTE MAPS
BASELINE OPTION

Appendix K

ROUTE MAPS
TRANS-ISLAND OPTION

Appendix L

ROUTE MAPS
SUBMARINE CABLE OPTION

Appendix M

ROUTE MAPS
WEST ROUTE OPTION