CONTRACTOR FRONT SHEET

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LOWER CHURCHILL PROJECT

Contract Number and Description:	Contractor Name:
	Teshmont Consultants Inc.

Document Title:	Total Pages (Inc. Cover):
Gull Island to Soldiers Pond HVDC Interconnection Volume 1 - Engineering Review and Update of Capital Cost Estimate (June 1998)	**163**

Contractor Document Number	Contractor Rev.	Date	Contractor Approval – Name and Signature

Submitted For:	☐ INFO	☐ REVIEW	Nalcor Energy – Lower Churchill Project

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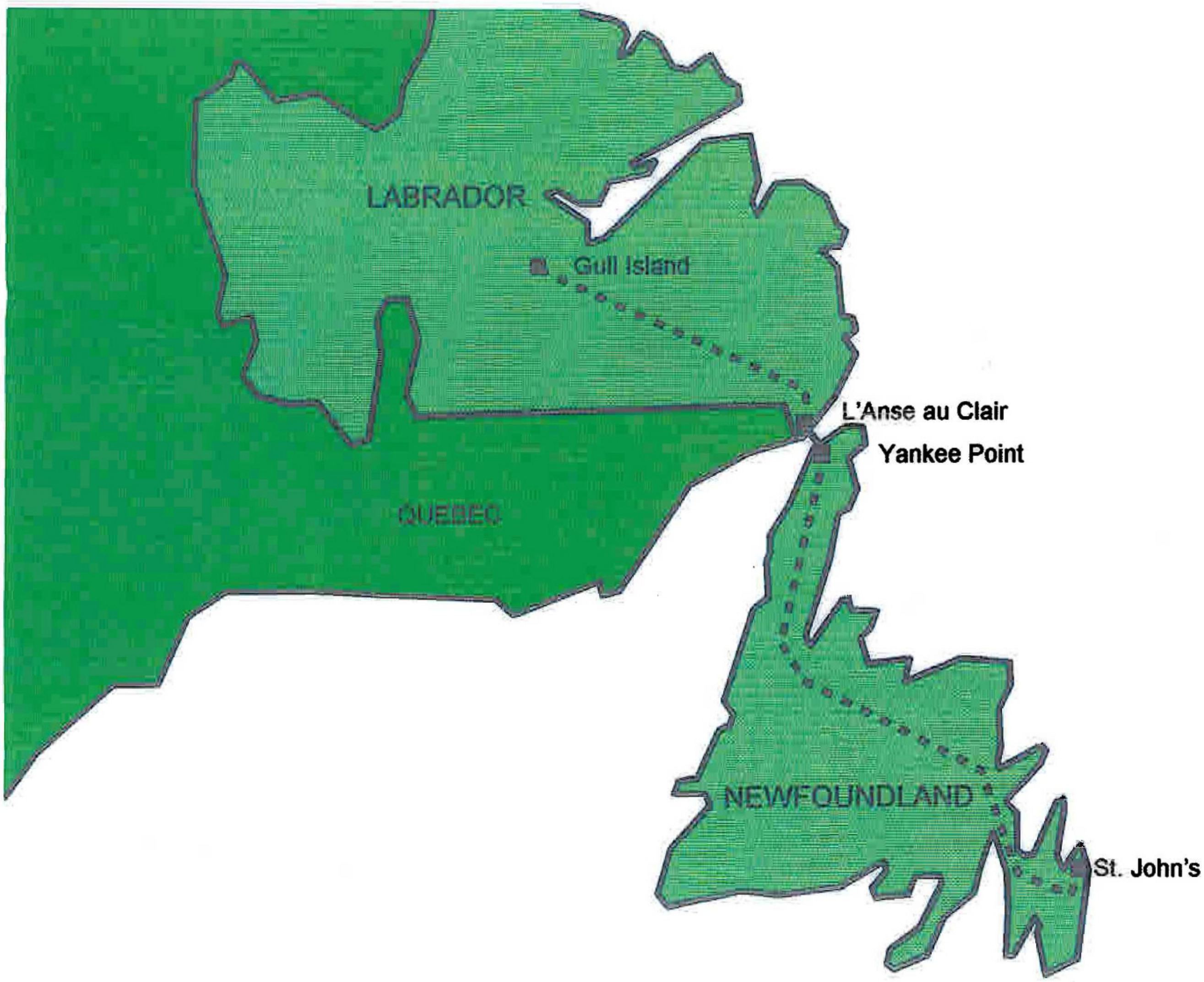
NE-LCP SIGNATURE: [signature]

DATE: March 2, 2011

NE – LCP DOCUMENT #:	Rev.
ILK-TM-CD-6200-TL-RP-0001-01	**B1**

NEWFOUNDLAND AND LABRADOR HYDRO

GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION



VOLUME 1

ENGINEERING REVIEW AND UPDATE OF CAPITAL COST ESTIMATE

Teshmont Consultants Inc.

June 1998

NEWFOUNDLAND AND LABRADOR HYDRO

GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION

VOLUME 1

ENGINEERING REVIEW AND UPDATE OF CAPITAL COST ESTIMATE

Teshmont Consultants Inc.
1190 Waverley Street
Winnipeg, MB R3T 0P4
Canada

June 19, 1998

Report Number 182-10000

NEWFOUNDLAND AND LABRADOR HYDRO
GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION

VOLUME 1

ENGINEERING REVIEW AND
UPDATE OF CAPITAL COST ESTIMATE

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1. EXECUTIVE SUMMARY

1.1 Introduction

Teshmont was engaged by Newfoundland and Labrador Hydro to carry out an engineering review of previous studies and update the cost estimate for the proposed HVDC Interconnection which will transmit up to 800 MW from the Gull Island Generating Plant in Labrador to a HVDC converter station at Soldiers Pond, near St. John's as shown in Figure 1-1.

This engineering review not only included consideration of earlier study work but also took into account recent advances in technology. The review resulted in some improvements to the base configuration compared with earlier studies.

The report summarizes the findings of the engineering review and provides an updated 1998 cost estimate and a cash flow for implementation of the transmission system. A master schedule for construction is also included. The labour requirements for the construction are given on an annual basis and estimated annual operating and maintenance costs are provided.

The capital cost estimates are based on a review of the engineering parameters established in earlier studies together with the configuration changes noted herein. Estimating prices were obtained from contractors and equipment manufacturers based on mini specifications and were used to arrive at the cost of each project component based on the selected configuration.

1.2 Summary

The conclusion of this engineering review is that, with current proven technology, the transmission of 800 MW from the Gull Island generating plant to Soldiers Pond is completely feasible and will improve the reliability of the supply of electricity to the customers on the Island of Newfoundland.

The review of cost estimates indicates that the system could be built for a capital cost based on 1998 Canadian dollars of $1,428,000,000 within an accuracy of ±10%.

1.3 Project Description

The main transmission facilities, shown on Figure 1-2, consist of the following:

- converter stations at Gull Island and Soldiers Pond
- 1088 km of overhead transmission line in Labrador and on the Island of Newfoundland
- 38 km of submarine cable and 3.7 km of land cable between L'Anse au Clair and Yankee Point
- communication system between converter stations with leased communication circuits as back-up

The HVDC transmission system will have a continuous rating at the Gull Island Converter Station of ±400 kV, 800 MW during the summer and 920 MW at low ambient temperatures during the winter and will deliver 744 MW and 845 MW respectively at Soldiers Pond. The AC switchyards at both converter stations will be at 230 kV.

The cable crossing of the Strait of Belle Isle will consist of three cables. There will be one cable for each pole plus a spare cable. The spare cable can be switched into either pole and will normally be connected to one of the poles to reduce the cable losses.

1.4 Changes to Previous Design of Interconnection

During the technical review some improvements were identified and incorporated which will improve the performance and reliability of the Interconnection and lower the overall costs. These changes are as follows:

- The valve groups will be designed for continuous and short time overload capability so that load shedding will not occur in the Newfoundland AC system for transient and permanent pole outages on the Interconnection.
- The DC converters will have a single valve group per pole rather than two groups per pole. This will reduce costs and provide a more reliable system compared to systems considered in previous studies.
- The DC line will be constructed with an overhead ground wire. The overhead ground wire will greatly reduce the number of transient pole faults from lightning strikes.
- The submarine cable crossing of the Strait of Belle Isle will consist of three submarine cables, each rated for 1500A. This rating allows continuous operation of up to 50% overload on each pole with a single cable. One cable is provided as a spare.

1.5 System Performance

The Interconnection will provide the equivalent of 744 MW of generation to the Island and the overload capability will enhance the performance of the Newfoundland AC system by reducing the number of occurrences of under-frequency load shedding.

The DC system will have a short-time monopole overload rating which will enable one pole to transmit up to 800 MW for about ten minutes following an outage of the other pole. This will be sufficient time for gas turbines to be started and the output of hydro units to be increased in Newfoundland and so avoid load shedding for this condition.

Each pole of the DC system will have a continuous overload current rating of 1500A. This will permit one pole to continuously transmit up to 528 MW to Soldiers Pond following an outage of the other pole. Thus only 216 MW of gas turbines or increased output of hydro units will be required in the event of a pole outage during full load operation of the bipole.

The performance of the Newfoundland AC system following the addition of the DC system is summarized as follows:

- for temporary or permanent faults on a DC pole (line, cable or converter) when the DC system is operating up to 800 MW, the DC system will continue to deliver full power to Soldiers Pond for a sufficient time period to allow start-up of local generation. Load shedding on the Island will not occur for this condition.

- load shedding may be required for pole faults if the DC system is operating at loadings above 800 MW during low ambient temperatures.

- if any generator in the Newfoundland AC system trips, the DC system will automatically increase power delivered to the Island so as to prevent load shedding.

- normally cleared (6 cycle duration) faults in the Newfoundland AC system will not require load shedding.

- load shedding may be required for faults in the Newfoundland AC system which are cleared by back-up protection.

- severe faults in the AC system near Gull Island will reduce the power transfer on the DC system and may require load shedding in the Newfoundland AC system if the fault is cleared by back-up protection.

The HVDC system will be designed to operate at reduced voltage (down to 70%) to permit transfer of power even if the DC line insulation is polluted by salt and cannot support full voltage.

1.6 DC Transmission Line

The transmission line for the HVDC interconnection will be a bipolar line operating at ±400 kV. There will be a single conductor per pole, with guyed tangent towers with I string insulation in light wind and ice loading areas and V string insulation in medium and heavy wind and ice loading areas.

The engineering review confirms the adequacy of the line routing and the line configuration previously established. Similarly for transmission of 800 MW, the voltage of ±400 kV previously selected is confirmed to be appropriate.

The values of wind and ice loading for the Long Range Mountain crossing and other line sections assumed in earlier reports were reviewed and it was confirmed that the originally recommended loadings are appropriate.

The transmission line design is based on a single AASC 54 mm diameter conductor.

The transmission line will have an overhead ground wire over its entire length for protection against outages due to lightning.

The electric field effects from the DC transmission line are within acceptable limits.

Porcelain or glass insulators are utilized in the design rather than composite insulators. Composite insulators are not considered as an alternative due to limited service experience on HVDC lines and lack of experience under heavy icing conditions.

Foundations and anchors for the guyed towers are based on design concepts utilized from previous studies and similar current projects. Terrain types and their distribution are based on aerial photography conducted for previous studies.

Transmission line cost and staffing estimates are based on detailed costs for each line section using manufacturers' and suppliers' estimated costs for materials, and contractors' and consultants' estimates for construction.

1.7 Converter Stations

Converter stations will be located near Gull Island, Labrador and at Soldiers Pond near St. John's. Each converter station will include an AC switchyard, DC converter equipment, converter building, DC switchyard, AC reactive compensation, other associated equipment and other buildings. The converters will have one valve group per pole.

The converter stations will have an AC bus voltage of 230 kV. A comparison of station costs for the Gull Island Converter Station indicated that using a bus voltage of 230 kV rather than 345 kV results in a significantly lower cost.

Breaker and one-third switching arrangements and SF_6 breakers will be used in the AC switchyards at each site. There will be four bays at Gull Island and six bays at Soldiers Pond. This switching arrangement is widely used in North America and is considered to be reliable and economical.

The cost estimates are based on a sea electrode in Lake Melville. The sea electrode for Soldiers Pond Converter Station has been assumed to be located near Holyrood.

1.8 Crossing of the Strait of Belle Isle

The crossing of the Strait of Belle Isle will consist of three submarine cables. The cables terminate at L'Anse au Clair in Labrador and Yankee Point on the Island of Newfoundland as shown on Figure 1-3. The length of the underwater crossing is 38 km and the length of land cables is 1.3 km and 2.4 km at L'Anse au Clair and Yankee Point respectively.

Solid type cables (mass impregnated) with paper insulation will be specified. Each cable will be rated at 400 kV, 1500A to correspond to the pole continuous overload rating of the converter equipment.

The submarine cables will be embedded to protect them against damage from icebergs, shore ice, shore wave action and fishing operations.

Cable embedment depths from previous investigations are summarized as follows:

Type of Material	Water Depth	Embedment Depth
Overburden	down to 70m	2.0m
Rock	down to 70m	2.0m
Overburden	below 70m	0.6m
Overburden less than 0.6m	below 70m	concrete mattresses

Previous investigations determined that it is necessary to protect against iceberg grounding where the water depth is less than 70m.

The bedrock at Yankee Point has a high compressive strength. However, contractors have confirmed that it is practical to trench in the rock by either using a trenching machine or by drilling and blasting.

1.9 Communications Systems

HVDC transmission systems require highly reliable and secure communications systems. The communication system is needed both for the normal steady-state control and for the implementation of modulation functions to enhance the performance of the AC systems. Voice communication between sites and communications to the SCADA control centre are also needed.

In addition to the control, SCADA and data circuits interconnecting the HVDC converter stations, SCADA and telephone connections will also be required to L'Anse au Clair and Yankee Point cable terminal stations on the Strait of Belle Isle and the Energy Control Centre in St. John's.

The cost estimates are based on the main communications link between all sites along the DC line being a new digital microwave system between Gull Island and Soldiers Pond which will be constructed as part of this project. Backup communications for the critical HVDC control functions will consist of leased circuits on an existing carrier. A communication system utilizing fibre optic cable in the overhead ground wire could be an alternative to the main microwave system.

1.10 Transportation and Logistics

Materials for the Labrador portion of the transmission line amounting to about 11850 tonnes will be delivered by truck or rail to Labrador City or by sea to Happy Valley - Goose Bay and transported to the Owners storage yard by truck.

Approximately 3500 tonnes of materials will be delivered to the Gull Island Converter Station. Heavy loads, consisting of seven converter transformers weighing up to 200 tonnes each, will be delivered to Goose Bay and transported to the converter station by CFLCo's transformer transporter.

In Newfoundland approximately 22,150 tonnes of material for the transmission line will be delivered to the appropriate ports and from there to the transmission line by truck.

Approximately 3500 tonnes of various materials for the Soldiers Pond Converter Station will be delivered by truck from St. John's. Heavy loads, consisting of seven converter transformers weighing up to 200 tonnes each and stators and rotors for two synchronous condensers (each weighing less than 200 tonnes), will be delivered by truck from St. John's.

Submarine cables will be delivered by the cable laying ship or by cargo ship. Spare submarine cable will be stored at a convenient location such as Corner Brook. Cable terminal materials will be delivered to Corner Brook and transported by truck to Yankee Point, Newfoundland and by truck and ferry to L'Anse au Clair, Labrador.

1.11 Project Staffing Requirements

Project staffing requirements for the Gull Island to Soldiers Pond HVDC Interconnection have been estimated to total about 26,000 person months. Details of the staffing requirement estimate are shown in Table 1-1.

The construction personnel requirements for the transmission lines are based on production rates and crew sizes required to complete each task in the given times.

The construction personnel staffing requirements for converter stations, cable terminal stations and the communication system are derived from construction and installation labour cost data. Manufacturing personnel and manufacturers supervisory personnel have not been included in the staffing requirements.

The construction personnel requirements for the submarine cable installation are based on construction cost data and estimates of the Canadian labour content. Foreign labour is not included in Table 1-1.

1.12 Cost Estimates

Cost estimates were prepared based on the costs obtained on other projects and prices obtained from AC and DC equipment manufacturers, cable suppliers and transmission line material suppliers and contractors. Costs for buildings, installation of equipment and construction reflect price levels in Labrador and Newfoundland.

The estimated cost of the Gull Island to Soldiers Pond HVDC Interconnection is $1428 million with a level of accuracy of ±10%. The costs are based on a January 1998 price level.

The estimated costs of the major components of the Interconnection are given in Table 1-2 and the estimated cash flow for the construction of the Interconnection is given by quarter in Table 1-3.

1.13 Contingencies

A contingency of 10% is included for the DC transmission lines and converter stations. The contingency for the submarine cable is 13% based on the risk evaluation.

1.14 Project Schedule

The project schedule shows a duration of five years and three months to completion. The HVDC system is scheduled to be complete and in service shortly after the first Gull Island generators are available. Figure 1-4 shows the master schedule for the project.

1.15 Activities Prior to Project Release

Some activities should be completed prior to Project Release in order to optimize the design, refine the system performance and maintain the overall project schedule. The results of these activities will not affect the feasibility of the Interconnection but should enable refinements to the design and thus reduce the overall project cost. These activities are as follows:

a) Investigate the integration of the DC system into the Island AC system to establish:

- loss of load probability and overall system reliability
- overload ratings of the DC system
- reactive compensation
- AC system reinforcements
- generation dispatch criteria
- loading shedding scheme
- AC system fault survey

b) Investigate the integration of the DC system into the Labrador AC system including:

- system operation including power interchange with Churchill Falls and Quebec
- reactive power requirements at Gull Island Converter Station
- integration of Muskrat Falls Generating Station

c) Investigate the DC transmission line design in the Long Range Mountains area to establish if there should be two monopolar lines on different routes or a strengthened bipolar line.

d) Investigate the DC transmission line design to establish if it is preferable to use tubular steel towers to reduce the effect of ice loading or use lattice steel towers.

e) Review and finalize the DC transmission line mechanical loading using the additional ice loading information now available.

f) Investigate the use of a compact conductor to provide lower electrical resistance and possible reduced wind loading.

g) Investigate insulator contamination due to salt pollution.

h) Establish the location of electrodes for the Gull Island and Soldiers Pond Converter Stations. At Gull Island, initial investigations are needed to establish if a land electrode is feasible and, if so, locate a suitable site.

i) Establish submarine cable embedment depths in various sea bottom materials.

j) Finalize the submarine cable route by:

   i) establishing if Yankee Point is the most appropriate landing site on the Island by conducting further surveys of the coast south of Yankee Point including determining if there are areas where the rock is easier to trench.

   ii) conducting a detailed survey of the selected route to define the route and provide information for the submarine cable specification. This will include investigation of seabed bathymetry, sub-bottom material and obstacles and debris and will use a narrow beam echo sounder, side scan sonar and high resolution multi-beam sonar and a penetrating echo sounder.

k) Establish if the main communication link for the Interconnection should be by microwave or by fibre optic cable located in the overhead ground wire.

GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION

TABLE 1-1

STAFFING ESTIMATE
PERSON MONTHS

Activity Description	Years				In Service Date ↓		Person Months
	1	2	3	4	5	6	
Pre-Project Release Investigation [1]							144
Transmission Line [2] [3]	144	908	4044	3095	348	0	8539
Converter Stations [2] [3]	0	0	373	3044	2779	0	6196
Cable and Cable Terminals [2]	10	45	524	410	0	0	989
Communications [2]	0	30	127	153	0	0	310
Subtotal	154	983	5068	6702	3127	0	16178
Management & Engineering [1]	850	1919	3094	2738	1075	194	9870
Total Person Months/Year	1004	2902	8162	9440	4202	194	
					Total Person Months		26048

Notes:

1) Calculation of person months is based on 160 hr/month
2) Calculation of person months is based on 237 hr/month in Labrador and remote areas of Newfoundland
3) Calculation of person months is based on 194 hr/month at Soldiers Pond and in accessible areas of Newfoundland

GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION

TABLE 1-2

PROJECT COST ESTIMATE
(January 1998 Cost Level)

Item	Amount (Million $)
Pre-Project Release Investigations	4
Transmission Line	275
Converter Stations	508
Submarine Cable	299
Communications	82
Contingency	126
Project Management and Engineering	134
Total	1428

GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION

TABLE 1-3

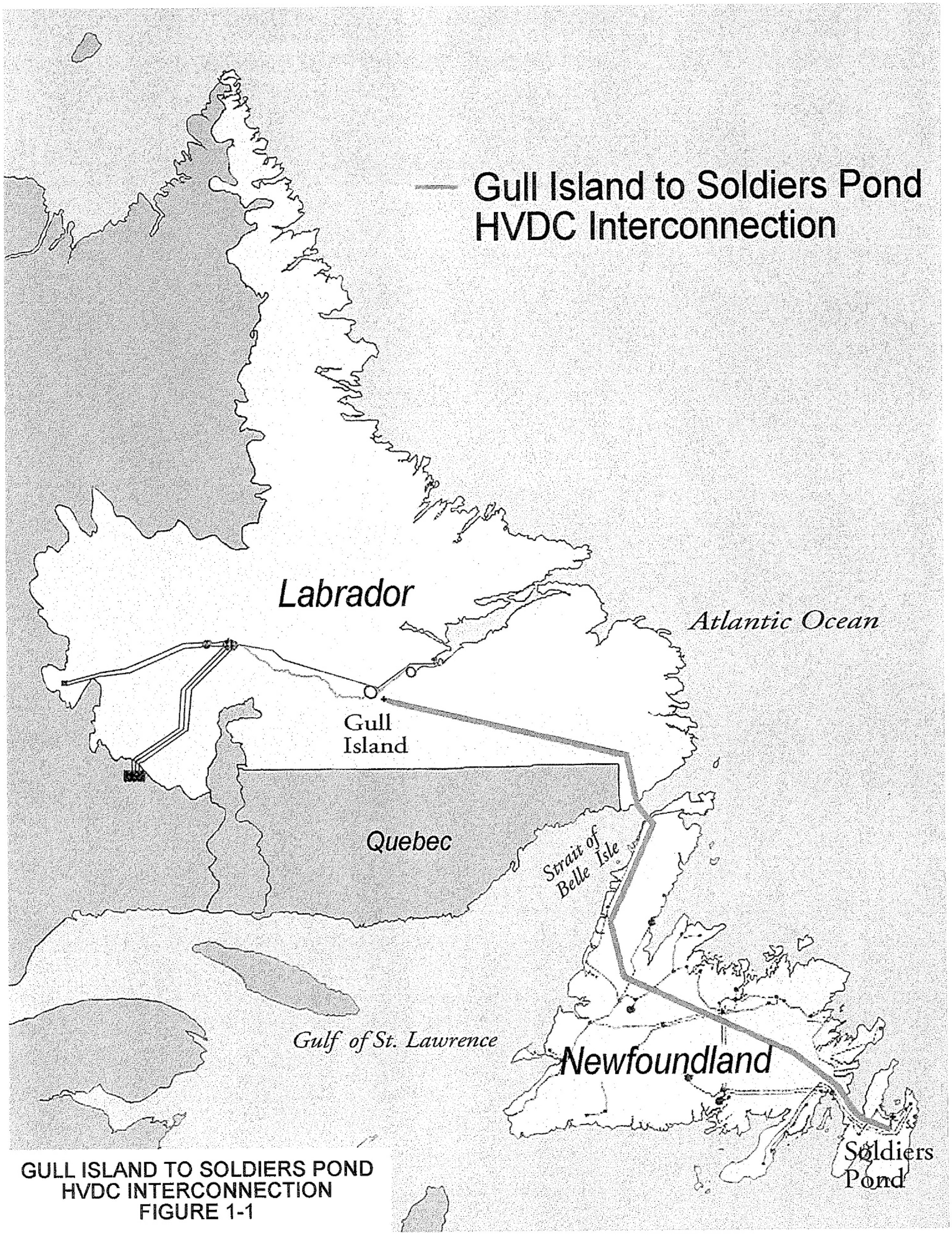
PROJECT ESTIMATED CASH FLOW
(MILLION $)
(January 1998 Cost Level)

Item	Amount	Year 1				Year 2				Year 3				Year 4				Year 5				Year 6			
		Quarters				Quarters				Quarters				Quarters				Quarters				Quarters			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Transmission Line	302				12	22	33	33	36	42	30	15	11	17	15	13	11	9	3						
Converter Stations	559								10	36	47	50	52	53	60	65	66	58	53	9					
Submarine Cable	339		2	2			1	1		35	63	71	44	38	33	38	11								
Communications	90									1	6	7	2	2	12	12	5	7	15	15	6				
Project Management and Engineering	138 *	2	2	3	3	4	5	8	9	10	10	10	10	10	10	10	10	7	5	2	2	1	1		
Total	1428	2	4	5	15	26	39	42	55	124	156	153	119	120	130	138	103	81	76	26	8	1	1	0	0

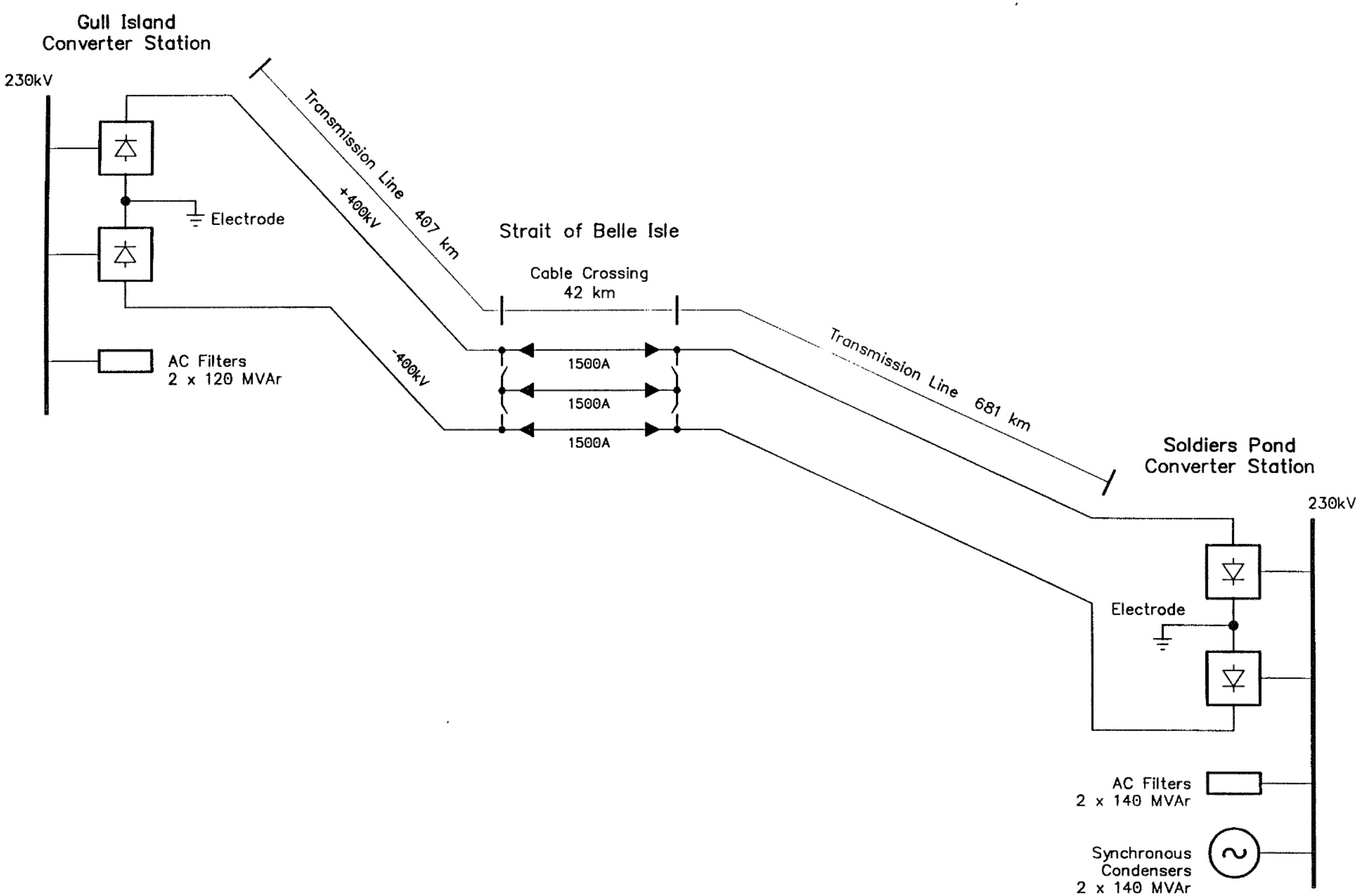
Notes:

1. Pole 1 in service January, Year 6
2. Pole 2 in service March, Year 6
3. Cash flow amounts include contingency

* Includes $4 million for pre-project release investigations.



GULL ISLAND TO SOLDIERS POND
HVDC INTERCONNECTION
FIGURE 1-1



Gull Island to Soldiers Pond HVDC Interconnection
±400 kV, 800 MW
Single Line Diagram
Figure 1-2

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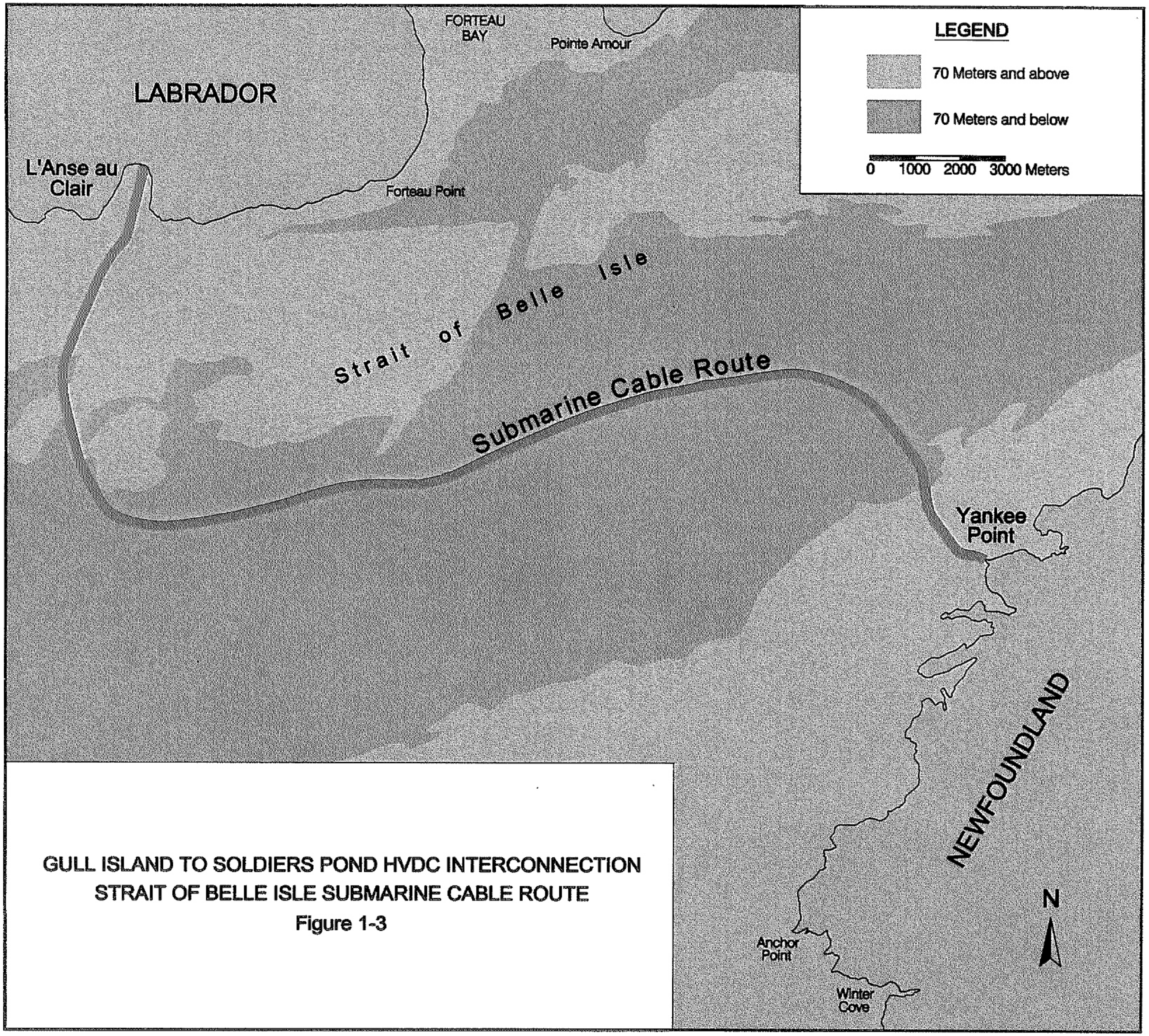
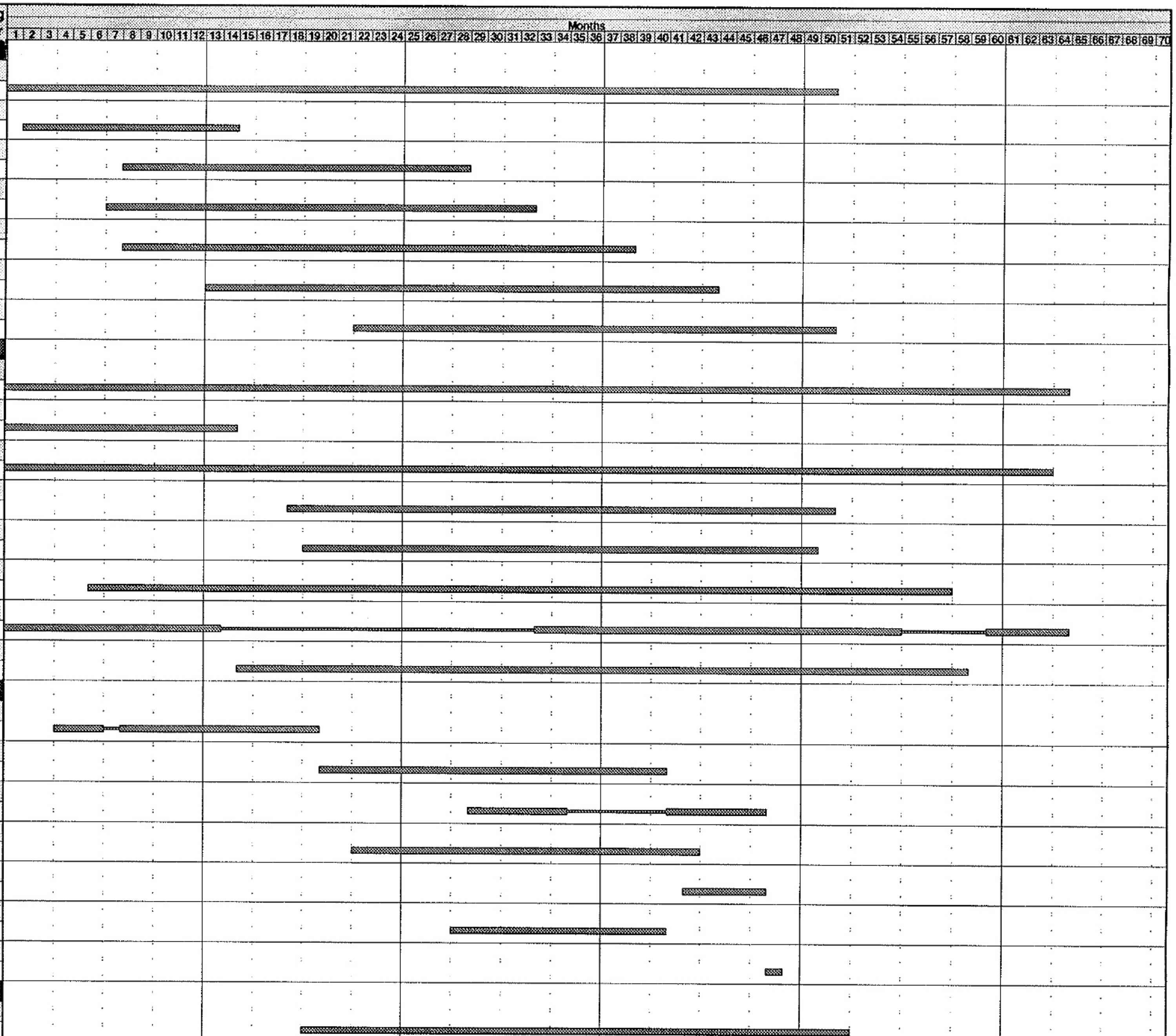


GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION
STRAIT OF BELLE ISLE SUBMARINE CABLE ROUTE
Figure 1-3

Activity Description	Orig Dur
400 KV HVDC SINGLE BIPOLE TRANSMISSION LINE	
+ Engineering & Design	50
+ Survey	13
+ Clearing & Access Roads	21
+ Foundations & Anchors	26
+ Towers	31
+ Conductor	31
+ Construction Contract	29
HVDC CONVERTER STATION	
+ System Studies	64
+ Environmental & Regulatory	14
+ HVDC Converter Equipment Supply/Install	63
+ Converter Station	33
+ Converter Building	31
+ Synchronous Condensers & Auxiliaries	52
+ Ground Electrode & Electrode Line	64
+ AC/DC Switchyards	44
SUBMARINE CABLE CROSSING	
+ Preliminary Work	16
+ Cable Manufacturing	21
+ Cable Laying	18
+ Termination Buildings	21
+ Shore Cable	5
+ Cable Storage Facility	13
+ Testing Cable	1
COMMUNICATIONS	
+	33



Project Start	01-JAN-98
Project Finish	30-APR-03
Data Date	01-JAN-98
Plot Date	18-JUN-98

Early Bar

Progress Bar

182G

Sheet 1 of 1

GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION

Master Project Schedule

Figure 1-4

2. INTRODUCTION AND SCOPE OF WORK

2.1 Introduction

On January 14, 1998 Newfoundland and Labrador Hydro (NLH) authorized Teshmont Consultants Inc. (Teshmont) to carry out an engineering review and to update the capital cost estimate of the ±400 kV, 800 MW DC interconnection between the Gull Island Generating Plant in Labrador and a station at Soldiers Pond, near St. John's, on the Island of Newfoundland. The capital cost estimate is to be provided in January 1998 Canadian dollars, with an accuracy of ±10%.

The interconnection was first proposed in the mid 1970's, and further investigations were carried out in the early 1980's. This report is based largely on the earlier work but technical aspects are reviewed to ascertain whether they are still valid in light of current technology. This report builds on the previously confirmed technical feasibility of the project and provides significant enhancement over schemes considered in earlier reports.

2.2 Scope of Work

The scope of work for the engineering review and cost update of the Interconnection was defined by NLH and includes the following:

- selection of ratings of the DC system and review of system performance to ensure the DC transmission system is properly integrated into the AC systems in Labrador and the Island of Newfoundland
- the design of the converter stations at Gull Island and Soldiers Pond, including selection of 230 kV or 345 kV as the converter station AC voltage
- comments on a monopolar configuration for the DC system as an alternative to a bipolar configuration
- confirmation of ±400 kV as the voltage for the DC system
- design of the DC transmission line in Labrador and on the Island including confirmation of transmission line rating, conductor size, loading conditions and comments on the requirements for an overhead shield wire
- location and design of electrodes for the DC system
- submarine cable routing, number of cables, rating of cables and mechanical protection
- communication system between converter stations and cable terminal stations and the SCADA system
- detailed master schedule for the construction of the Interconnection
- construction method with recommendations on contract packaging
- estimate of labor requirements on an annual basis
- operating and maintenance costs
- capital cost estimates with a quarterly cash flow
- risk/contingency analysis of costs

Areas which are not included in the work are:

- AC transmission lines
- environmental issues
- native peoples issues

2.3 Report Organization

The report on the work is presented in two volumes.

Volume 1

Chapter 1 is the executive summary, which includes a brief description of the project, identifies the main technical issues and contains a summary capital cost estimate.

Chapter 2 outlines the scope of work for the engineering review and the update of the cost estimate.

Chapter 3 describes the technical issues.

Chapter 4 contains the cost estimate, the contract packaging, and the risk analysis.

Chapter 5 provides the project schedule.

Chapter 6 lists the references.

Volume 2

Chapter 1 contains the results on the investigations into load shedding on the Island, the DC system transient overload and reactive power requirements at Soldiers Pond Converter Station.

Chapters 2, 3 and 4 contain the requests for estimating prices, responses from manufacturers and contractors and cost details for the DC transmission line, converter stations and submarine cables respectively.

Chapter 5 contains the communication system detailed costs obtained from Newfoundland and Labrador Hydro.

Chapter 6 gives the breakdown for determining the cost of management and engineering.

3. TECHNICAL REVIEW

3.1 DC System

3.1.1 Description

The Gull Island to Soldiers Pond HVDC Interconnection is a bipolar ±400 kV, 800 MW DC transmission system. The transmission route is shown in Figure 3.1-1 and power circuit diagram is shown in Figure 3.1-2.

The major facilities comprising the project are:

Converter Stations	Gull Island	Soldiers Pond
• Continuous bipolar power rating		
· normal ambient rating	800 MW	744 MW
· low ambient rating	920 MW	845 MW
• Short time monopolar power rating (10 minutes)		
· normal ambient rating		744 MW
· low ambient rating		744 MW
• Continuous monopolar overload rating following ramping down from short time overload		
· maximum ambient		528 MW
· low ambient		528 MW
• AC Filter Banks at Gull Island	2 x 120 MVAr	
• AC Filter Banks at Soldiers Pond		2 x 140 MVAr
• Synchronous Condensers at Soldiers Pond		2 x 140 MVAr

DC Transmission Line

• Transmission line ±400 kV, one 54 mm diameter 2312 kcmil AASC conductor per pole, overhead shield wire	
· Gull Island to L'Anse au Clair	407 km
· Yankee Point to Soldiers Pond	681 km
Total Transmission Line Length	1088 km

Cable Crossing of Strait of Belle Isle

• Three land and submarine cables between L'Anse au Clair, Labrador and Yankee Point, Island of Newfoundland	
• Rating of each cable	400 kV, 1500 A

- Cable length (per cable)
  - Land cable length to L'Anse au Clair Terminal Station — 1.3 km
  - Submarine cable L'Anse au Clair to Yankee Point — 38 km
  - Land cable length at Yankee Point Terminal Station — 2.4 km
  - Total Cable Length — 41.7 km
- Total Transmission Distance (line and cables) — 1130 km

Communication System

- Microwave system between Gull Island Converter Station and Soldiers Pond Converter Station with connection to cable terminal stations at L'Anse au Clair and Yankee Point and NLH Control Centre
- Back-up communication system by leased circuits between Gull Island Converter Station and Soldiers Pond Converter Station

3.1.2 Rating of DC System

a) Normal Continuous Power Rating

The nominal power rating of the DC system is 800 MW. This is the rating at the DC line terminals of the Gull Island Converter Station and is available at maximum ambient temperature conditions. The power delivered to the AC bus at the Soldiers Pond Converter Station is 744 MW, based on 7% transmission losses. Transmission losses during monopolar operation are assumed to be 8% taking into account additional resistance of the electrode lines and electrodes.

The nominal current rating of the DC system is 1000 A per pole.

b) Low Ambient Temperature Continuous Power Rating

The nominal ratings of the DC system are based on a maximum 24 hour average ambient temperature of 30°C as per the ANSI standards. This temperature would be revised to reflect conditions at Gull Island and Soldiers Pond when the converter equipment specification is prepared.

A higher continuous power rating is available when the ambient temperature is substantially below the maximum values used in the design. For the rating of the DC system, the converter transformers are the main items affected by 24 hour average ambient temperature.

When the 24 hour average ambient temperature is below 15°C, the power rating can be increased by 15% to 920 MW at Gull Island (845 MW at Soldiers Pond) without exceeding the allowable transformer hot spot temperature.

This low ambient temperature rating is the same as has been assumed in previous studies of the Interconnection.

c) Short Time Monopole Overload Rating

Each pole of the DC system will have a short time overload rating at maximum ambient temperature of 744 MW (2300A at about 325 kV) for about ten minutes at Soldiers Pond followed by a ramping down in five minutes to a continuous rating of 528 MW (1500A) at Soldiers Pond. This rating will be utilized following the outage of a pole. Figure 3.1-3 shows the short time overload rating.

This rating will permit one pole to transmit the pre-outage power of the bipole for a short time (10 minutes) following an outage of a pole.

The duration for which the short time overload rating is available will permit gas turbines to be started and the output of hydro units to be increased.

The short time monopole overload and continuous monopole overload capability will enable the Island AC system to operate without load shedding following a permanent pole fault. Based on previous experience with other DC systems, there could typically be about ten pole (line and station) permanent outages per year.

There is no additional short-time overload rating above 744 MW during low ambient conditions .

d) Continuous Monopole Overload Rating

Each pole of the DC system will have continuous overload rating of 1500 A at maximum ambient temperature.

This will permit one pole to transmit up to 528 MW at Soldiers Pond following an outage of the other pole. Thus, only about 216 MW of gas turbines or increased output of hydro units need be provided in the event of a pole outage during full load operation of the bipole. Without this continuous overload capability, 376 MW of generation would have to be brought into service following the loss of a pole when operating at rated power.

The actual amount of the fast start generation required and the continuous overload rating of each pole should be further optimized.

This "continuous" overload of about 50% is assumed to be required for a limited period only, that is, up to say three days for each occurrence. Most pole outages due to converter equipment mis-operation are of a much shorter duration typically less than 4 hours. Three days should be adequate for the infrequent event of replacing a major equipment item such as a converter transformer.

Higher converter transformer temperature rises will be permitted for the continuous overload. This results in some loss-of-life but is considered acceptable as the condition is infrequent and is for a short duration.

The standard design hot spot temperature for transformers is 110°C, based on a 24 hour average ambient of 30°C, an average winding rise of 65°C (measured by resistance) and a gradient between winding hot-spot and average winding temperature of 15°C. An overload of 50% will increase the hot-spot gradient above the average winding temperature to a value typically within the range of 25°C - 30°C. This temperature rise entails some loss-of-life.

The 50% overload is assumed to be utilized only when a pole is out of service and consequently no additional reactive power is required above that provided by the AC filters and synchronous condensers for bipolar operation.

e) Impact on AC System

It is understood that the DC system could operate so that it provides a higher proportion of the Island system load than was envisaged in earlier studies. For example, the DC system could be required to supply up to 80% of the total AC system load. In previous studies, the highest proportion of the AC system load that was supplied by the DC system was only 60 to 70%.

The impact of faults on the integrated AC/DC system during the initial years of operation of the DC system were investigated for this report. These studies included investigation of the drop of frequency for various fault conditions. The detailed results are described in Volume 2 of this report.

Based on the results of these studies and the parameters selected for the DC systems, the performance of the integrated AC/DC system is summarized as follows:

i) load shedding on the Island will not occur for a permanent or temporary pole fault when the bipole DC system is operating up to 800 MW.

ii) load shedding of about 130 MW may occur on the Island for a permanent pole fault when the bipole DC system is operating at the low ambient rating of 920 MW.

iii) load shedding will not occur on the Island for the loss of a generator on the Island.

iv) AC system faults on the Island (6 cycle duration) will not result in load shedding on the Island.

v) AC system faults on the Island which reduce DC transmission capability and are cleared by back-up protection are likely to result in load shedding on the Island.

It is assumed that gas turbine or increased output of hydro units will be provided within ten minutes in the event of a pole outage.

No investigations were carried out for AC system faults in the Gull Island area. The AC system in this area is strong and from the results of previous studies will have less impact than the fault conditions considered above.

Further investigation of the DC system rating and AC system operating conditions is required to properly optimize the DC system and its integration in the AC system.

In the existing AC system on the Island, load shedding results if there is loss of a larger generator unit. When the DC interconnection is added, the DC system will automatically increase its power transfer (up to its short time rating) and provide replacement power so that there is virtually no drop in frequency following the loss of a generator on the Island. This should significantly reduce the load shedding that currently occurs on the Island.

AC system faults on the Island or in Labrador depress the AC voltage at the converter stations and can reduce transmission on the DC system until the fault is cleared, typically for 50 to 100 ms and for the subsequent recovery period following the fault, typically an additional 50 to 100 ms. The AC system frequency on the Island will drop rapidly during such faults.

The impact of such faults depends, in part, on the DC system loading compared to the total AC system load and duration of the fault. In an extreme case where the DC system is operating at 800 MW and the system load on the Island is about 1000 MW, an AC system fault of 100 ms on the Island that affects the AC bus voltage at Soldiers Pond to the extent that DC power cannot be transmitted will result in the AC system frequency dropping to about 59 Hz. This is near the first level of load shedding, but no load shedding occurs. Some adjustments of Island load shedding settings may be necessary to ensure that load shedding will not occur for this situation. For faults cleared by backup protection (30 cycles) there will be extensive load shedding throughout the AC system. This may result in load shedding of about 120 MW based on the current load shedding scheme.

f) Reduced DC Voltage Operation

The DC system will be designed to operate down to 70% DC voltage (at correspondingly reduced power). This permits transmission of some power over the DC system during periods of reduced voltage withstand of the DC line insulators due to, for example, salt pollution on the DC transmission line.

During reduced voltage operation, the DC current may have to be reduced as well depending on the amount of reactive power available at the converter stations. Typically, 70% of normal DC voltage and 70% of rated current will result in the same amount of reactive power absorbed by the DC system as at full load.

3.1.3 Reactive Power Supply

The reactive power required by the DC converters will be supplied by:

Gull Island Converter Station

- Two 120 MVAr filter banks
- Gull Island generators

Soldier's Pond Converter Station

- Two 140 MVAr filter/capacitor banks
- Two 140 MVA local synchronous condensers
- Holyrood Unit # 3, operating as a synchronous condenser

At Gull Island, even though the vars available from the generators are more than the vars consumed by the converters, capacitive vars must still be supplied for AC filtering. To achieve an acceptable level of AC filtering, it is estimated that about 240 MVAr will be required. In the earlier studies, three filter banks were proposed to achieve the level of redundancy required for two bipoles. With only a single bipole, two filter banks of 120 MVAr each are considered adequate.

At Soldier's Pond, two basic design conditions have been considered:

- Operation at nominal rated power (800 MW at Gull Island) with an outage of any one of the reactive power supply components out of service (including Holyrood unit #3)
- Operation at the low ambient rated power transfer level (920 MW at Gull Island) with all reactive power supply components available for service

The var supply configuration proposed will provide:

- Sufficient vars for the DC converter and adjacent AC system
- A minimum equivalent short circuit ratio of 2.5
- Sufficient capacitive vars for AC filtering.

At both stations, the requirement for filter switching will be minimal. At Gull Island, the 2200 MWs of generation have sufficient var swing capability to cater to the variation in converter var consumption over the complete DC load range from minimum to maximum power transfer. At Soldier's Pond, with both synchronous condensers in service, the var swing range available is about the same as the swing in var consumption of the converter. Occasional filter switching may be required, particularly at light DC loading conditions.

The var requirements of the converters will increase under the short time overload conditions. When power is transferred from 'normal' operation of the bipole, to an overload condition on a pole, the voltage drop across the DC line and cable system more than doubles. To accommodate the increased voltage drop, the Soldiers Pond converter must operate at a higher than normal extinction angle resulting in a lower power factor for the converter. The increased var demand will result in a sustained 230 kV AC voltage reduction at Soldiers Pond to about 90% of the voltage prior to the disturbance. The reduced AC bus voltages will last until the converter transformer tapchangers can operate to restore the extinction angle to a near normal value. With 1¼% taps and a tap-changer rate of operation of 12 taps per minute, the voltage should be restored within 40 seconds.

3.1.4 DC Voltage

A voltage of ±400 kV is appropriate for the Interconnection as cables of suitable ratings are possible and it is about the maximum voltage which would be possible with a single transmission line conductor in each pole. Bundled conductors would significantly increase the ice loadings and hence the cost of the DC line.

Previous studies had shown this voltage level to be close to the optimum for the DC transmission line. A single large conductor will be used in each pole of the HVDC transmission line. Radio interference and audible noise with the single conductor per pole are within normally acceptable limits.

The maximum expected voltage gradients under the DC transmission line are compared with values on other schemes in Table 3.1.4-1. The total electric field at ground level E_{tot} for the Interconnection for the typical expected midspan clearance of 10.5 metres is no higher than the values on a number of other transmission systems.

Mass impregnated submarine cables with a rating of 400 kV AC, 1500 A are available and this rating has been used on the Denmark-Germany Kontek HVDC Interconnection. There are several other submarine cable projects with a transmission capacity of 600 MW per cable.

3.1.5 Number of Valve Groups Per Pole

The proposed HVDC transmission system has one valve group per pole. The configuration considered in earlier studies included two valve groups per pole.

Utilizing two valve groups per pole reduces the number of pole forced outages due to station equipment to about 3 per pole per year versus about 5 per pole per year for one valve group per pole based on experience on other DC schemes reported to CIGRE. Since pole faults cannot be completely eliminated regardless of the number of valve groups per pole, they must be considered when assessing the impact of the DC transmission on the AC systems. In either case the design criteria would need to allow for complete loss of a pole, and there is no performance advantage with two valve groups per pole. In both cases the converter equipment would require the same short-time overload capability to avoid load shedding following faults.

A factor favouring two valve groups per pole is the smaller amount of transmission capacity lost during maintenance of valve groups. Maintenance requirements are typically one week per valve group per year. Hence the comparison is loss of 25% capacity for four weeks for the two valve group per pole system versus loss of 50% capacity for two weeks for the one valve group system. The reduction in energy transfer capability is about the same in either case.

The estimated cost premium of a two valve group per pole system compared to one valve group per pole system is about CAN $25,000,000 or 20% of the converter station cost. The cost difference is due to the economy of scale of the one valve group per pole system in that it consists of a single large valve group in each pole, fewer converter transformers, a smaller converter building and less switching and measuring equipment.

The simpler design of the single valve group arrangement will also result in a more reliable DC system and require less maintenance.

In view of the lower cost, lower maintenance requirements, better reliability and similar performance, the Interconnection is based on a single valve group per pole configuration.

3.1.6 Bipolar System Compared to a Monopolar System

A monopolar system could consist of one 800 MW (or two 400 MW valve groups) operating at a DC voltage of 450 kV or 500 kV, a DC line (with two conductors operated in parallel) and a DC cable (with a second cable spare). Cable manufacturers are developing cables for such a rating. The return DC current path would be by sea through electrode lines and sea electrodes.

Such a monopolar system would result in the loss of 800 MW of transmission capacity with every permanent pole fault, resulting in shut down of the Island AC system. Even a temporary fault on the DC line resulting from lightning would result in extensive load shedding on the Island.

Although a monopolar system may be less expensive, the impact of DC system outages would be unacceptable. Thus a monopolar system was not investigated further.

3.1.7 Operating Modes

The DC system is designed to operate in the following modes:

- Bipolar Balanced Mode

  In this mode both poles operate at full voltage and at nominally the same current. The only current in the ground path is due to the inaccuracies of the pole current measuring equipment.

- Unbalanced Bipolar Operation.

  In this mode the currents in the two poles are not balanced because of operating restrictions in one of the two poles.

- Monopolar Sea Return

  In this mode the current from the single operating pole returns via the electrodes and the sea return path.

- Monopolar Metallic Return.

  In this mode the pole current from the single operating pole returns via the conductor of the other pole which is out of service.

In addition to these basic modes the following operating states will be possible:

- Reduced Pole Voltage on One or Both Poles

  This will cater for situations where the insulation strength of the line is reduced by pollution and cannot withstand full voltage.

- Reverse Power Operation.

  This will allow power to be sent from Newfoundland to Labrador. The Interconnection will be capable of transmitting about 730 MW from Soldiers Pond Converter Station to Gull Island Converter Station. This rating is within the rating of the components of the transmission system and so can be achieved at no significant cost.

- Overload Operation.

  Operation up to the inherent capability of the converter equipment at the prevailing ambient temperature will be allowed.

The capability of parallelling of both poles onto a single line conductor is not provided. In previous studies (Reference 4) pole parallelling was considered necessary to take into account transmission line or cable permanent faults. With the current DC scheme a spare cable is provided in case of a cable outage and, in the event of a transmission line permanent conductor outage, the remaining pole can operate at approximately 50% overload until generation can be brought into service. The removal of the switching associated with pole parallelling simplifies the switching arrangement in the converter stations.

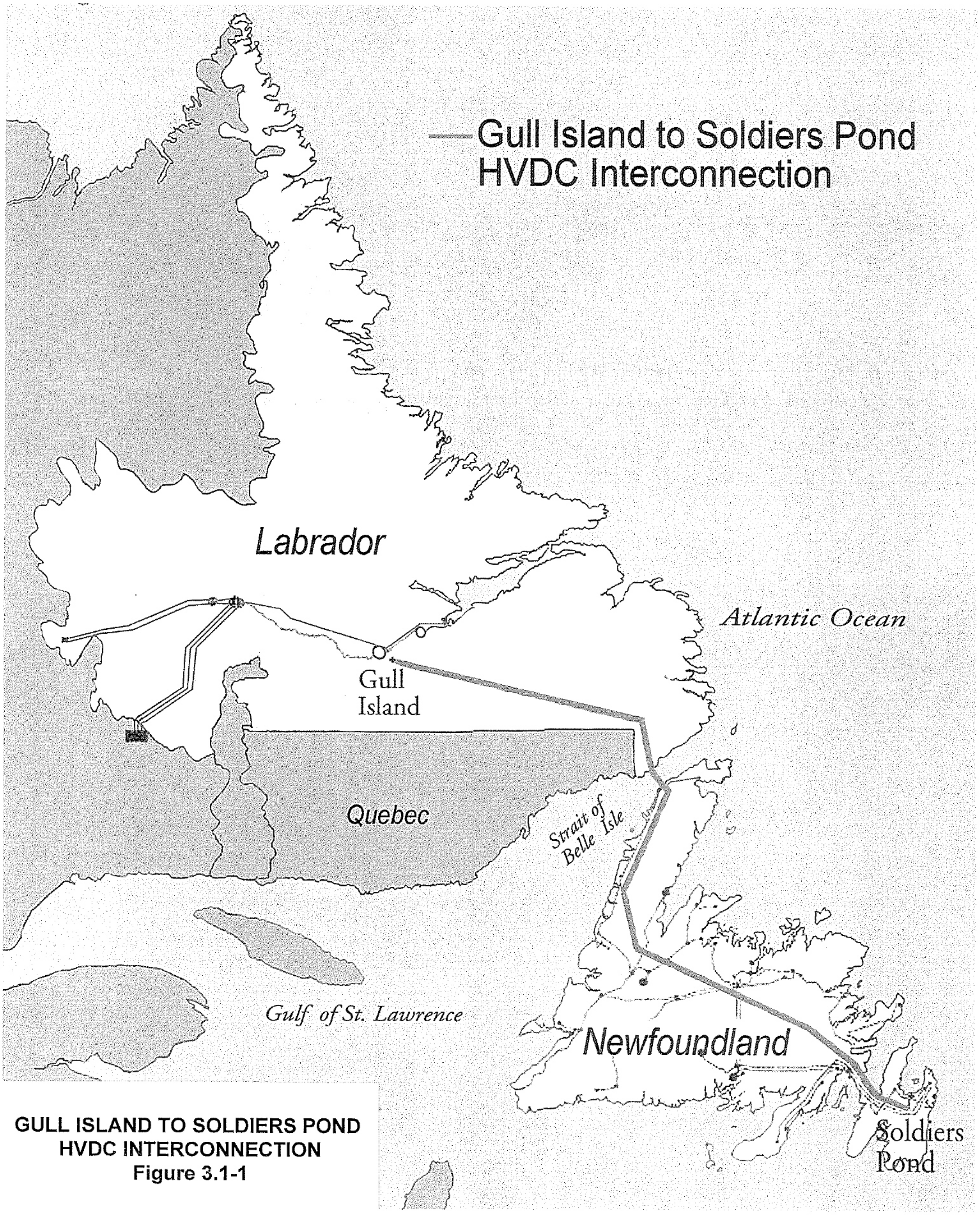
The spare cable can be switched to either pole and will normally be connected in one pole to reduce losses in that pole.

TABLE 3.1-1

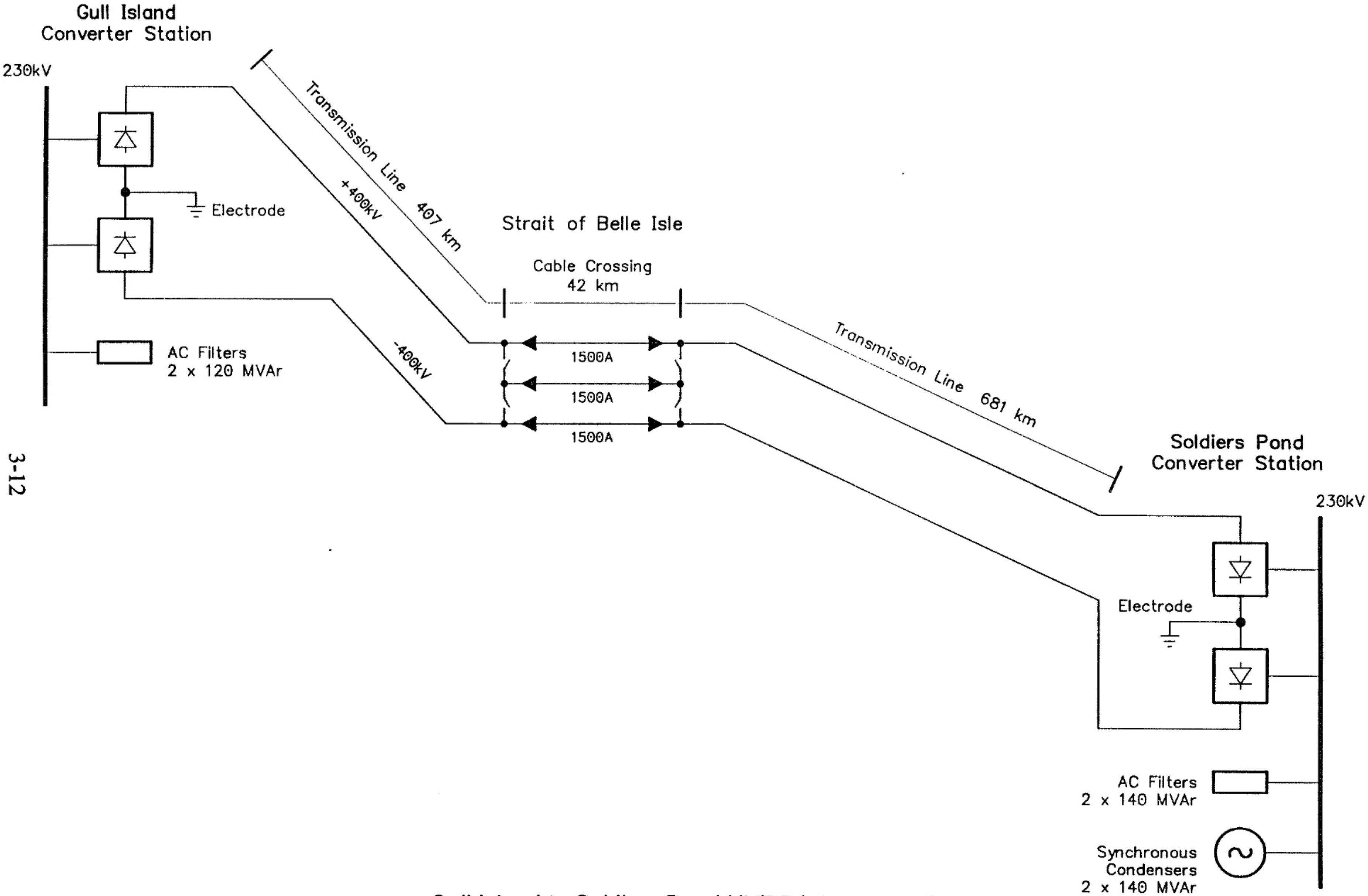
OPERATING HVDC LINES
PEAK FAIR WEATHER ELECTRIC FIELD
PARAMETERS UNDER CONDUCTORS

Line		DC Voltage kV	HVDC Line Configuration			Calculated Values			Measured Values		
			Con-ductor	Mid-Span Height	Pole Spacing	Conductor Max Gradient	Max E_{nom} at Ground	Max E_{tot} at Ground	E_{nom}	E_{50}	E_5
			(cm)	(m)	(m)	(kV/cm)	(kV/m)	(kV/m)	(kV/m)	(kV/m)	(kV/m)
New Zealand		±250	2 x 3.84	8.0	8.0	16.5	7.9	14.5			
		±350	2 x 3.84	8.5	8.0	22.9	10.1	30.0			
Square-Butte		±250	1 x 5.04	8.84	7.4	17.8	4.9	13.3	3.3	8	15
CU	(1)	±400	2 x 3.81	10.67	12.19	24.3	9.6	29.5			
	(2)	±400	2 x 3.81	15.24	12.19	24.0	5.1	18.3	5	10	20
Pacific Intertie		±400	2 x 4.57	12.19	12.19	20.4	8.0	22.0	8	13	22
	(3)	±500	2 x 4.57	12.19	12.19	26.0	9.6	32.7	10	20	30
N.R. Bipole 1	(4)	±450	2 x 4.06	12.19	13.41	25.3	9.0	29.4			
	(5)	±450	2 x 4.06	15.30	13.41	25.1	6.1	21.8			
N.R. Bipole 2		±500	2 x 4.06	12.19	13.41	28.1	10.0	34.8	6	11.5	17.5
Quebec - N.E.		±450	3 x 5.04	11.58	13.73	17.8	11.3	21.3	12	17	22
IPP		±500	3 x 4.58	10.68	12.81	21.7	14.0	34.1			
Gezhouba-Shanghai		±500	4 x 2.37	14.4	15.0	28.4	9.4	30.1			
Rihand - Delhi		±500	4 x 3.51	12.75	12.75	21.6	10.9	27.9			
Thailand - Malaysia		±300	2 x 3.04	8.5	10.0	23.2		28.0			
Gull Island	(6)	±400	1 x 5.40	10.5	11	25.4	6.9	28.9			
	(7)	±400	1 x 5.40	8.5	11	25.4	10.4	38.1			

Notes:
1. North Dakota Section (normal mid-span height)
2. Minnesota Section (high mid-span height due to irrigation requirements)
3. Operating voltage of line as of January 1986
4. Conductor mid-span height design value
5. Actual mid-span height when measurements were made
6. Typical mid-span height
7. Design mid-span height
8. E_{50} = 50% chance of being exceeded
   E_5 = 5% chance of being exceeded



GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION
Figure 3.1-1



Gull Island to Soldiers Pond HVDC Interconnection
±400 kV, 800 MW
Single Line Diagram
Figure 3.1-2

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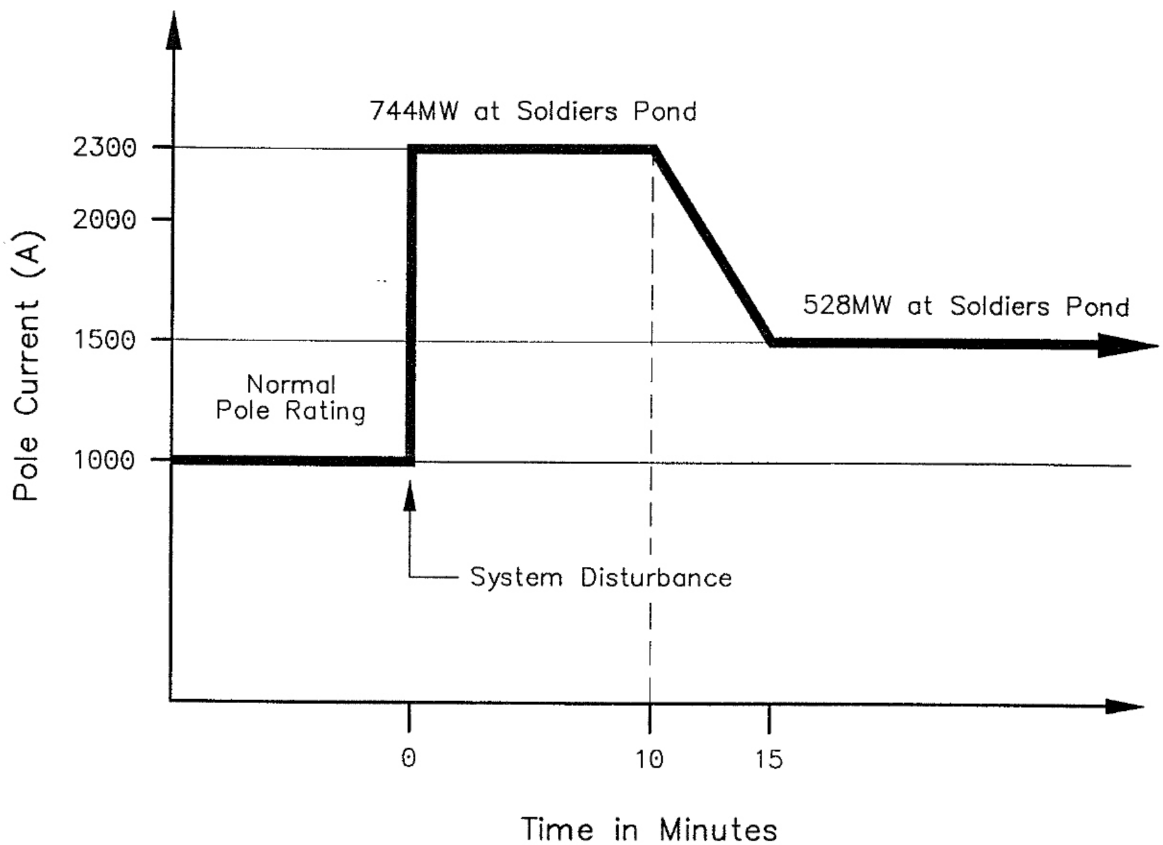

Pole Rating following an Outage of Other Pole
Figure 3.1-3

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3.2 DC Transmission Lines

3.2.1 Description

The transmission line for the HVDC interconnection will be a bipolar line operating at ±400 kV DC connecting the Gull Island Converter Station in Labrador to the Soldiers Pond Converter Station on the Island of Newfoundland.

The current estimate for the length of the transmission line route, excluding the cable crossing of the Strait of Belle Isle, is 1088 km.

From the Gull Island Converter Station, the line route heads southeast across Labrador, then turns south at the Quebec - Labrador provincial boundary and heads for the cable crossing terminal at L'Anse au Clair.

From the cable crossing terminal at Yankee Point on the Island, the line proceeds down the northern peninsula, crosses the Long Range Mountains by an "as-yet" not optimized route, and then heads east across the Island to the Soldiers Pond Converter Station.

Previous studies recommend the line configuration to be as follows: ±400 kV bipolar line, single conductor per pole, guyed tangent towers with I string insulation in light loading areas and V string insulation in medium and heavy loading areas.

The engineering review conducted for this report shows no need to change either the line route or line configuration previously established other than to add an overhead shield wire for the complete length of the line.

3.2.2 Design Criteria

The key items of design criteria that were established in previous studies are as follows:

- Rated Power
- Voltage
- Weather Loadings
- Insulation Withstand Creepage Distances

A review of the voltage level for a transmission capacity of 800 MW for this link indicates that a voltage of ±400 kV, as previously selected for the HVDC interconnection, is appropriate.

Since the project was first studied in the early 1970's, extensive meteorological studies by consultants together with ongoing data collection by NLH have established a significant data base on weather conditions in the project area. A review of the various weather loadings proposed in earlier studies together with a review of subsequent reports by NLH does not indicate any need to change the previously proposed weather loadings. The weather loadings proposed for the various line sections are provided for reference in Table 3.2-1.

A major concern existed previously over the probable weather loading which could occur on the line where it crosses the Long Range Mountains. Since the initial meteorological studies were carried out, twenty additional years of data have been collected but the data has not been analysed and the ice loadings along the route have not been updated. A brief review of the data indicates that the original loadings still appear to be generally appropriate and any differences would not significantly affect the line cost. Hence the original loadings were used in the cost estimate in this report. The wind and ice loadings and other data for the Long Range Mountains crossing and for all other sections of the line are shown in Table 3.2-1.

During the engineering review, a comparison was made between the coastal levels of pollution (salt spray) adjacent to the cable terminal stations and those adopted and experienced near the coast for the ±350 kV New Zealand HVDC link between the South and North Islands. The comparison indicates that the number of insulator units per string proposed in previous studies for the coastal areas near L'Anse au Clair and Yankee Point may be somewhat low. In the final transmission line design it will be necessary to re-evaluate the insulation requirements.

3.2.3 Lightning Protection of the DC Transmission Line

The DC transmission line will have an overhead shield wire over its entire length.

The overhead shield wire will significantly reduce the number of transient pole outages due to lightning strikes. Previous studies (Reference 10) have shown that there could be about 40 pole flashovers per year due to direct lightning strikes to the pole conductors. With an overhead ground wire direct lightning strokes to the pole conductors are virtually eliminated.

Although the DC system is designed to avoid load shedding on the Island during transient pole faults due to lightning by utilizing overload, it is prudent to install an overload ground wire to minimize the number of events of this type and thus avoid potential disturbances to the AC system.

Lightning strikes to the ground wire or tower can result in back flashovers to a pole conductor. The frequency of back flashovers to a pole will be approximately 0.5 to 1.0 per year, depending on footing resistances (Reference 11).

The overhead shield wire increases the cost estimate for the DC transmission by about 7% ($20 million dollars) compared to no shield wire.

3.2.4 Conductors

Previous studies have determined that a single large conductor per pole is more economical than two or more bundled conductors due primarily to the severe ice loading conditions. An AASC-6101-HC stranded conductor with a diameter in the range 51 to 54 mm was found to be the optimum size. The cost estimate in this report is based on a 54 mm conductor. Since changes in conductor size influence the tower and foundation costs to a degree, a more detailed line optimization study, based on then current interest rates, cost of losses and more detailed line costs, should be undertaken when it is decided to proceed with the project.

3.2.5 Insulators

Insulators, although a minor cost component of the line, are a key component in line design and performance. At the present time, most HVDC projects around the world use either porcelain or glass insulators manufactured mainly by NGK and Sediver respectively. For the lightly loaded weather sections I strings are proposed. For the medium and heavy loaded sections, V strings are necessary to accommodate the heavy loads and provide better load transference to the towers. While synthetic insulators are gaining acceptance by many utilities on AC lines at voltages up to 500 kV, there is not, apart from a small section of line on the Pacific Intertie, any major HVDC line in service which utilizes synthetic (composite) insulators. The present concepts of shed design with these insulators would, in our opinion, give cause for concern as to their performance under heavy concentrations of ice. Research would be needed on this aspect together with more in-service data on this type of unit on HVDC lines before we would recommend consideration for their extensive use on this project.

3.2.6 Towers and Foundations

The information on towers and foundations in Table 3.2-2 is based on data extracted from previous studies but modified to include an OHSW on all towers and with additional strain structures added to prevent cascading. It summarizes the tower types utilized for each of the sections together with the basic design spans and type, rating and units/string for the insulators. Figures 3.2-1, 3.2-2 and 3.2-3 provide the outline concepts of the various tower types. During examination of the guyed tower types, it was recognized that the significant ice loading specified in the design criteria, in addition to adding considerable weight to the tower, also adds considerable area for the wind to act upon. It was considered appropriate to conduct a preliminary investigation into a tubular guyed tower concept. This was in expectation that the additional ice loading (weight and area) on a tubular tower would be much less in comparison to that for a lattice steel tower. The preliminary outline for this tower is shown on Figure 3.2-7 and a cost comparison between tubular and lattice steel towers shows the installed cost of the tubular suspension structures to be significantly more expensive (about 50% more). However, when the project proceeds a detailed design comparison should be undertaken to verify which type of structure is most economic based on a total installed cost.

For the extreme loading section over the Long Range Mountains, the earlier studies proposed splitting the line into two monopolar line sections to provide greater reliability. The cost estimate included in this report is based on that arrangement.

An alternative, although slightly more costly would be to provide two bipolar lines in this section, with significant separation between the routes, so that in the event one bipolar line fails due to extreme loads, full power could be carried on the other bipolar line.

Another alternative would be to use a single bipole arrangement only but substantially increase the design criteria to withstand significantly greater wind and ice loadings.

The foundations and anchors for the guyed towers (which form the bulk of the towers on the project) are based on design concepts utilized on previous projects. Typical outlines for the mast foundations and the guy anchors are shown on Figures 3.2-4, 3.2-5 and 3.2-6. Early studies on the project developed an estimate of the various terrain types transversed by the line. Table 3.2-3 shows a summary of the expected percentages of the various types of foundation conditions expected to be encountered in each of the line sections. The methodology of terrain typing from aerial photography followed by selected ground proofing to verify actual conditions at various locations has worked well on other projects and forms the basis for providing estimates of the various foundation types and quantities.

During the study, in order to reduce the possibility of cascading, additional guyed strain towers were added to replace suspension towers. This was to provide a strain tower every 23-25 towers. Newfoundland and Labrador Hydro then requested that these guyed towers be replaced with dead end towers of the conventional free standing lattice type.

When a recalculation was completed it was found that there was no significant difference in total overall cost with 0-45° guyed strain towers compared with 90° dead end towers. The cost of the extra steel in the 90° dead end towers is offset by the cost of the 0-45° tower guy hardware and foundation costs. It is concluded that the estimate includes sufficient funds to meet the anti-cascading criteria.

GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION

TABLE 3.2-1
800 MW 400 kV DC BIPOLE LINE
LOADING AND SPAN INFORMATION

Line Section	Route Distance		Section Length	Wind & Ice Loading			Combined Wind & Ice			Load Zone	Ruling Span	Wind Span	Weight Span
	From	To		Max. Gust	Max. Radial Ice		Max. Gust	Max. Radial Ice					
					Glaze	Rime		Glaze	Rime				
	km	km	km	km/h	mm	mm	km/h	mm	mm		m	m	m
R1	0	68	68	155	55	120	105	25	60	Medium	400	440	510
	68	106	38	130	35	40	95	15	25	Light	500	495	570
	106	211	105	150	60	110	105	30	50	Medium	400	44	510
R2	211	336	125	150	55	55	105	25	30	Light	450	500	570
R3	336	380	44	200	100	170	115	70	115	Heavy	270	300	350
	380	392	12	200	100	170	115	70	115	Heavy	270	300	350
	392	407	15	180	90	80	115	65	45	Medium	350	390	450
R4	407	449	42	180	100	145	115	70	85	Heavy	330	370	420
R5	449	468	19	180	90	80	105	65	45	Medium	350	390	450
	468	496	28	190	90	155	120	65	100	Heavy	300	330	380
	496	563	67	180	90	80	105	65	45	Medium	300	390	450
R6	563	608	45	250	110	240	160	85	175	Special	200		
R7	608	638	30	165	80	55	105	50	30	Medium	430	490	550
R8	638	786	148	210	90	130	125	65	70	Medium	350	390	450
R9	786	927	141	190	85	120	105	60	60	Medium	400	440	510
R10	927	1032	105	210	110	160	125	85	100	Heavy	300	330	380
R11	1032	1088	56	200	95	145	115	70	85	Heavy	300	370	420

Note: See Figure 4.2-1 for line section numbers.

GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION

TABLE 3.2-2
400 kV DC BIPOLE LINE
TOWER TYPE DISTRIBUTION

km	Tower Type Distribution					Spans				Insulators		
	Suspension Towers		Strain Towers		Total	Load Zone	Ruling Span (m)	Wind Span (m)	Weight Span (m)	Type	M&E Rating kN	Units
	Tangent Normal	Angle	0-45°	90°, D.E.								
0-68	154	18	2	5	197	Medium	400	440	510	I	300	16
68-106	75	10	1	3	99	Light	500	495	570	I	160	19
106-211	234	31	2	9	307	Medium	400	440	510	I	300	16
211-336	253	30	4	7	324	Light	450	500	570	I	160	19
336-380	141	15	3	4	178	Heavy	270	300	350	V	300	19
380-392	47	6	1	1	61	Heavy	270	300	350	V	210	33
392-407	38	3	1	4	49	Medium	350	390	450	V	210	33
407-449	117	13	1	4	148	Heavy	330	370	420	V	210	33
449-468	49	9	1	1	69	Medium	350	390	450	I	300	22
468-496	83	11	1	3	109	Heavy	300	330	380	V	210	26
496-563	175	25	2	6	233	Medium	350	390	450	I	300	22
563-608	216 Special V, 9 strain				225	Special	200	-	-	V	300	33
608-638	61	8	0	3	80	Medium	430	490	550	I	300	18
638-786	383	44	8	10	489	Medium	350	390	450	I	300	18
786-927	313	38	3	2	394	Medium	400	440	510	I	300	18
927-1032	315	47	6	9	424	Heavy	300	330	380	V	210	33
1032-1088	156	23	6	2	210	Heavy	330	370	420	V	210	26
Total	2594	331	51	83	3275							

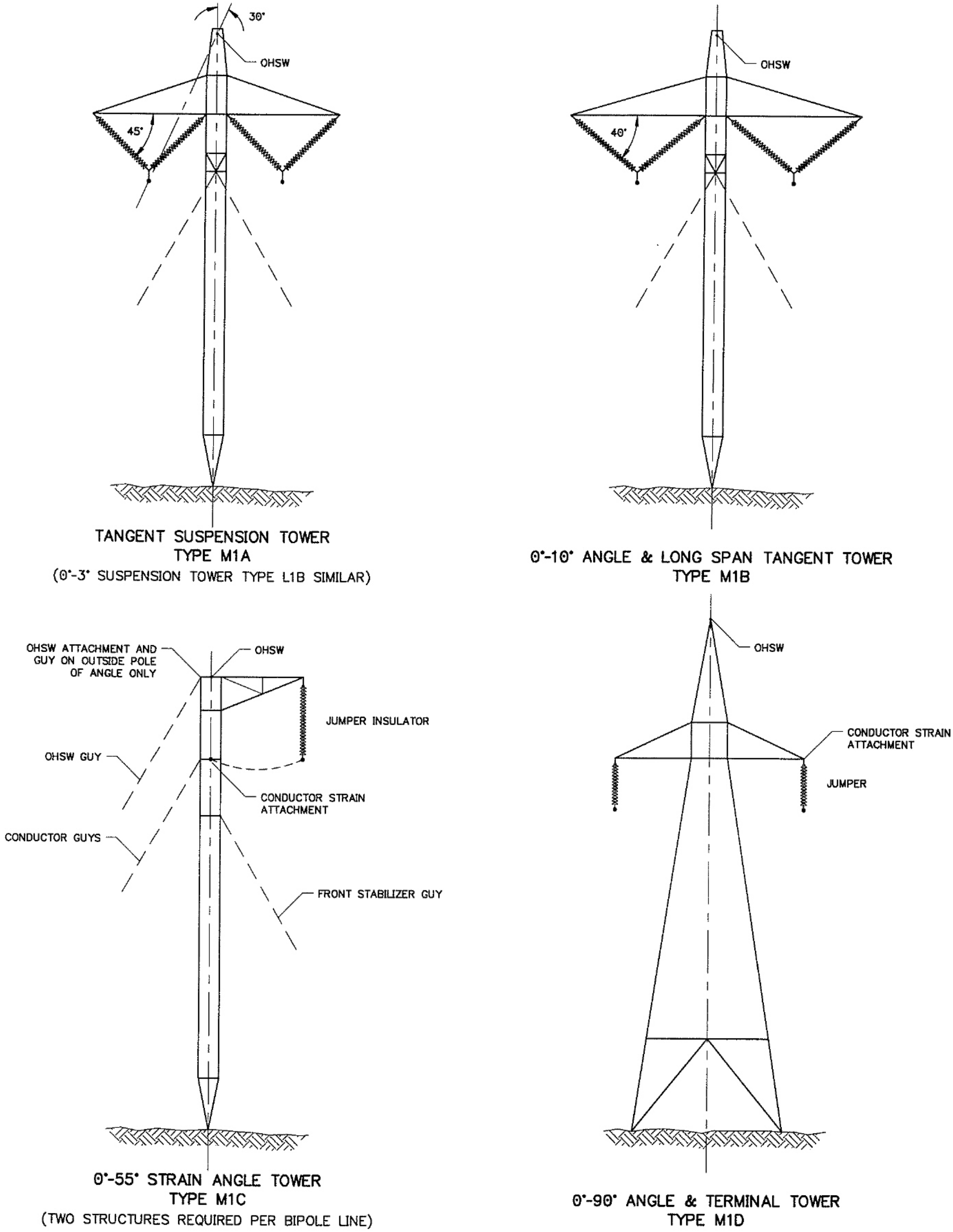
GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION

TABLE 3.2-3

TERRAIN TYPES

Distance From Gull Island km	Percentage of Route Length Covered by Major Terrain Types				
	Deep Moraine	Shallow Moraine	Rock	Gravel	Clay - Silts and Peats
0 - 336	67	10	5	10	8
336 - 407	-	4	81	7	8
407 - 449	4	37	23	1	35
449 - 563	19	38	27	3	13
563 - 608	5	25	66	-	4
608 - 927	47	24	14	1	14
927 - 1088	39	26	28	-	7

Note:
1. Except in areas of exposed rock, the groundwater level was generally found at a depth of 1.0 metre or less.
2. The thickness of peat deposit shows large variations but will not often exceed 1.5 metres in Labrador and 4.5 metres in Newfoundland.
3. Table based on References 2 and 3.



Typical Tower Configurations
with OHSW added
Figure 3.2-1

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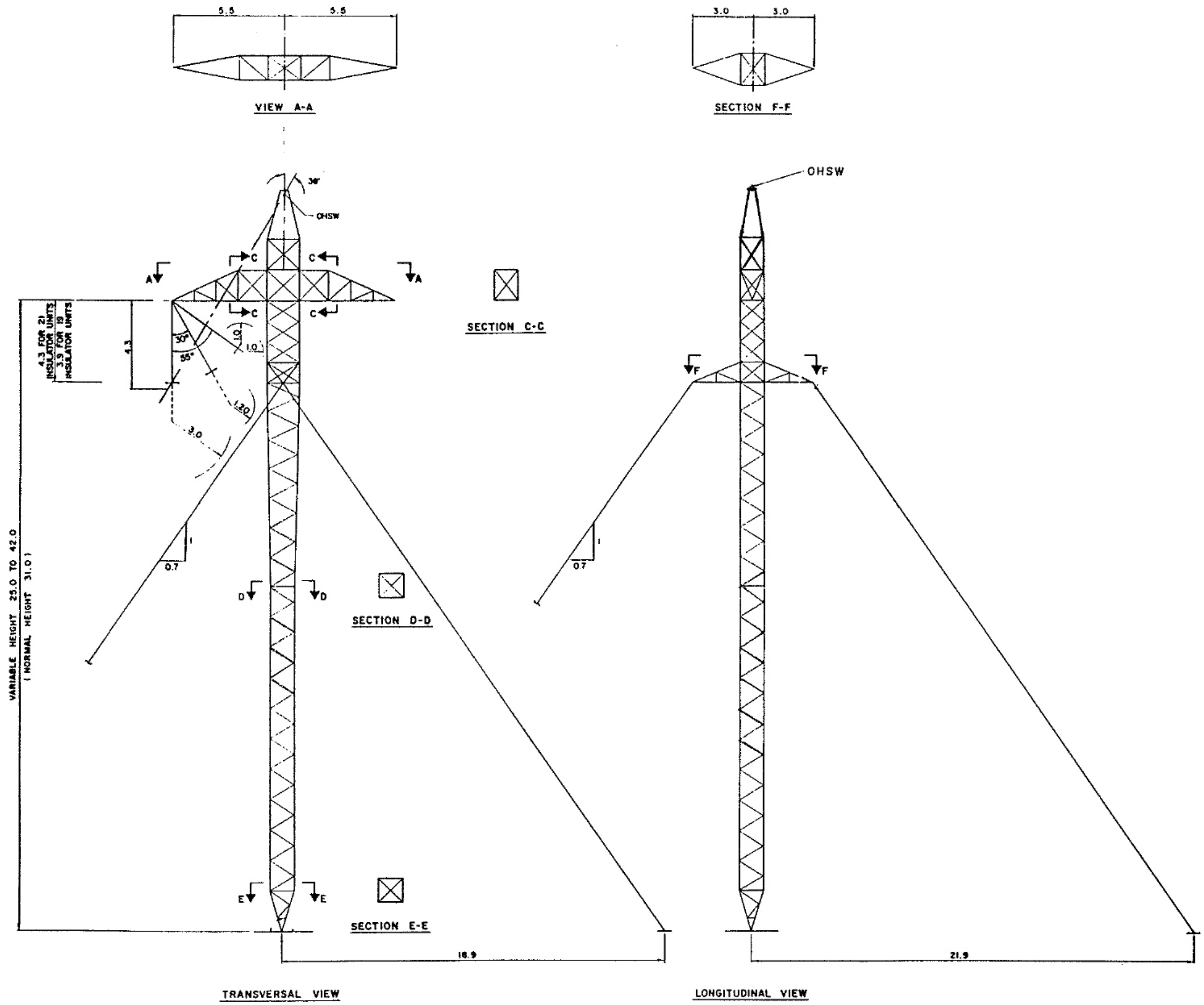
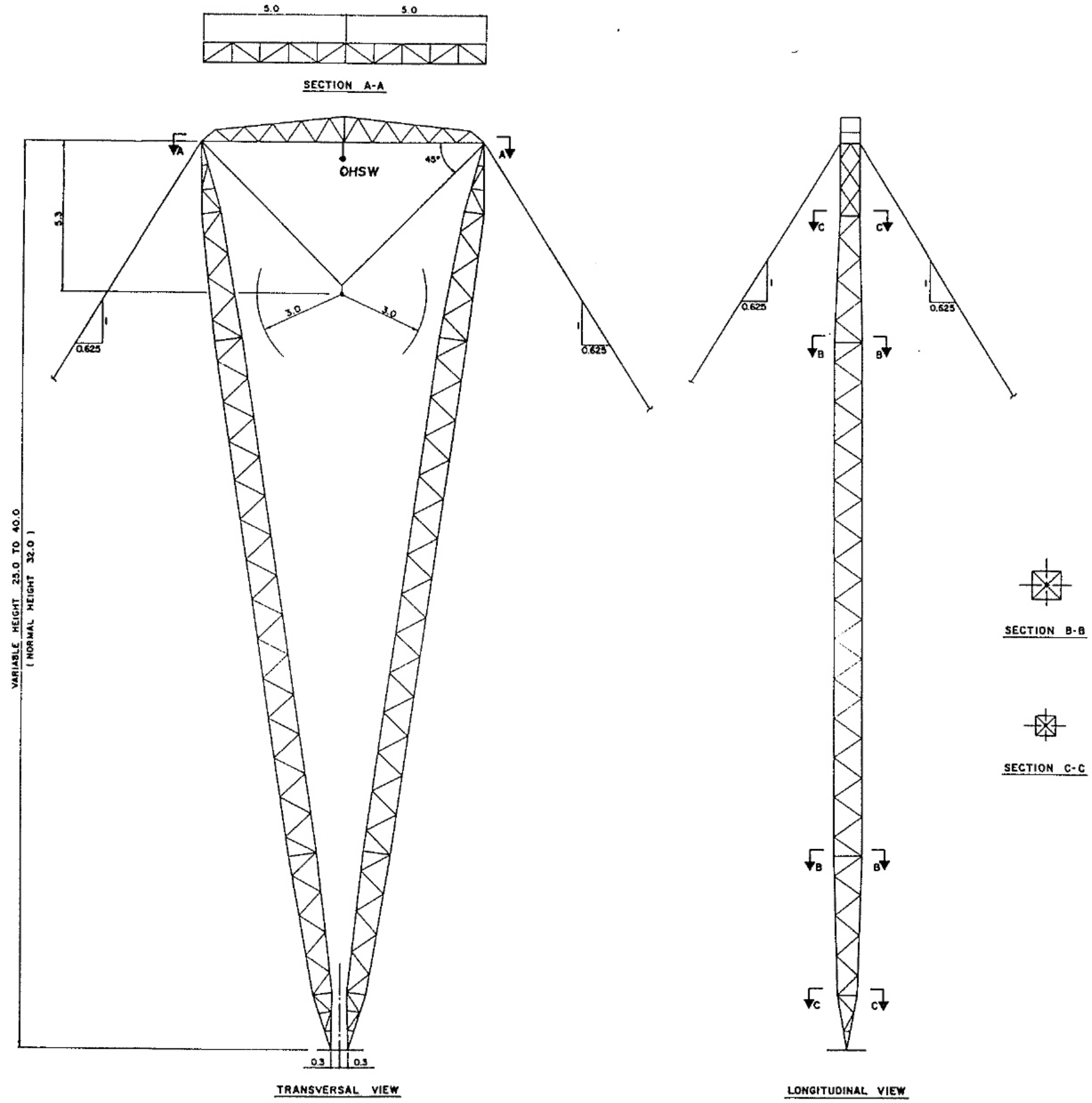
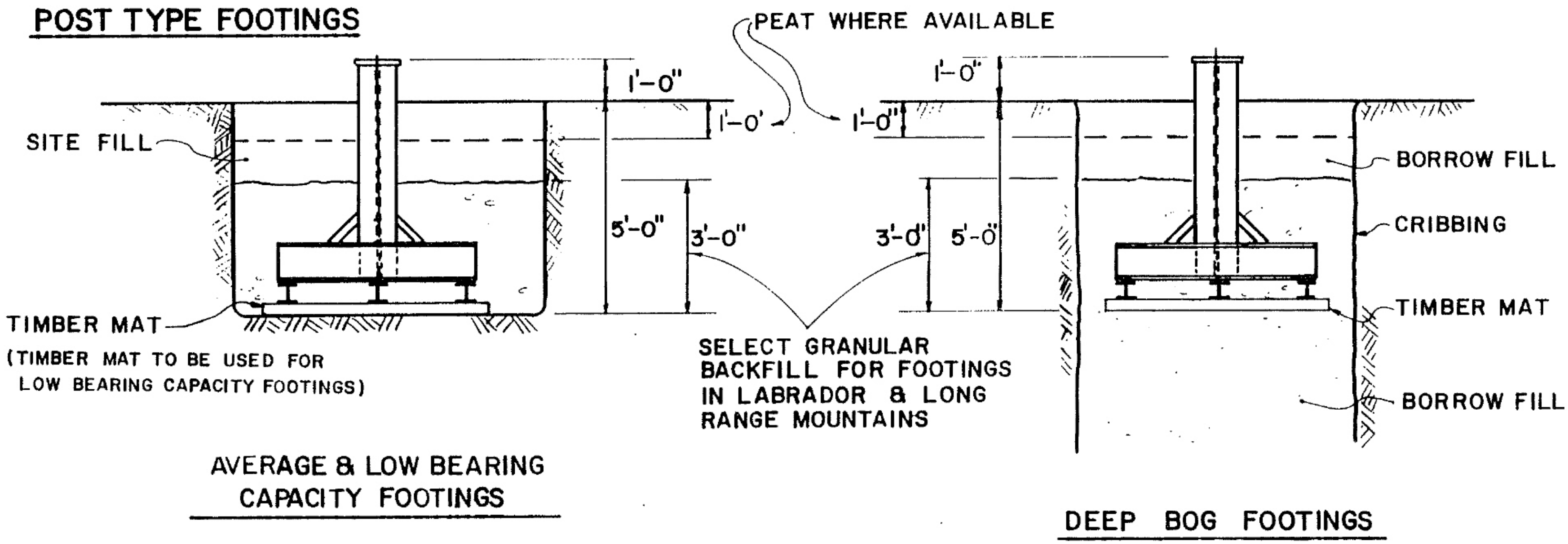


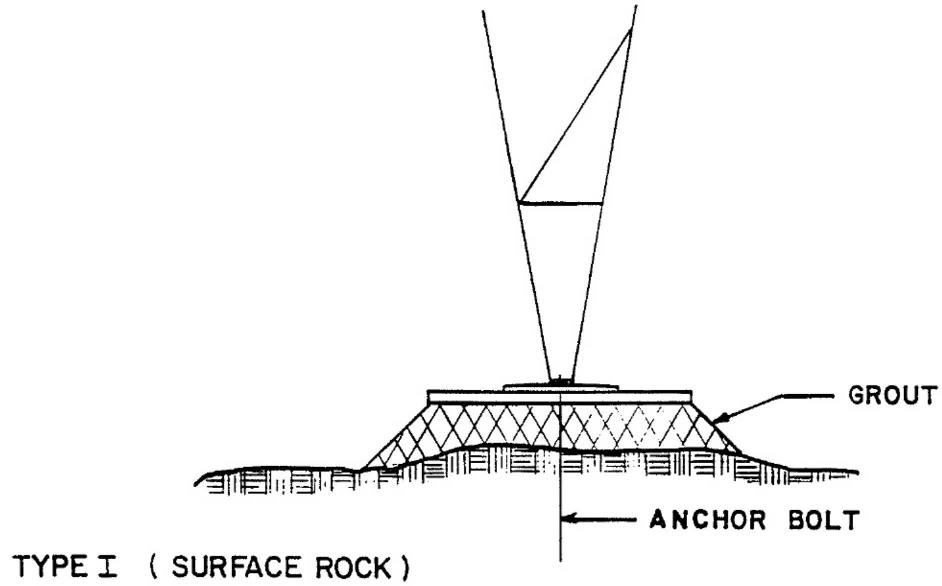
Typical Guyed Tower
Figure 3.2-2

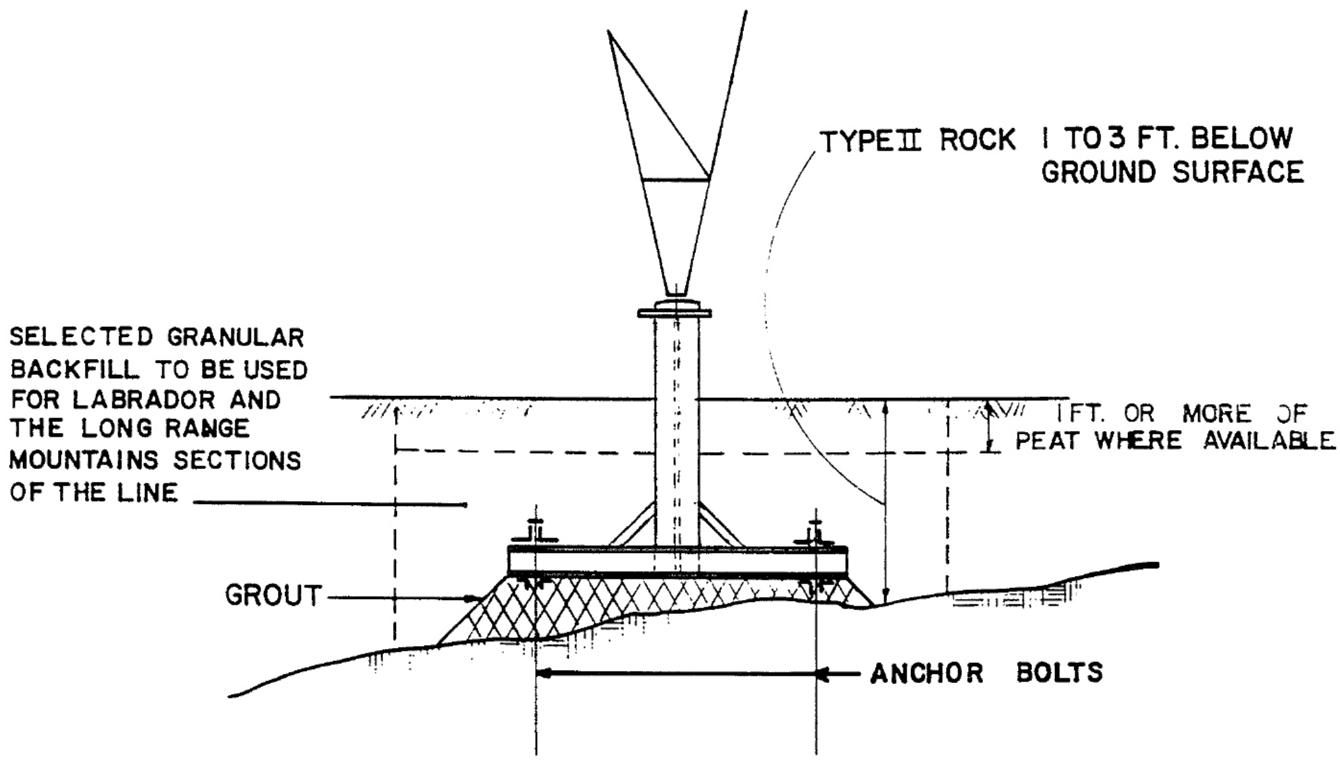


Typical Guyed Special V Tower
Figure 3.2-3

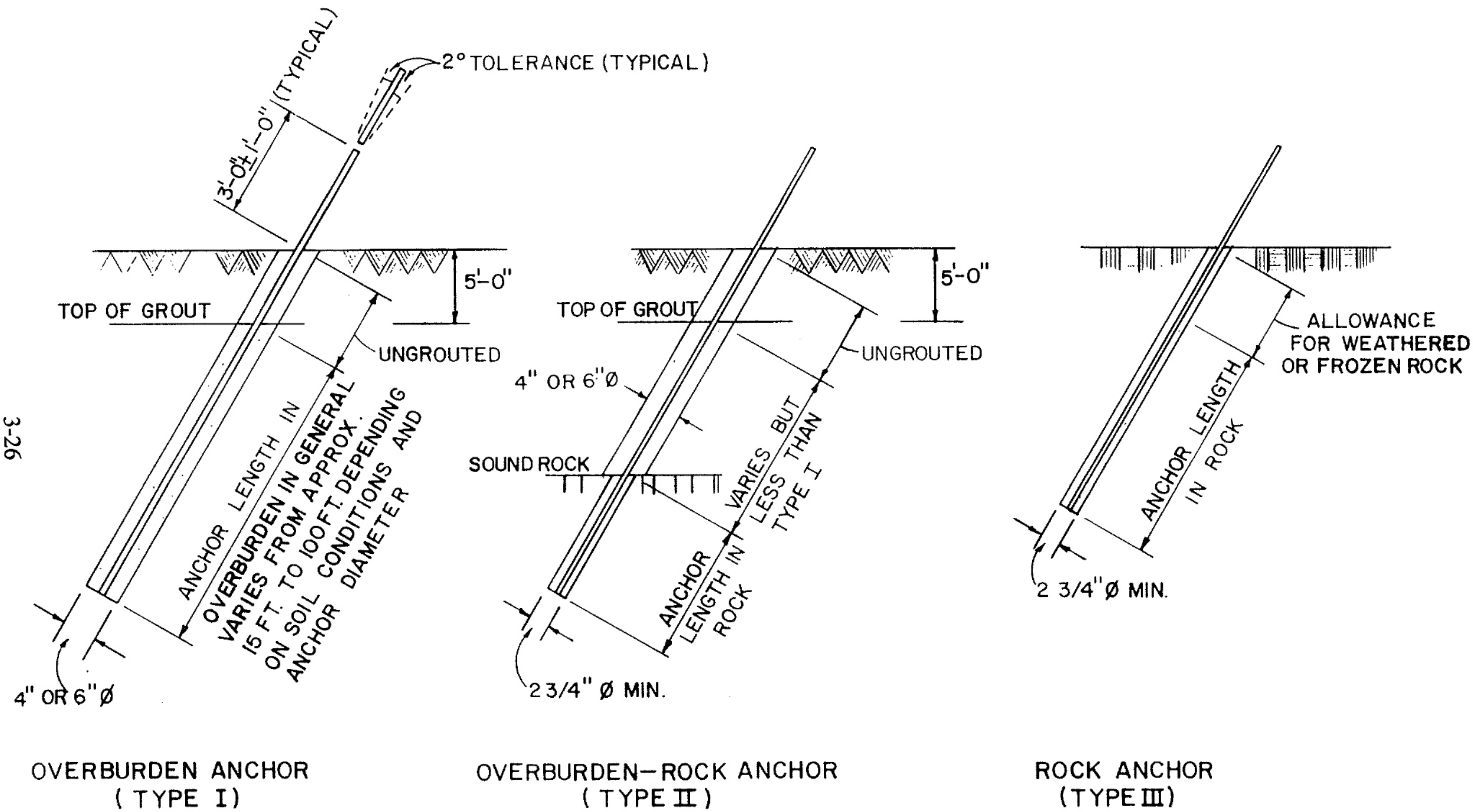


Proposed Guyed Tower Overburden Footings
(Typical Arrangements Only)
Figure 3.2-4

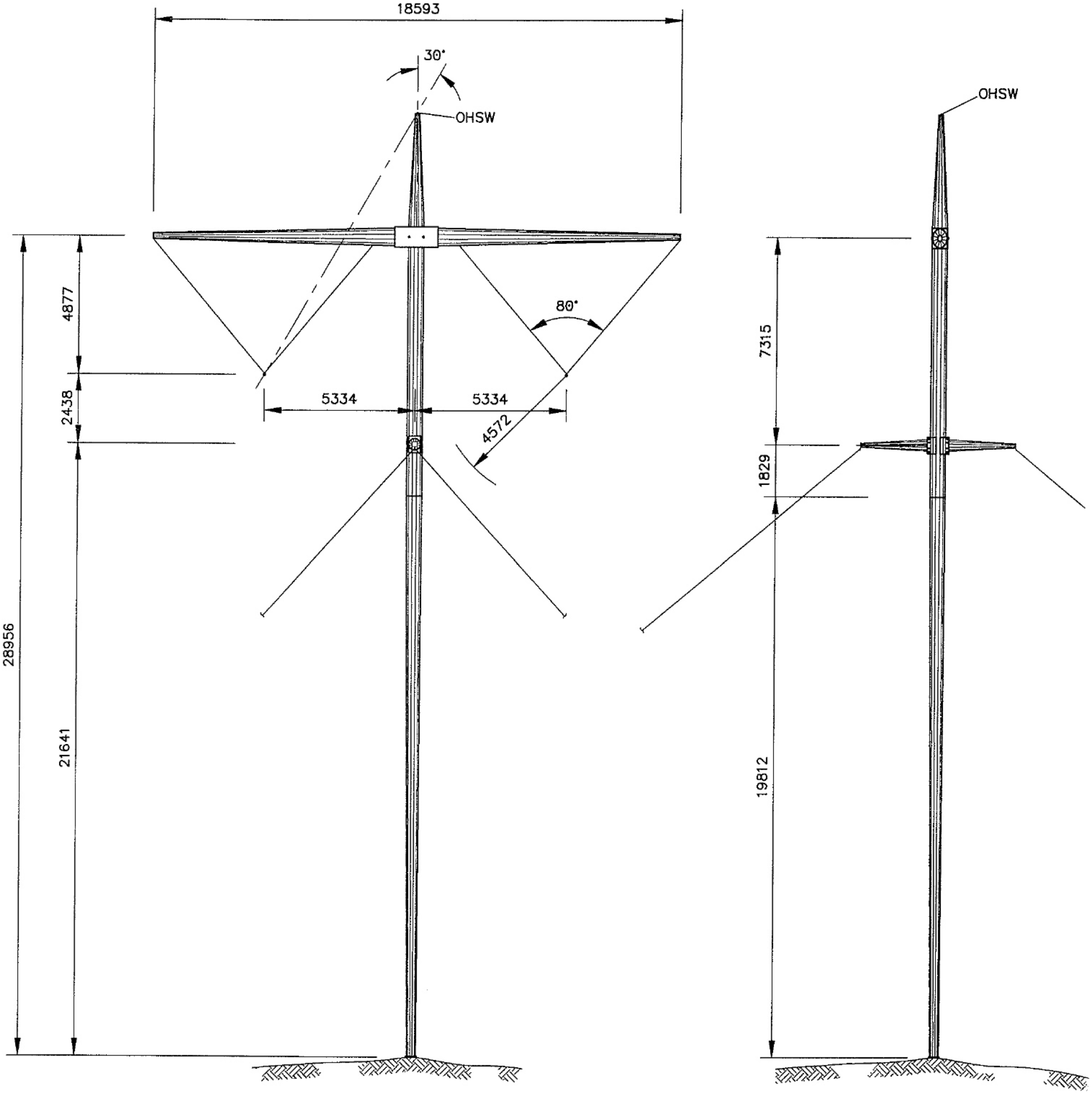




Proposed Guyed Tower Rock Footings
(Typical Arrangements Only)
Figure 3.2-5



Proposed Guy Anchors
(Typical Arrangements Only)
Figure 3.2-6



Tubular Steel Tangent Tower
Conceptual Outline

Figure 3.2-7

Plot 1:200 182\100001\32-7

3.3 Converter Stations

3.3.1 General

The project includes two HVDC converter stations, one at Gull Island and one at Soldiers pond. Each HVDC converter station will consist of a 230 kV AC switchyard, one bipole of DC converter equipment and AC filter/var compensation areas. The converter station cost estimates include all equipment up to the outgoing AC transmission lines and the DC transmission lines. An electrode and electrode line is included for each converter station.

The DC transmission system assumed in the cost estimate consists of a bipole with a single 400 kV 400 MW valve group per pole as shown in Figure 3.1-2. Each valve group will have a short time overload capability of 100% and a continuous overload capability of 50%. This overload capability will lessen the impact of a forced outage of a valve group.

Reactive compensation for the converters will be supplied from AC filters and from a combination of AC filters and synchronous condensers at Soldiers Pond.

Both the Gull Island and Soldiers Pond AC switchyards are a breaker and one-third arrangement. The breaker and one-third arrangement has been proposed in previous reports and is reliable and widely used. The one and one third circuit breaker bays are arranged in a "W" type layout which was proposed in a previous report (Reference 3). The switchyard bay layout should be reviewed before finalizing the design, however the layout will not have a significant impact on the cost of the project.

The following AC apparatus has been assumed for the estimates:

- Circuit breakers would be either SF_6 live tank circuit breakers or dead tank circuit breakers. Live tank circuit breakers will use free standing current transformers and the dead tank circuit breakers will have current transformers incorporated into the bushings. Both the live tank and dead tank designs are competitive with no significant cost difference when evaluated with current transformers. In cold environments the SF_6 circuit breakers will either use a nitrogen/SF_6 mixture or pure SF_6 with heaters.

- Current transformers and capacitive type potential transformers are of the conventional type.

- All AC disconnect switches are motor operated. Ground switches are manually operated.

- The AC control and protection uses modern numerical relays and a distributed type switchyard control system. Distributed relay buildings with one building serving no more than two switchyard bays are provided. Switchyard control is from the converter building control room.

- Rigid and strain bus arrangements are conventional with galvanized lattice type structures on concrete foundations.

Transmission lines and apparatus connections to the switchyard bays have been arranged to provide the maximum reliability using the following criteria:

- Two transmission lines to the same destination must be in separate bays.
- Three transmission lines to the same destination must have at least one line in a separate bay.
- Any two items of the same major apparatus type i.e. converter poles, filters or synchronous condensers, must be in separate bays.
- Equipment seldom switched i.e. station service transformers should be connected next to the main bus rather than at the centre of a breaker and a third bay.

The converter equipment for Gull Island and Soldiers Pond will be identical except as follows:

a) The rating of the Gull Island converter transformers and valves will be higher than Soldiers pond by the amount of the transmission line and cable loss.
b) The Gull Island converter transformer will have a different tap range than Soldiers Pond because of the DC transmission line voltage drop.

Conventional outdoor 400 kV DC switchyards have been assumed at both stations for the estimate.

The Soldiers Pond Converter Station is subject to salt pollution which could have a serious impact on the number of DC forced outages. It is recommended that indoor DC switching be considered at that location.

3.3.2 Gull Island Converter Station

3.3.2.1 Location

The Gull Island Converter station is located on the south bank of the Churchill River. This is a convenient location for the station relative to the Gull Island Hydro Plant AC switchyard. Earlier investigations had located the station on the north side of the river.

The location and area required for the converter station are shown in Figures 3.3-1 and 3.3-2 respectively.

3.3.2.2 Choice of AC Voltage

A cost comparison was made of the converter station at Gull Island using AC bus voltages of 230 kV and 345 kV. The cost of the converter station with the 230 kV bus was $19,000,000 less than when using 345 kV.

The use of a voltage of 230 kV at Gull Island Converter Station is appropriate. The AC system short circuit level is not likely to exceed 50 kA with the AC system as currently proposed.

3.3.2.3 AC Switchyard

A breaker and one-third switching arrangement is proposed. The circuit breakers will have a rated interrupting capacity of 50 kA.

The single line diagram of the switchyard is shown in Figure 3.3-3 and the layout is shown in Figure 3.3-4. The AC switchyard will consist of four bays of switching equipment with entries for connection of the following equipment:

- four transmission lines to Muskrat Falls Power Plant
- two transmission lines to Gull Island Power Plant
- two station service power transformers
- two converter transformer connections (one for each pole)
- two AC filter banks

The cost estimates include the cost of the two transmission circuits between the converter station and the Gull Island Generating station.

The two breakers and associated equipment connecting the lines to the Gull Island 230 kV buses are also included.

3.3.2.4 DC Converter Equipment

The converter station design is based on one valve group per pole. Figure 3.3-5 shows a typical DC power circuit for the DC converter station. Minor differences in the DC power circuit arrangement may occur with different DC equipment contractors.

A conventional outdoor DC switchyard is proposed as the pollution at this site will be modest.

3.3.2.5 AC Filters and Reactive Compensation Equipment

Two filter banks each connected to a bay entrance (a breaker and one-third connection) in separate bays are assumed.

The banks will most likely consist of broad band high pass type filters arranged in two subbanks in each filter bank. The subbanks are connected to the filter bus via disconnect switches. Discharge potential transformers are not provided as there is no requirement to rapidly re-energize a disconnected filter.

AC filter layout details will depend on the design of the AC filter and var compensation system which may vary between DC equipment contractors. Typical area requirements are shown in Figure 3.3-2.

3.3.2.6 Station Service Power

Auxiliary power for the converter station is assumed to come from two 230 kV/4.16 kV station service transformers. Other alternative sources of station service power should be reviewed during the detailed design stage of the project. Some alternative sources are as follows:

- 735 kV autotransformer tertiaries
- power house supply
- converter transformer tertiaries

3.3.2.7 Converter Building

Valve Halls

A typical converter building layout is shown in Figure 3.3-6. The converter building is assumed to have a steel frame with insulated steel panels.

Valve halls are arranged on each side of the service and control area. Converter transformers are arranged with the DC side bushings protruding into the valve halls. This arrangement, which has been used on all recent installations, eliminates all wall bushings except for the 400 kV DC bushing and DC neutral bushing.

Control and Service Block

Figures 3.3-7 and 3.3-8 show the first and second floor of the service and control area. Valve cooling equipment, auxiliary power systems, a workshop, lunchroom, washroom and spare parts storage are provided on the first floor. The control room, electronics workshop and offices are provided on the second floor. The control room floor is a raised computer room type floor to provide for installation of cables.

3.3.2.8 Auxiliary Services

Water supplies are assumed to come from a well drilled on site.

Sewage disposal is by means of a seepage field.

Fire protection consisting of fire water storage, fire pump, ring main, transformer automatic deluge systems, fire extinguishing systems and early detection systems is included.

A 200 m^2 storage warehouse is included.

3.3.3 Soldiers Pond Converter Station

3.3.3.1 Location

Soldiers Pond Converter Station is located on the east side of Soldiers Pond south west of St. John's, Newfoundland. Existing transmission lines to Holyrood intersect Western Avalon to St. John's transmission lines at this point. The Converter station site is adjacent to the Trans-Canada Highway. The location and area required are shown in Figures 3.3-9 and 3.3-10 respectively.

3.3.3.2 AC Switchyard

A breaker and one-third switching arrangement is proposed. The circuit breakers will have an interrupting rating of 40 kA. The single line diagram is shown in Figure 3.3-11 and the layout is shown in Figure 3.3-12. The station consists of six bays of switching equipment with entries to accommodate the following equipment:

- three transmission lines to St. John's
- two transmission lines to Western Avalon
- three transmission lines to Holyrood
- two converter transformers
- two synchronous condensers
- two AC filter/shunt capacitor banks
- two station service power transformers

3.3.3.3 DC Converter Equipment

The converter station design is based on one valve group per pole as described in Section 3.3.2.4.

An indoor DC switchyard, although not included in the estimates, should be considered at this site as the pollution is expected to be severe. The layout of the DC switching equipment is shown in Figure 3.3-13. A section of the proposed indoor switchyard is shown in Figure 3.3-14.

3.3.3.4 AC Filters and Synchronous Condensers

The AC filters and reactive compensation equipment at Soldiers Pond will consist of the following:

- two AC filter/shunt capacitor banks
- two 140 MVAr synchronous condensers

Two filter banks each connected to a bay entrance (a breaker and one-third connection in most cases) in separate bays are assumed.

The banks will most likely consist of broad band high pass type filters arranged in two subbanks in each filter bank. The subbanks are connected to the filter bus via disconnect switches. Discharge potential transformers are not provided as there is no requirement to rapidly re-energize a disconnected filter.

AC filter layout details will depend on the design of the AC filter and var compensation system which may vary between DC equipment contractors. Typical area requirements are shown in the converter station layout in Figure 3.3-10.

The two 140 MVAr outdoor type hydrogen cooled synchronous condensers are each provided with unit transformers and connected to a bay entrance in separate bays. Figure 3.3-10 shows typical area requirements for the synchronous condensers and associated unit transformers and auxiliary buildings.

3.3.3.5 Station Service Transformers

Auxiliary power for the converter station is assumed to come from two 230 kV/4.16 kV station service transformers. Other alternatives sources of station service power should be reviewed during the detailed design stage of the project. Some alternative sources are as follows:

- synchronous condenser unit transformer tertiaries
- off site supply
- converter transformer tertiaries

3.3.3.6 Converter Buildings

The converter buildings at Soldiers Pond are similar to the converter buildings described for Gull Island in Section 3.3.2.7.

3.3.3.7 Indoor DC Switching

Figures 3.3-13, 3.3-14 and 3.3-15 show a converter building with indoor DC switching for Soldiers Pond which would avoid salt pollution problems. The indoor switchyard favours an oil cooled smoothing reactor and allows lower DC equipment insulation creepage distances. The additional cost of an indoor DC switchyard is approximately 4.3 million dollars.

3.3.3.8 Auxiliary Services

Water supplies are assumed to come from a well drilled on site.

Sewage disposal is by means of a seepage field.

Fire protection consisting of fire water storage, fire pump, ring main, transformer automatic deluge systems, fire extinguishing systems and early detection systems is included.

A 200 m^2 storage warehouse is included.

3.3.4 Electrodes

Although the types and locations of the electrodes for the Gull Island and Soldiers Pond converter stations are not established at this time, this does not affect the overall technical viability of the Interconnection and the cost of establishing locations and designs were considered in the risk analysis given in Table 4.11-2.

3.3.4.1 Gull Island

A sea electrode in Lake Melville is assumed for the estimate.

Very little field work has been carried out to identify a suitable electrode site for the Gull Island Converter Station. Typically the Canadian Shield is an area underlaid by high resistivity rock. Significant ground potentials due to high currents flowing to or from a ground electrode could extend for distances up to 50 km or more.

Further work should be carried out prior to deciding on the final electrode design. The purpose of this work would be to investigate whether suitable sites exist to construct a land electrode nearer to the station than Lake Melville. This may result in cost savings over the assumed sea electrode.

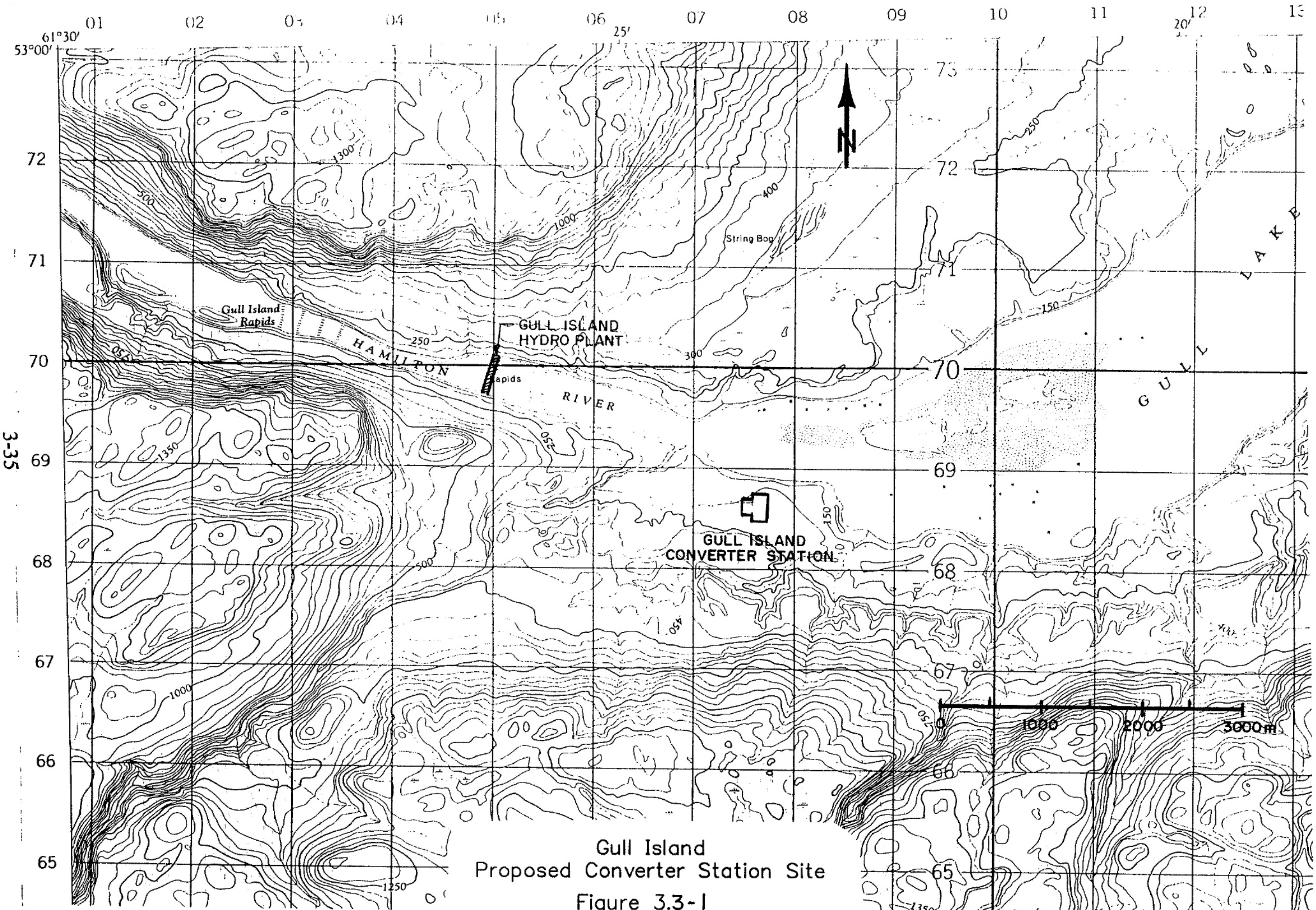
Studies are also required to determine the feasibility of constructing a sea electrode in Lake Melville. The resistivity of the water in Lake Melville and the potential impact of DC current on marine life and facilities at Goose Bay should be determined. A sea electrode in Lake Melville would require approximately 110 km of electrode line.

If it is not possible to construct a land electrode or a sea electrode in Lake Melville, then it may be necessary to build a longer electrode line to Groswater Bay which is relatively open to the sea and thus should have sufficiently low water resistivity. A sea electrode in Groswater Bay would require approximately 280 km of electrode line and would be significantly more expensive.

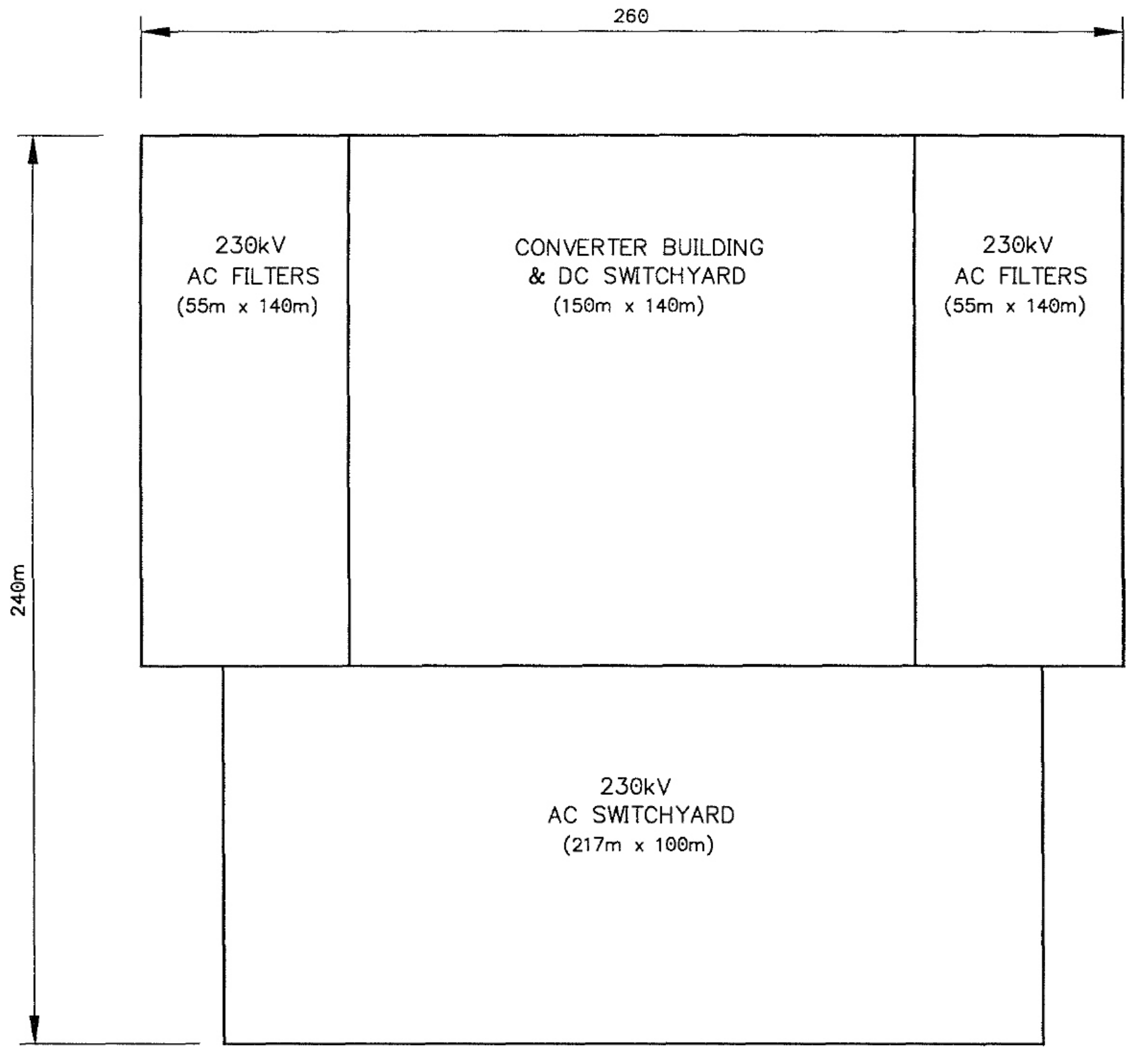
3.3.4.2 Soldiers Pond

A sea electrode in Holyrood Bay, Conception Bay is assumed for the Soldiers Pond converter station.

An electrode location on Holyrood Bay was not identified in the earlier reports. Studies should be carried out to confirm a site on the relatively long and narrow Holyrood Bay that will not adversely impact existing marine facilities or the marine life.

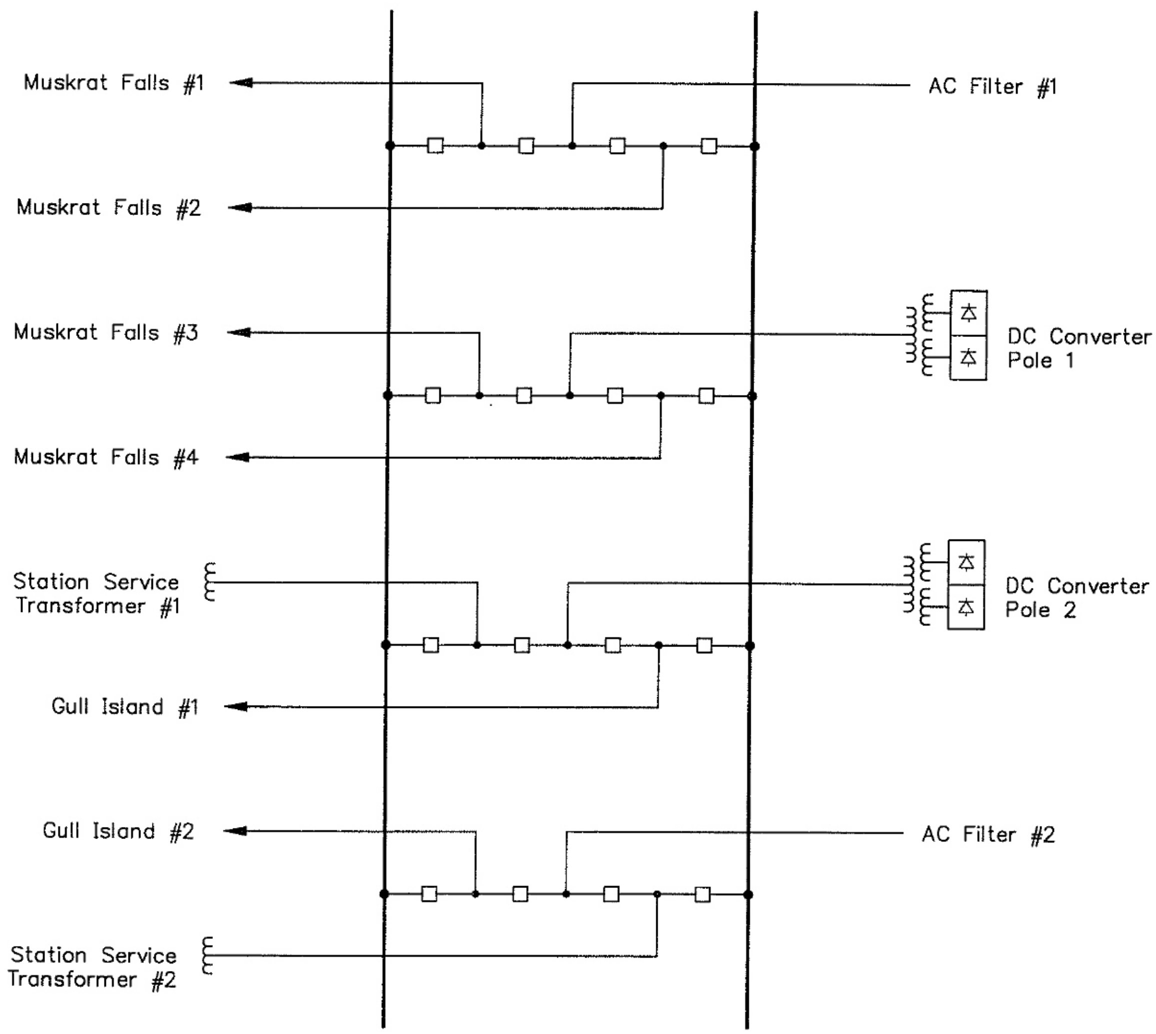


Gull Island
Proposed Converter Station Site
Figure 3.3-1



Gull Island
Converter Station Area Requirements
Figure 3.3-2

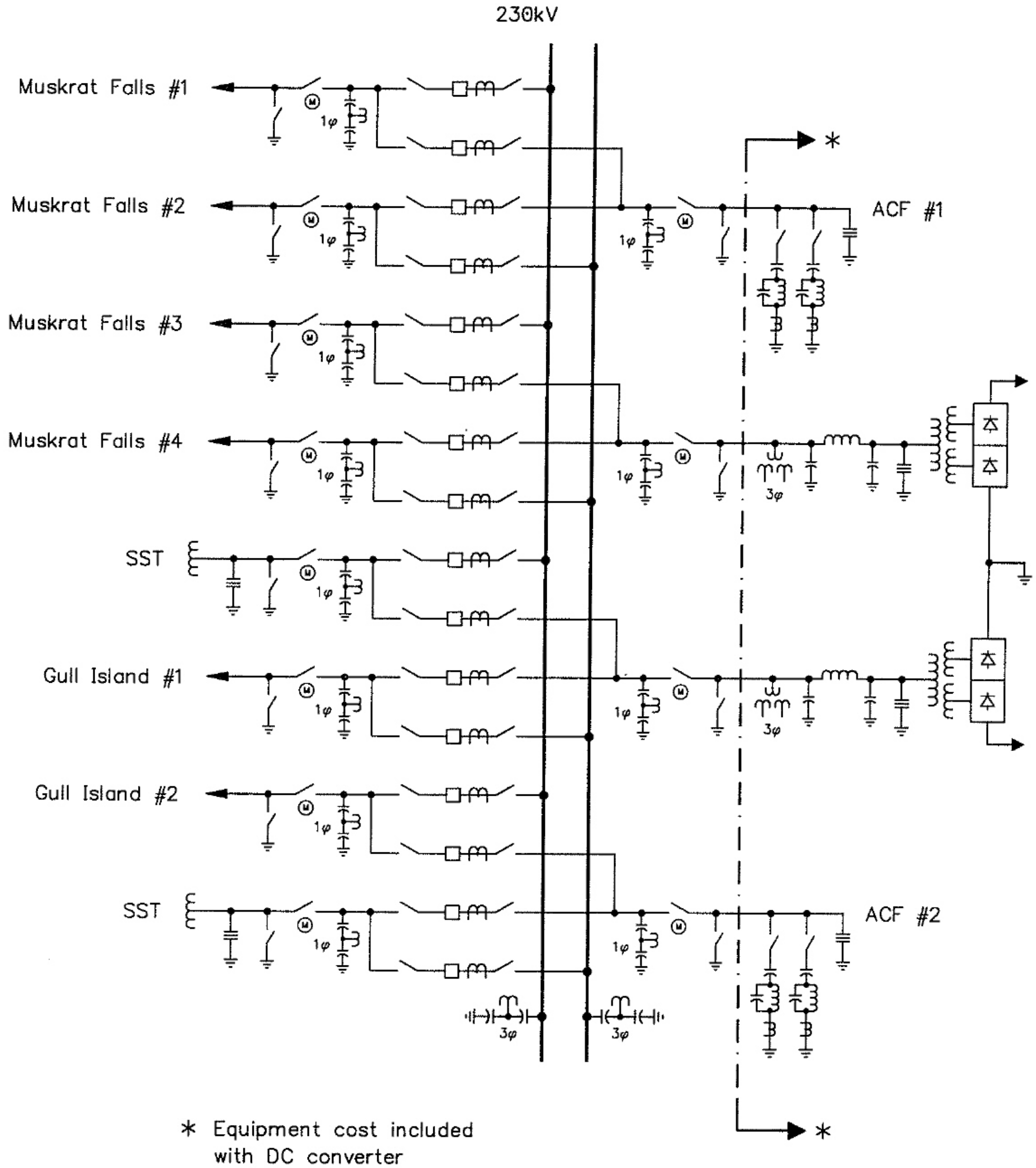
182\10300\02A



Gull Island 230kV
Single Line Diagram

Figure 3.3-3

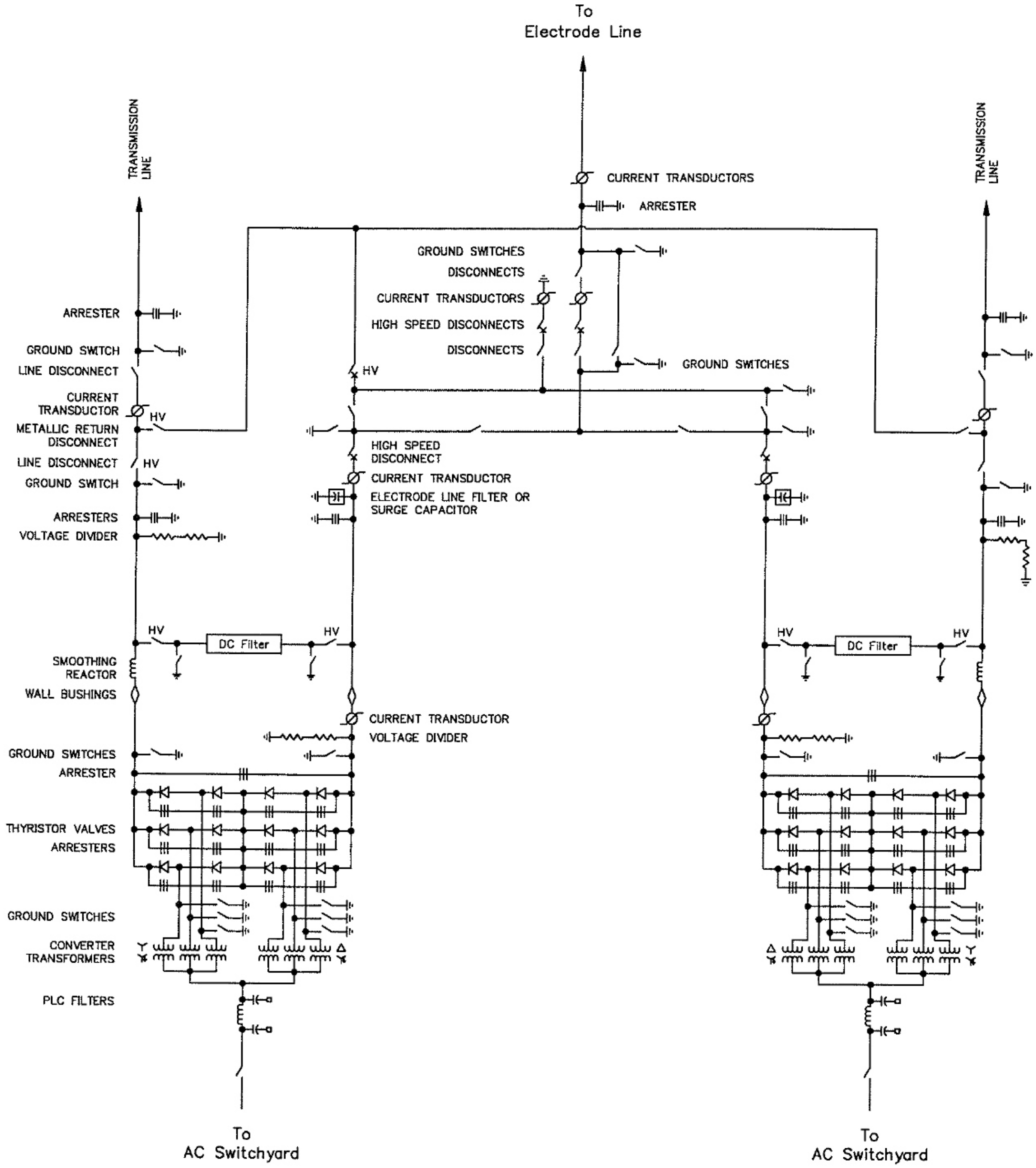
182\10001\33-3



Gull Island 230kV
AC Switchyard Layout

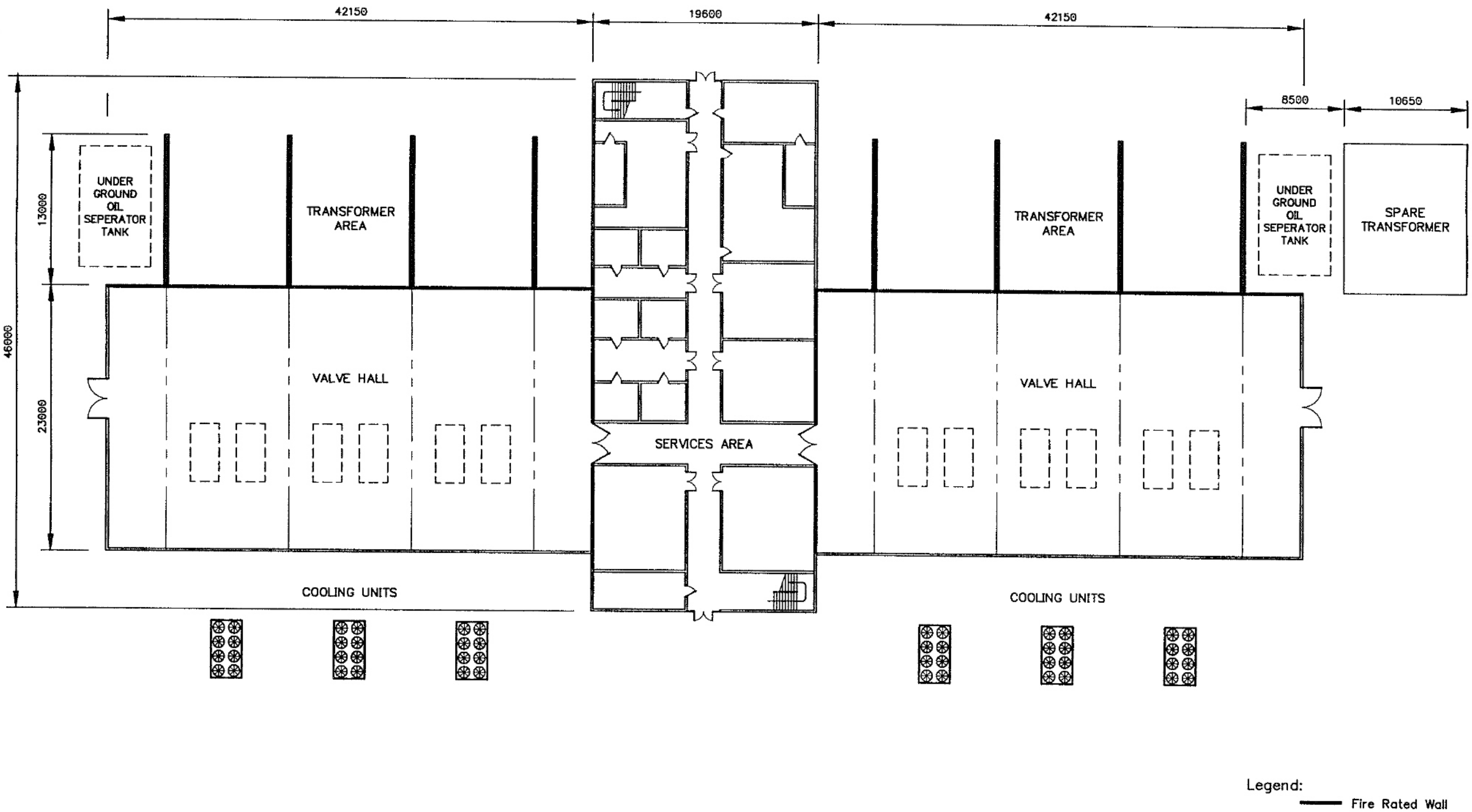
Figure 3.3-4

182\10001\33-4



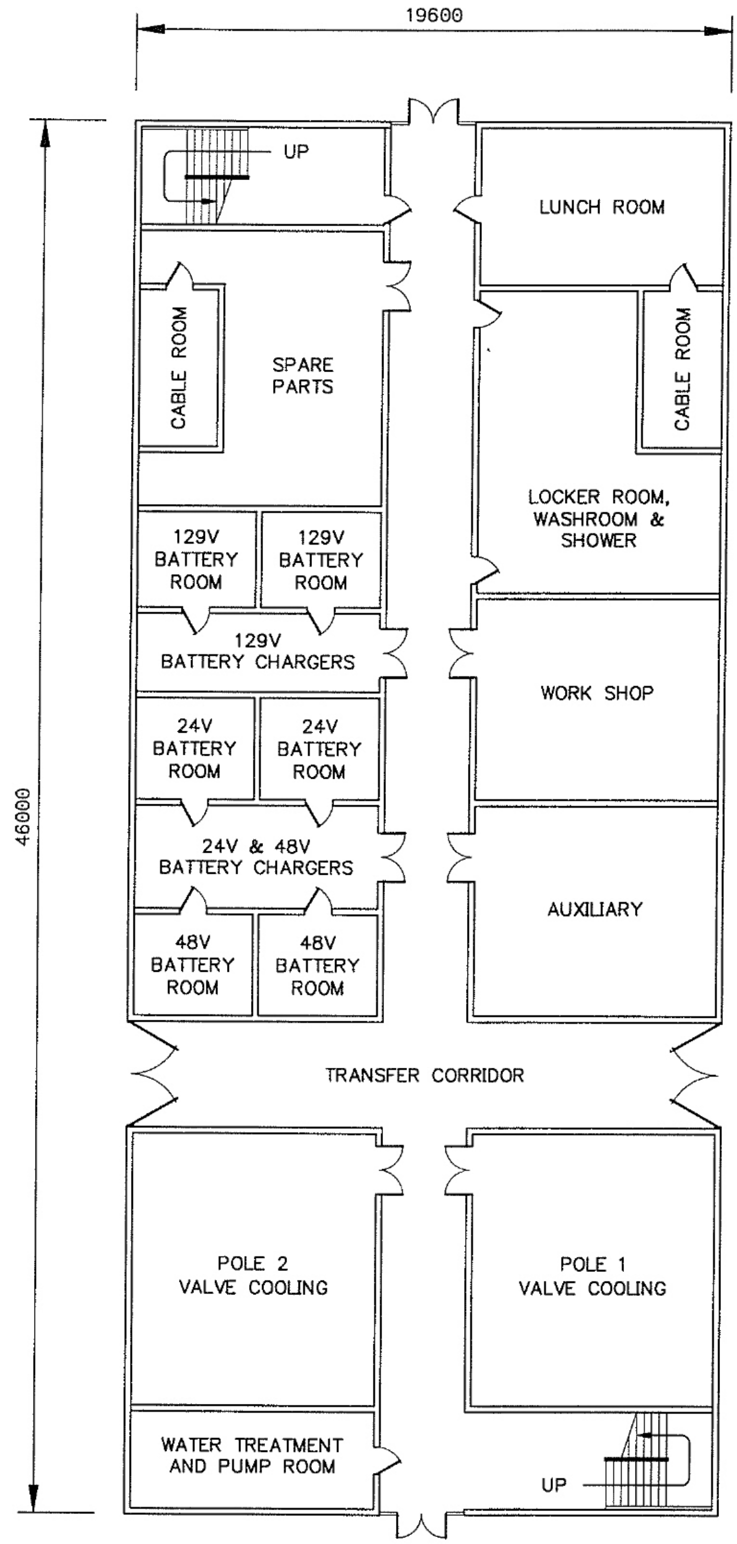
Gull Island to Soldiers Pond HVDC Interconnection
DC Power Circuit Diagram
Figure 3.3-5

182\10001\33-5



Converter Building
One Valve Group per Pole Conceptual Layout
Figure 3.3-6

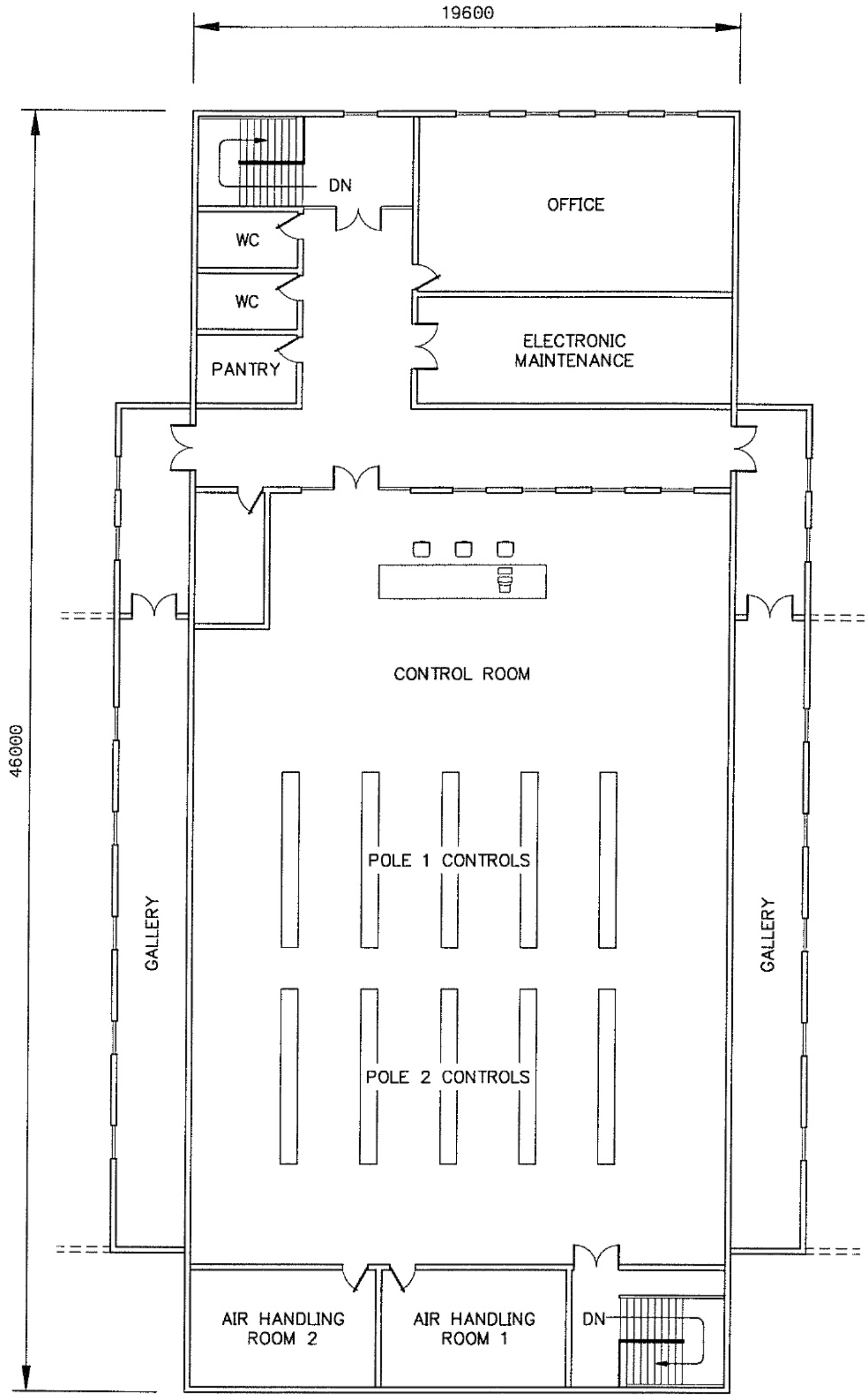
182\10001\a336



Converter Station Services Area
Main Floor Conceptual Layout

Figure 3.3-7

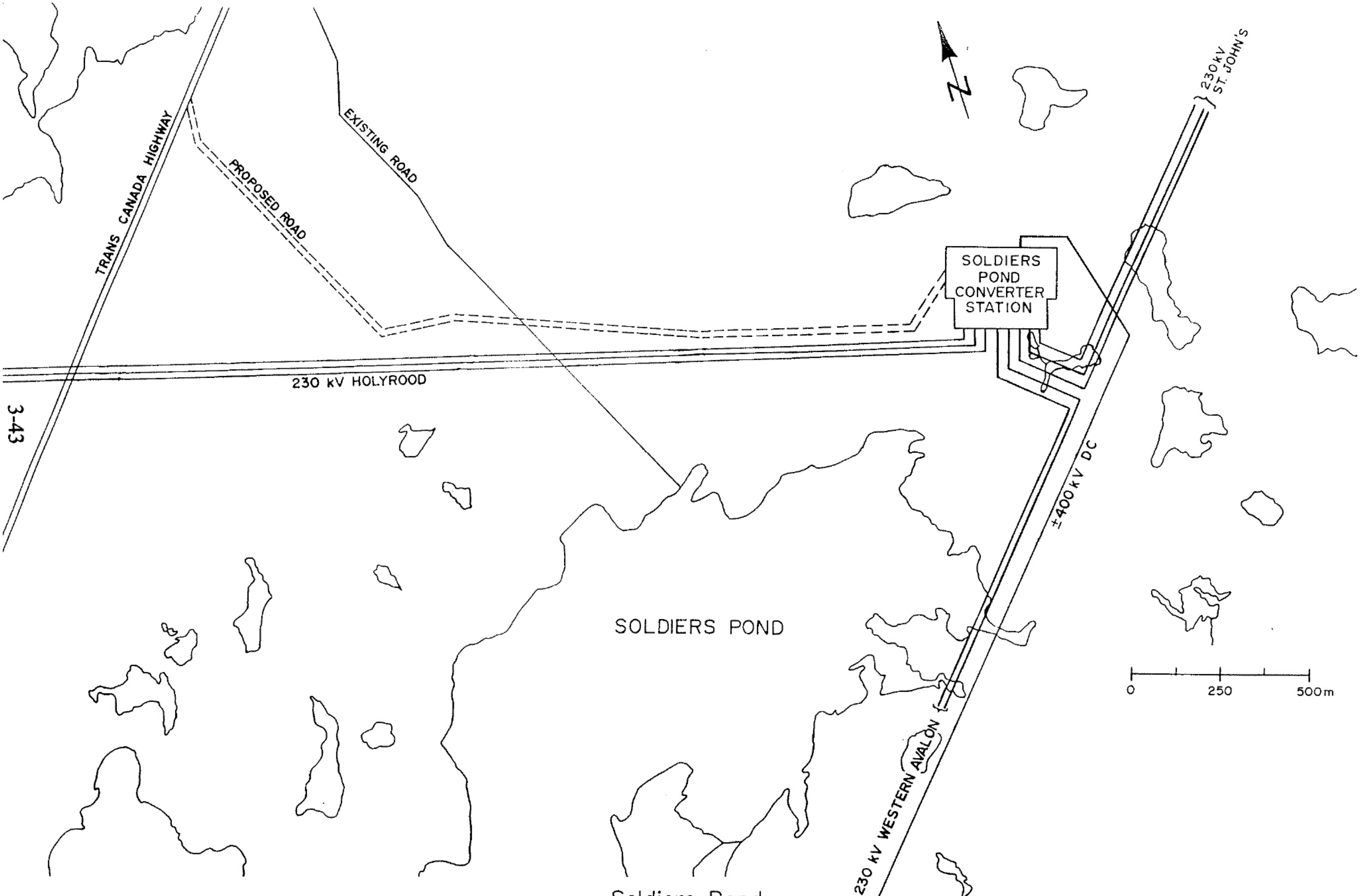
plot 1:250 182\10001\33-7



Converter Building Services Area
Second Floor Conceptual Layout

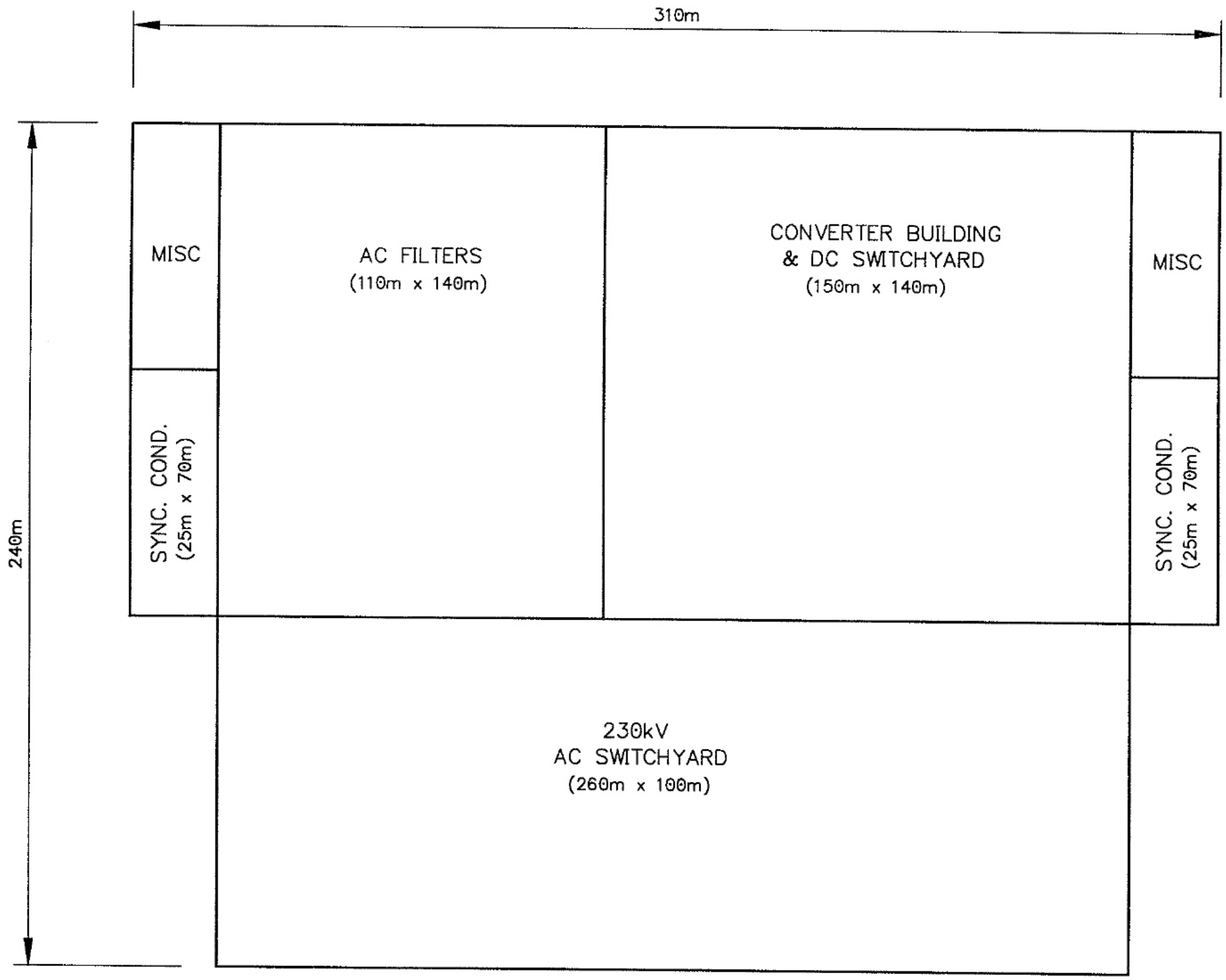
Figure 3.3-8

plot 1:250 182\10001\33-8



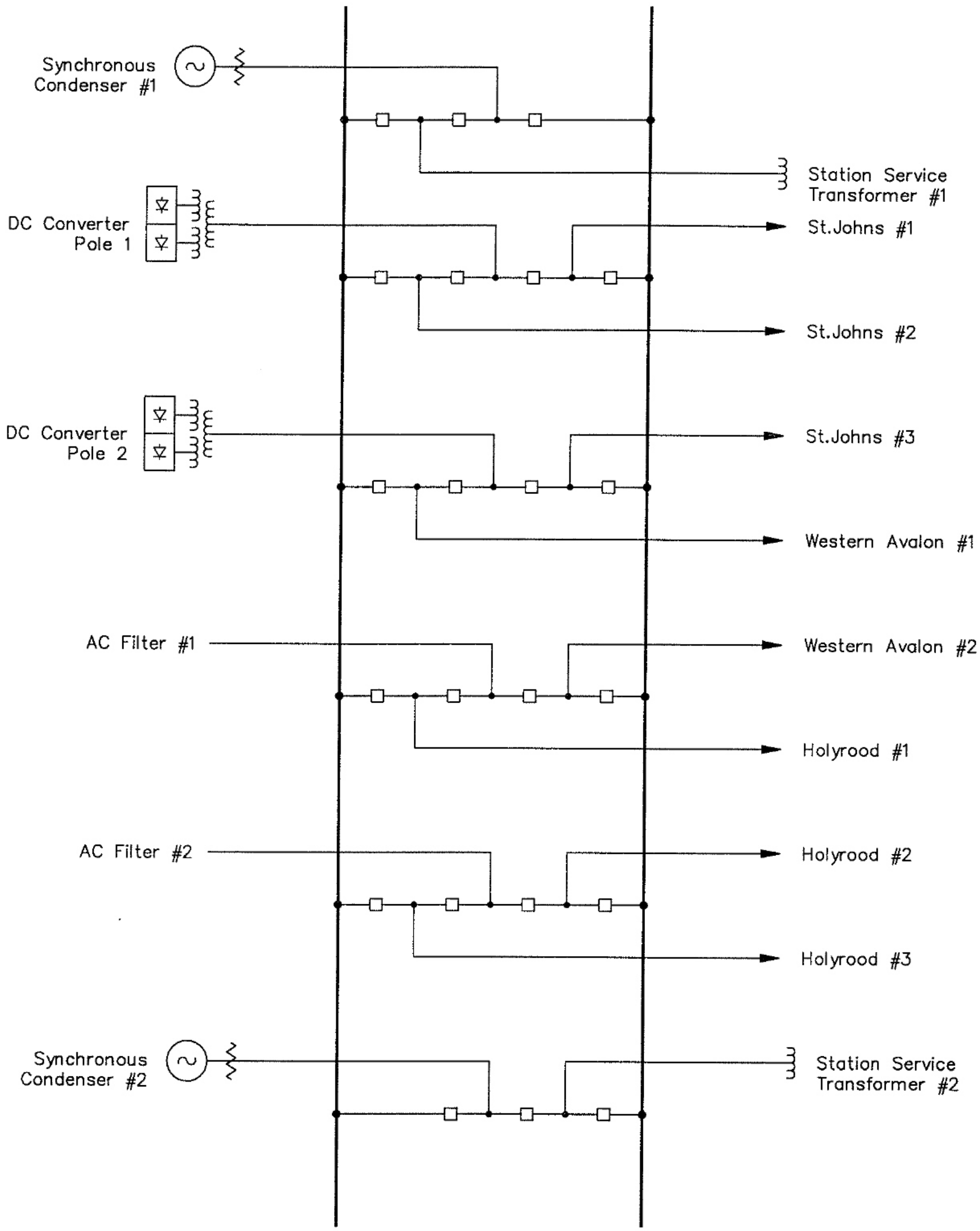
Soldiers Pond
Proposed Converter Station Site

Figure 3.3-9



Soldiers Pond
Converter Station Area Requirements
Figure 3.3-10

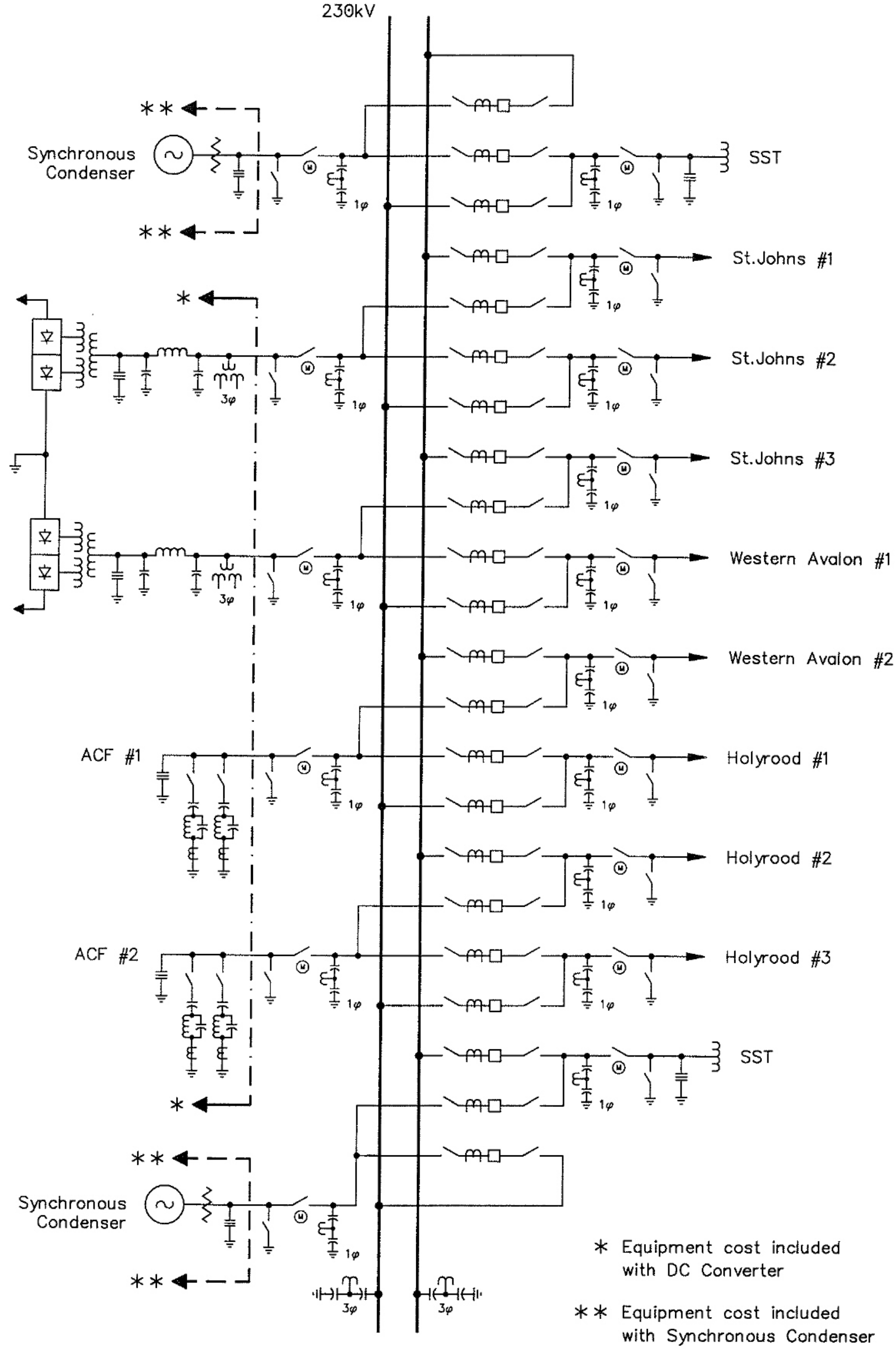
182\10300\01A



Soldiers Pond 230kV
Single Line Diagram

Figure 3.3-11

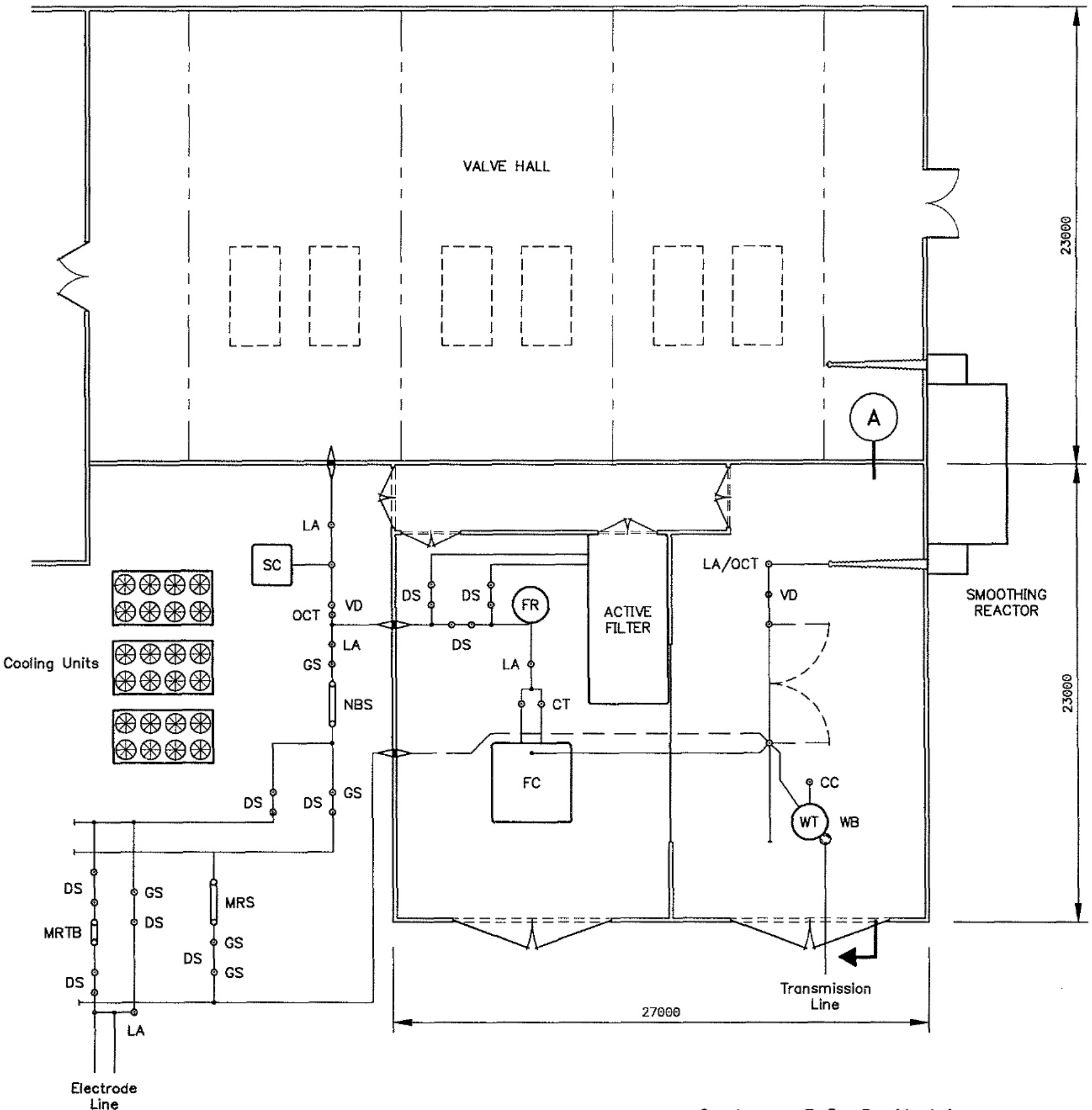
182\10001\33-11



Soldiers Pond 230kV
AC Switchyard Layout

Figure 3.3-12

182\10001\33-12



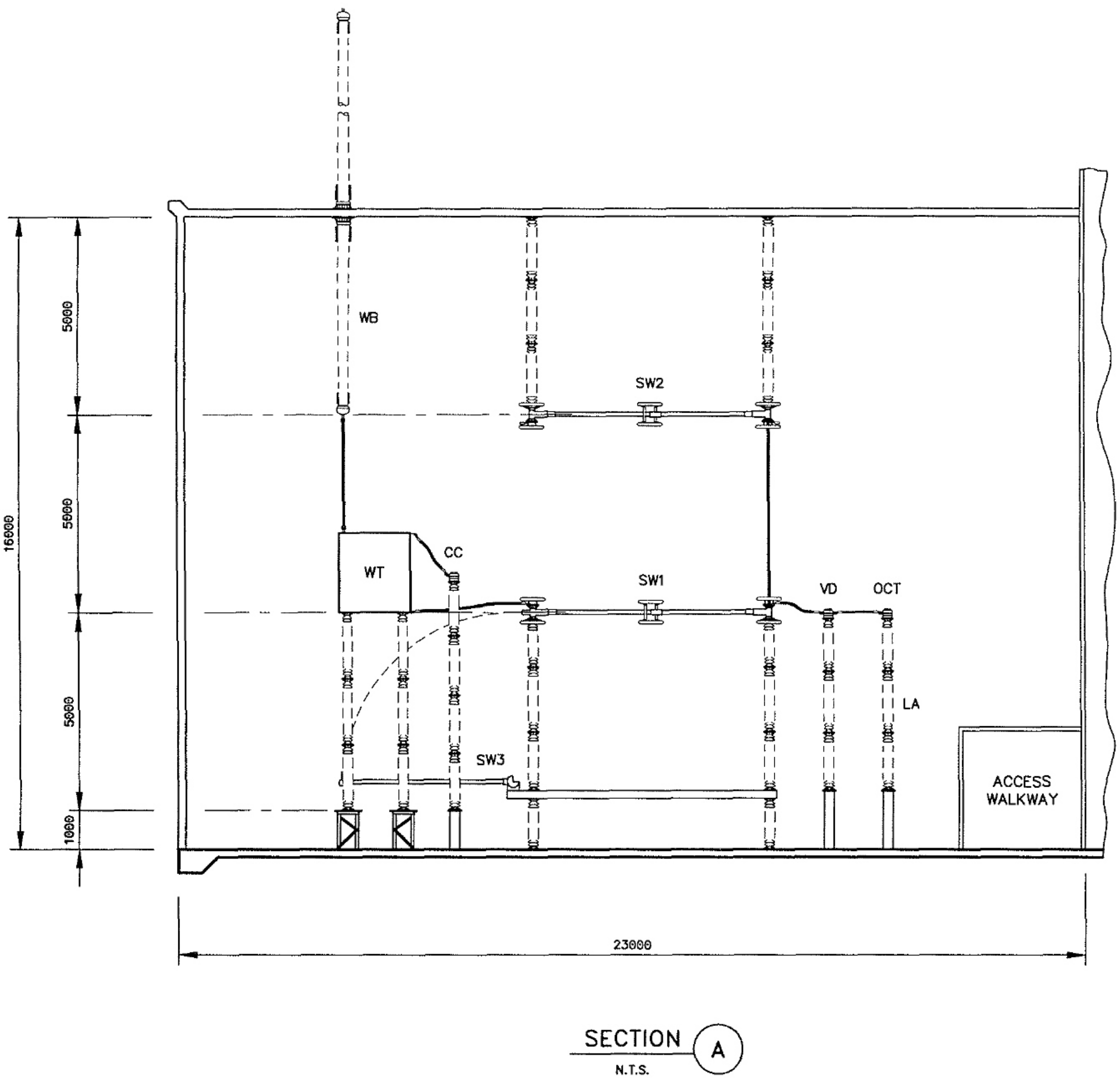
Note:
See Figure 3.4-14 for Section A

Legend:

CC	- Coupling Capacitor
CT	- DC Filter Unbalance CT
DS	- Low Voltage Disconnect Switch
FC	- DC Filter Capacitor
FR	- DC Filter Reactor
GS	- Ground Switch
LA	- Surge Arrestor
MRS	- Metallic Return Switch
MRTB	- Metalic Return Transfer Breaker
NBS	- Neutral Return Switch
OCT	- Optical Current Transformer
SC	- Surge Capacitor
SW1	- 500kV Line Switch
SW2	- 500kV DC Filter Switch
SW3	- 500kV Metallic Return Switch
VD	- Voltage Divider
WB	- 500kV Wall Bushing
WT	- PLC Wave Trap

Indoor DC Switching
Conceptual Layout
Figure 3.3-13

182\10001\a3313

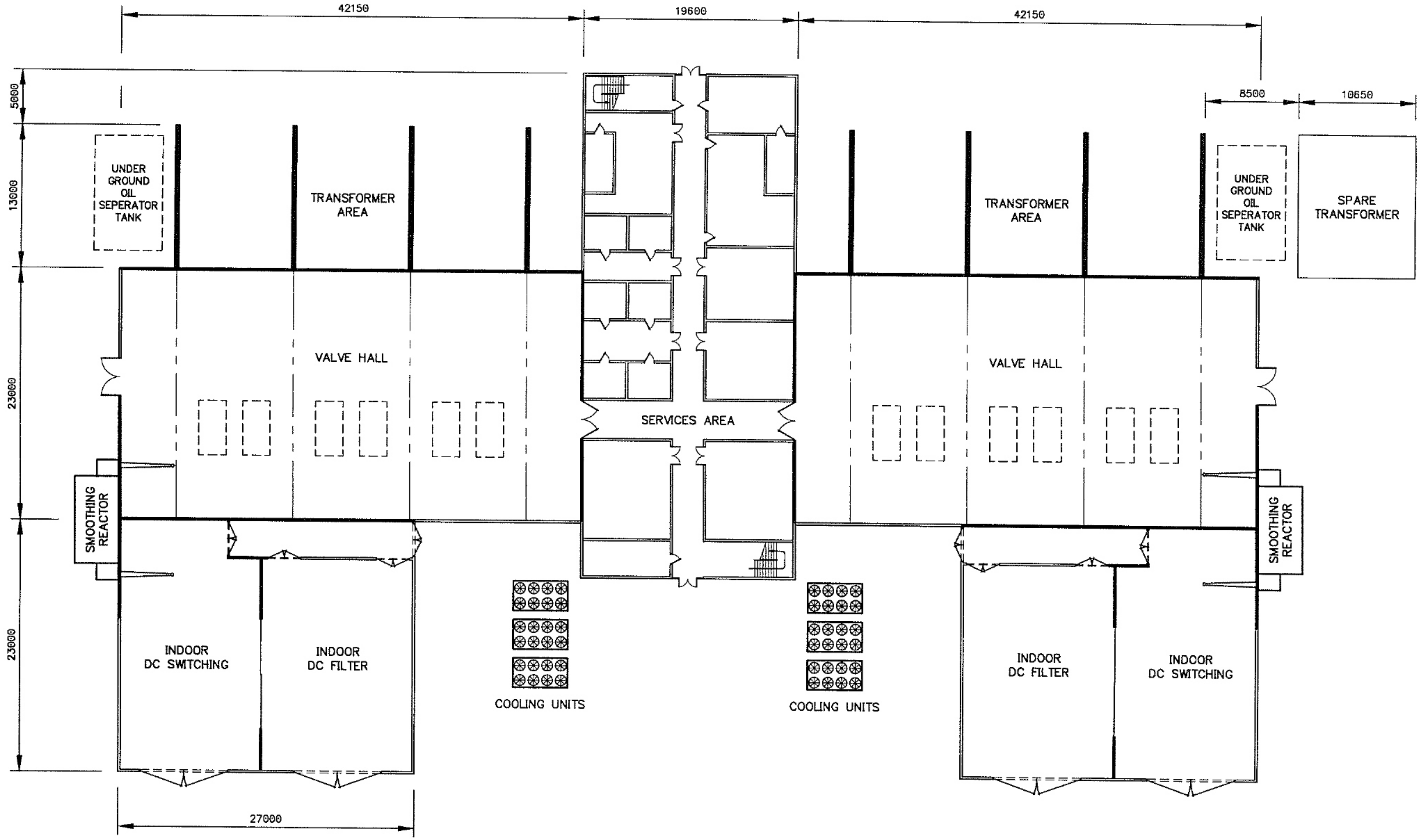


Legend:

CC	- Coupling Capacitor
CT	- DC Filter Unbalance CT
DS	- Low Voltage Disconnect Switch
FC	- DC Filter Capacitor
FR	- DC Filter Reactor
GS	- Ground Switch
LA	- Surge Arrestor
MRS	- Metallic Return Switch
MRTB	- Metallic Return Transfer Breaker
NBS	- Neutral Return Switch
OCT	- Optical Current Transformer
SC	- Surge Capacitor
SW1	- 500kV Line Switch
SW2	- 500kV DC Filter Switch
SW3	- 500kV Metallic Return Switch
VD	- Voltage Divider
WB	- 500kV Wall Bushing
WT	- PLC Wave Trap

Indoor DC Switching
Section
Figure 3.3-14

182\10001\a3314



Converter Building
with Indoor DC Switching
Figure 3.3-15

182\10001\a3315

3.4 Submarine Cable Crossing

3.4.1 Description

The Interconnection crosses the Strait of Belle Isle utilizing three submarine cables. The submarine cables terminate at L'Anse au Clair in Labrador and Yankee Point in Newfoundland as shown in Figure 3.4-1. The length of the underwater crossing is 38 km. Land cable sections of 1.3 km and 2.4 km will be required between the submarine cables and the cable terminal stations at L'Anse au Clair and Yankee Point respectively. The maximum depth of the cable crossing is 110m.

The cable terminal stations contain the cable potheads and connections to the overhead transmission line. Switching facilities for disconnecting a faulty cable by remote control are provided.

The submarine cables will be embedded for protection from damage by icebergs, shore ice, shore wave action and fishing operations.

3.4.2 Submarine Cable Route

Field investigations have been carried out in the past to select an appropriate submarine cable route across the Strait of Belle Isle. The routes investigated were:

- L'Anse au Clair to Yankee Point
- Forteau Point to Yankee Point
- L'Anse au Clair to Winter Cove

The investigations are summarized in Appendix III of Reference 6. The most significant conclusions based on the 1988 meeting which reviewed the Fenco Report on the 1986/87 Iceberg Monitoring Program are as follows:

- The preferred route is from L'Anse au Clair to Yankee Point.

- The sill area at the entrance to the Strait prevents icebergs with drafts greater than 70m from entering the proposed cable route areas. It is therefore considered necessary to protect submarine cables from iceberg grounding only in areas where the water depths are less than 70m. This protection may consist of an overburden or rock trench, an adit or a tunnel.

- Cables should be trenched into the sea bottom in depths greater than 70m for protection against fishing activity.

- At L'Anse au Clair, the cables could be protected out to the 70m water depths in overburden.

- At Yankee Point, the cables could be protected out to the 70m water depth in either an adit or rock trench.

The L'Anse au Clair to Yankee Point route was selected in previous investigations for a number of reasons. L'Anse au Clair offers a protected landing approach and the major part of the shore approach is covered by overburden allowing easier burial of the cables. In addition, there are fewer icebergs in the southern area of the Strait of Belle Isle. The Yankee Point landing provides for the shortest distance, about 3 km, from the 70m water depth to shore. An alternative landing site at Winter Cove, south of Yankee Point, required trenching for about 17 km.

The cables will be spaced at least 500m apart depending on subsea terrain and geology (Reference 4).

3.4.3 Landing Sites

L'Anse au Clair landing site, Labrador, is in a bay that offers some shelter as shown in Figure 3.4-2. The cable terminal will be located 1.3 km from shore to reduce the exposure of the DC transmission line to salt contamination.

Yankee Point landing site, Newfoundland, is relatively exposed as shown in Figure 3.4-3. Therefore, the cable terminal is located 2.4 km from the shore on the east side of the highway to reduce the exposure of DC transmission line to salt contamination.

3.4.4 Type of Cable

Solid type cables (mass impregnated) with paper insulation will be used. Solid type cables are suitable for transmitting 1500A at 400 kV, as required by the project.

The Kontec HVDC Interconnection between Denmark and Germany, which went into service in 1995, has a rating of 400 kV, 600 MW, 1500A.

Other submarine cable projects with 600 MW cable ratings are as follows:

	Voltage kV	**Current A**	**In Service Year**
Baltic Cable (Sweden and Germany)	450	1333	1994
SwePol (Sweden and Poland)	450	1388	1999

The NorNed Cable Project (Norway and Netherlands), Viking Cable Project (Norway and Germany), and the Eurocable Cable Project (Norway and Germany) which are planned for installation in the next few years will all have ratings at least 600 MW per cable.

Solid type cables are lower in cost than self-contained, oil-filled cables and do not require oil pressuring plants at the cable terminals.

The studies of the cable crossing of the Strait of Belle Isle carried out in the 1980's were based on oil filled cables as solid type cables of adequate rating had not been developed at that time.

3.4.5 Cable Rating

The cables will be rated at 400 kV, 1500A. This current rating corresponds to the nominal continuous overload rating of the converter equipment. The normal maximum continuous system operating current will be 1000A in the summer and 1150A in the winter.

The cable will have a short-time overload rating of 2300A for a duration of about ten minutes, then ramping down to 1500A in about five minutes as shown in Figure 3.1-3.

Each cable will have a diameter of about 120 mm. The copper conductor will have a cross section of about 1600 mm^2. There will be one layer of armour wire as the cable will be well protected from mechanical damage and pulling tensions do not warrant double layer armour.

3.4.6 Number of Submarine Cables

Three submarine cables will be installed. One cable is required for each pole, and one spare cable is provided to ensure reasonable availability of the DC system. The spare cable is switchable to either pole as shown in Figure 3.4-4. Repair of a cable fault is expected to take up to a year as repairs will not likely be possible during the six months of winter and suitable cable ships for repair may not be readily available from Europe or Japan.

Previous studies were based on a 2000A capacity being required per pole. This current would have occurred in the event of a transmission line or cable permanent fault where the associated converter equipment was to be connected in parallel with the converter equipment on the healthy pole. The previous studies considered two alternatives to meet the 2000A/pole requirement as follows:

Rating of individual cable (A)	Number of Cables Per Pole	Total Number of Cables
1150	2	4
2000	1	3

On the scheme currently proposed it is not necessary to parallel the valve groups onto a pole. A cable fault will not result in a prolonged outage of a pole because there is a spare cable that can be quickly switched into service. In addition, it is unlikely that a transmission line pole conductor will be out of service for a prolonged period of time.

3.4.7 Transportation of Cables

Cable laying ships such as the Skagerrak or Giulio Verne can transport three 38 km 1500A cables in one trip. Cargo ships can also transport the above cables in one trip.

3.4.8 Embedment of Cables

Previous studies (Reference 4) established that physical protection is required to protect the cables from:

a) fishing activity
b) wave action
c) ice ridging in near shore areas
d) icebergs

Special protection against anchors was not considered necessary (Reference 4). Although the Strait of Belle Isle is a major navigational corridor, large vessels do not anchor in the Strait and would only do so in case of an emergency. Therefore, it is considered that the likelihood of damage to the cables from anchors is remote.

Previous investigations indicated that it is necessary to protect against iceberg grounding where the water depth is less than 70m.

Embedment depths have been subject to extensive investigations (Reference 4). The embedment depths are summarized as follows:

Type of Material	Water Depth	Embedment Depth
Overburden	down to 70m	2.0m
Rock	down to 70m	2.0m
Overburden	below 70m	0.6m
Overburden less than 0.6m	below 70m	concrete mattresses

A sea bottom profile of the submarine cable route is shown in Figure 3.4-5.

It was established in previous investigations that burial in overburden will provide protection against icebergs (Reference 6). Recent work carried out on pipelines in the Arctic suggests that an embedment depth of 2m in overburden for protection against iceberg grounding recorded in the Strait of Belle Isle is likely adequate based on subscour deformation in granular soils (Reference 7).

The depth of embedment in rock is determined by the thickness of rock layers between bedding planes. Placing the cable below the level of the upper most rock layer will guard against damage from rock movement that may be caused by ice scour or seismic activity. A cable burial depth of 2.0m is considered appropriate. Yankee Point is the main areas where rock trenching is required. A lesser embedment depth may be acceptable in areas where the rock is not layered.

An embedment depth of 0.6m in overburden to protect against trawl boards was selected based on previous studies (Reference 4).

Previous investigations (Reference 4) have shown the overburden in the L'Anse au Clair area is composed of sand, gravel, cobbles and occasional boulders. The depth of overburden is generally greater than 2m.

From the L'Anse au Clair landing site, it is approximately 9 km until the water depth is consistently below 70m as shown in Figure 3.4-6. Analysis of data indicates that the depth of overburden is greater than 2m over most of the distances. Between 7000m to 8700m from shore the overburden is less than 2m. In this area it may be necessary to trench through the overburden to trench in the rock.

At Yankee Point the distance from the shore to the 70m depth is 2.6 km. The surface varies from exposed bedrock to overburden of about 2m depth as shown in Figure 3.4-7.

For the route below 70m, there is generally more than 0.6m of overburden. The overburden consists of sand, gravel, cobbles and boulders.

Embedment in overburden will likely be by ploughing or by water jetting the overburden after the cable is laid.

Rock trenching at Yankee Point and in a portion of the L'Anse au Clair landing will be accomplished by drilling and blasting or by using a rock trenching machine. Contractors have confirmed that each method is practical. The preferred method would likely be trenching by machine. There will be one cable per trench.

The bedrock at Yankee Point has a high compressive strength. The bedrock to a water depth of about 20m is Hawk Bay Limestone with an average compressive strength of about 290 MPa while in deeper water the bedrock is Hawk Bay Sandstone with an average compressive strength of about 140 MPa.

General Offshore, a contractor experienced in construction of trenches, noted that trenching for this project can be made by rock blasting or mechanical trenching, most likely a combination of both. General Offshore has burial equipment that could be modified for the project although it is more likely they would build a purpose built machine. A example of an General Offshore trenching machine is SPENCER, a tracked burial machine designed to lay and bury submarine cables. This machine has a racksaw chain cutter capable of excavating a trench in rock with a compressive strength of up to 60 MPa. The machine is described in Volume 2.

3.4.9 Installation of Cables

Installation of the cables would probably start from Yankee Point, Newfoundland. Yankee Point is a relatively exposed location. Calm sea conditions can be selected to start the installation but calm conditions cannot be guaranteed for the entire duration of a cable laying run. Two equipment groups would probably be used, one consisting of a cable ship and support vessels for laying the cable, and the other consisting of the embedding device, tug and support vessels for embedding the cable.

The cable laying operation would lay one cable per run across the Strait. Each run, once started, would proceed until completion unless interrupted by a severe storm, breakdown of equipment or other unforseen problem in which case it may be necessary to cut and cap the cable and return later to complete the operation. The cable laying run, if uninterrupted, would be expected to be complete in a day.

Cable embedment in overburden will be by jetting or ploughing. The complete embedment of the cables including covering trenches and providing concrete mattresses will likely take several months.

3.4.10 Land Cables

Land cables would be installed between the shore and the cable terminal. Land cables may have a larger conductor size as the cooling on land is not as good as in the sea. The land cables will be installed in a cable trench or concrete cable chase and therefore no armour is required.

3.4.11 Cable Terminals

The cable ends (potheads), lightning arresters, disconnect switches and current measuring devices are installed indoors to avoid insulator salt pollution problems. The wall bushing to the building would likely be of a composite design with silicon rubber sheds. Figure 3.4-8 shows a conceptual layout of the terminal building.

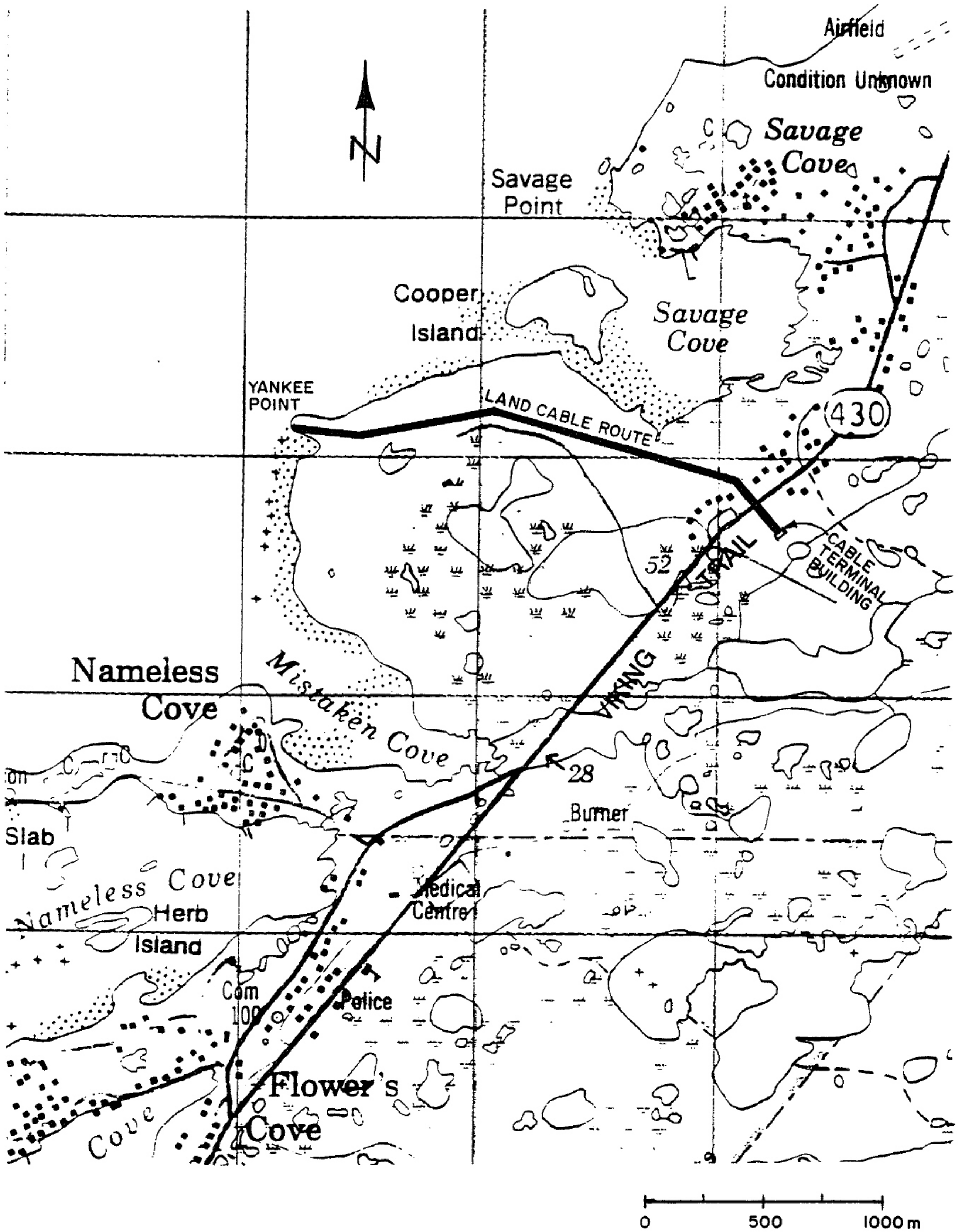
3.4.12 Spare Cable Storage

Manufacture of a length of cable to repair a damaged cable and shipping it to the site could involve a considerable time. To avoid excessive delays in repairing a damaged cable, it is proposed that three km of spare cable be stored at a convenient location such as Corner Brook. The cable storage facilities should be at dockside and should include facilities for loading the cable on a ship or barge.

3.4.13 Finalization of Cable Route

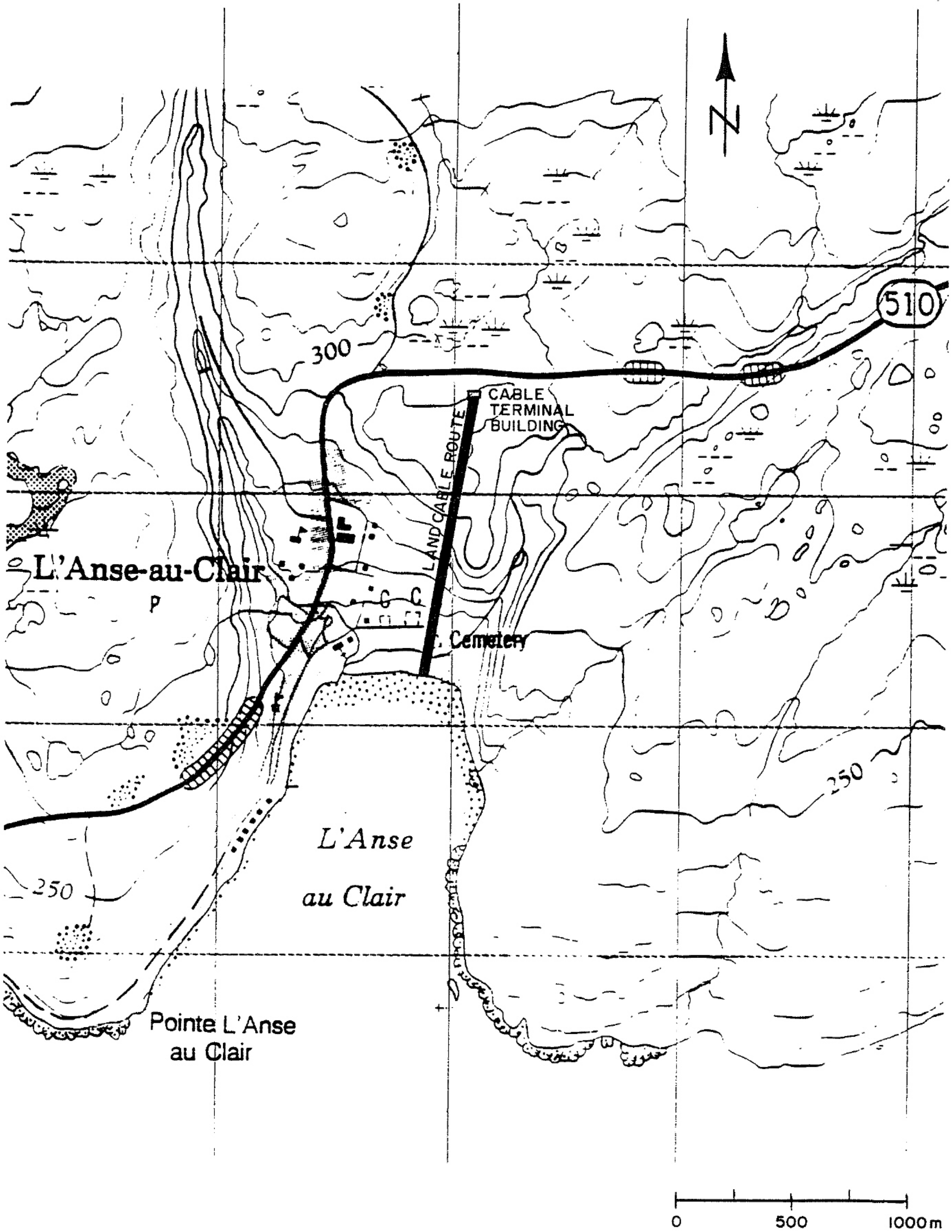
Further work is required to finalize the submarine cable route. The high cost of trenching in bedrock makes it essential to minimize the amount of rock cutting and select a route where the rock characteristics are such that it is easier to trench. In particular, additional measurements are required for the bedrock at Yankee Point.

The cable route will be selected to avoid rock ledges as these are costly to remove.

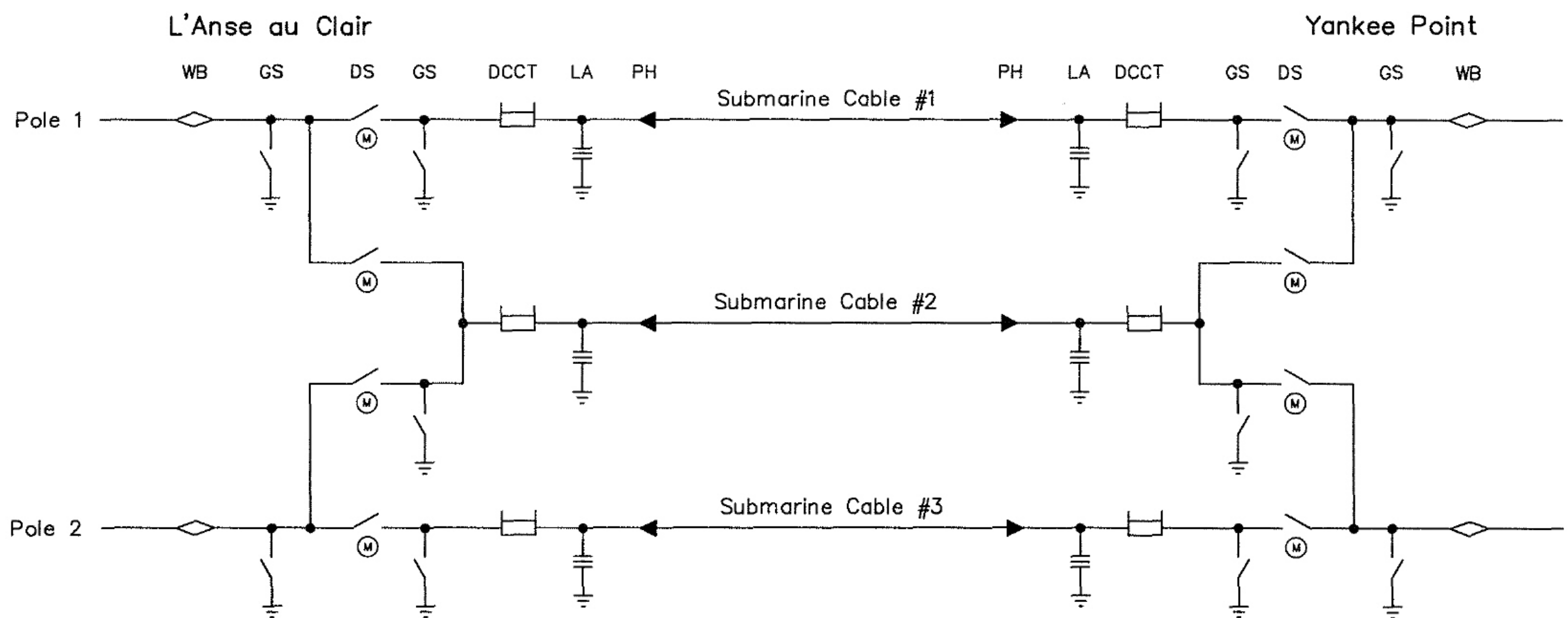


Strait of Belle Isle
Yankee Point Cable Landing

Figure 3.4-3



Strait of Belle Isle
L'Anse au Claire Cable Landing
Figure 3.4-2

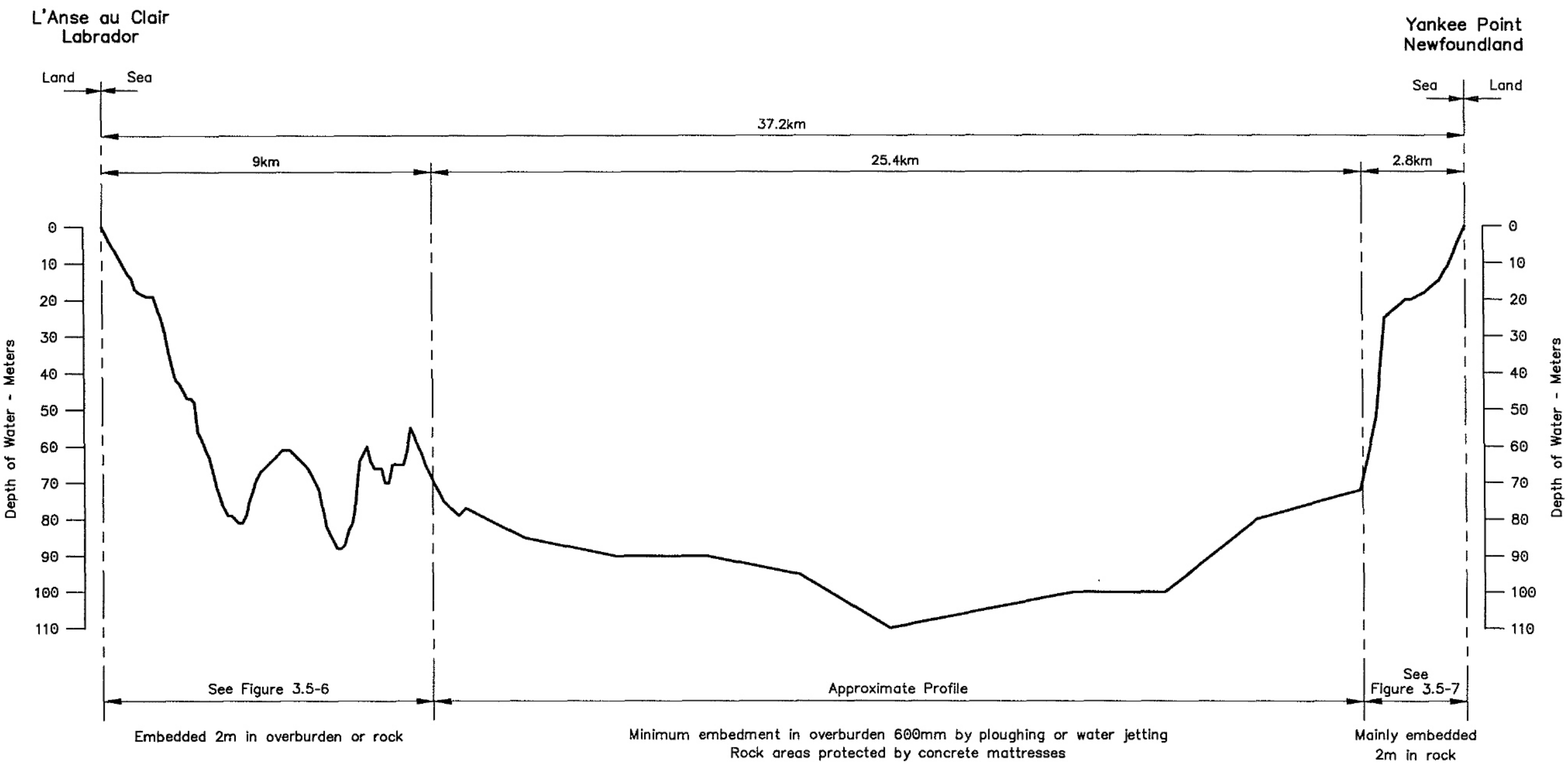


Legend:

WB	Wall Bushing
GS	Ground Switch
DS	Disconnect Switch (motor operated)
DCCT	DC Current Transformer (optical type)
LA	Surge Arrester
PH	Cable Termination

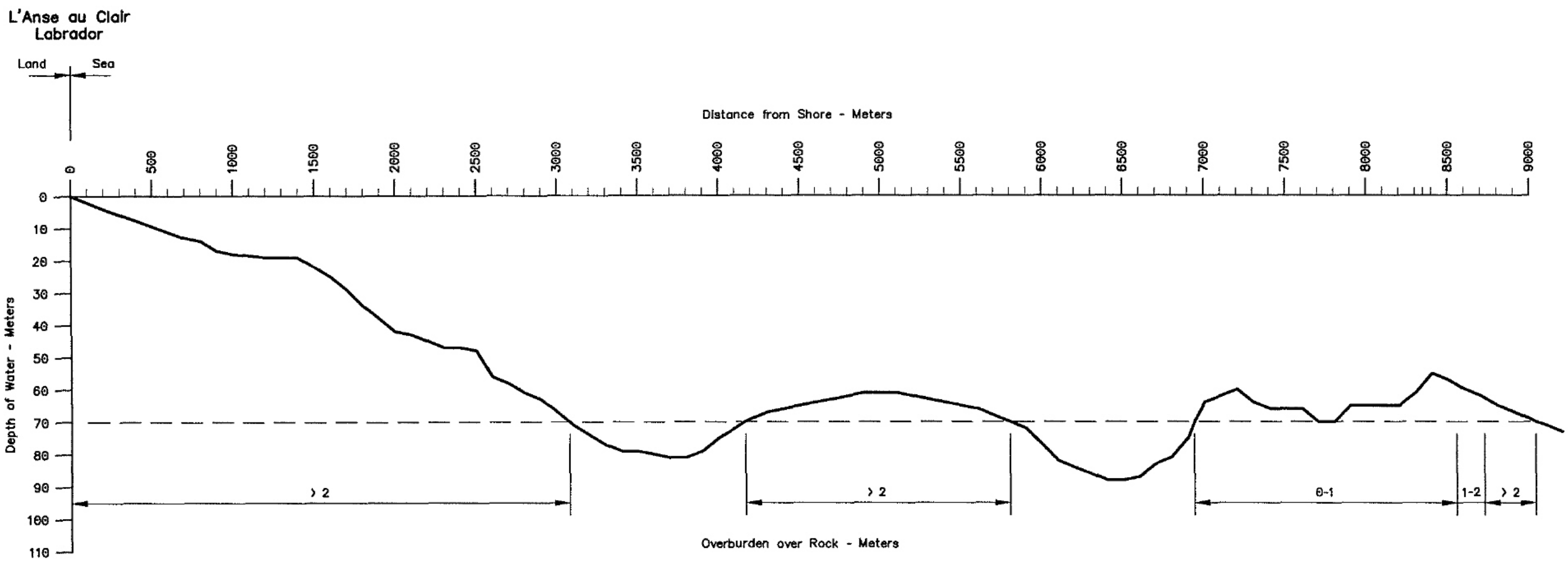
Strait of Belle Isle Three Cable Crossing
Single Line Diagram
Figure 3.4-4

182\10001\34-4



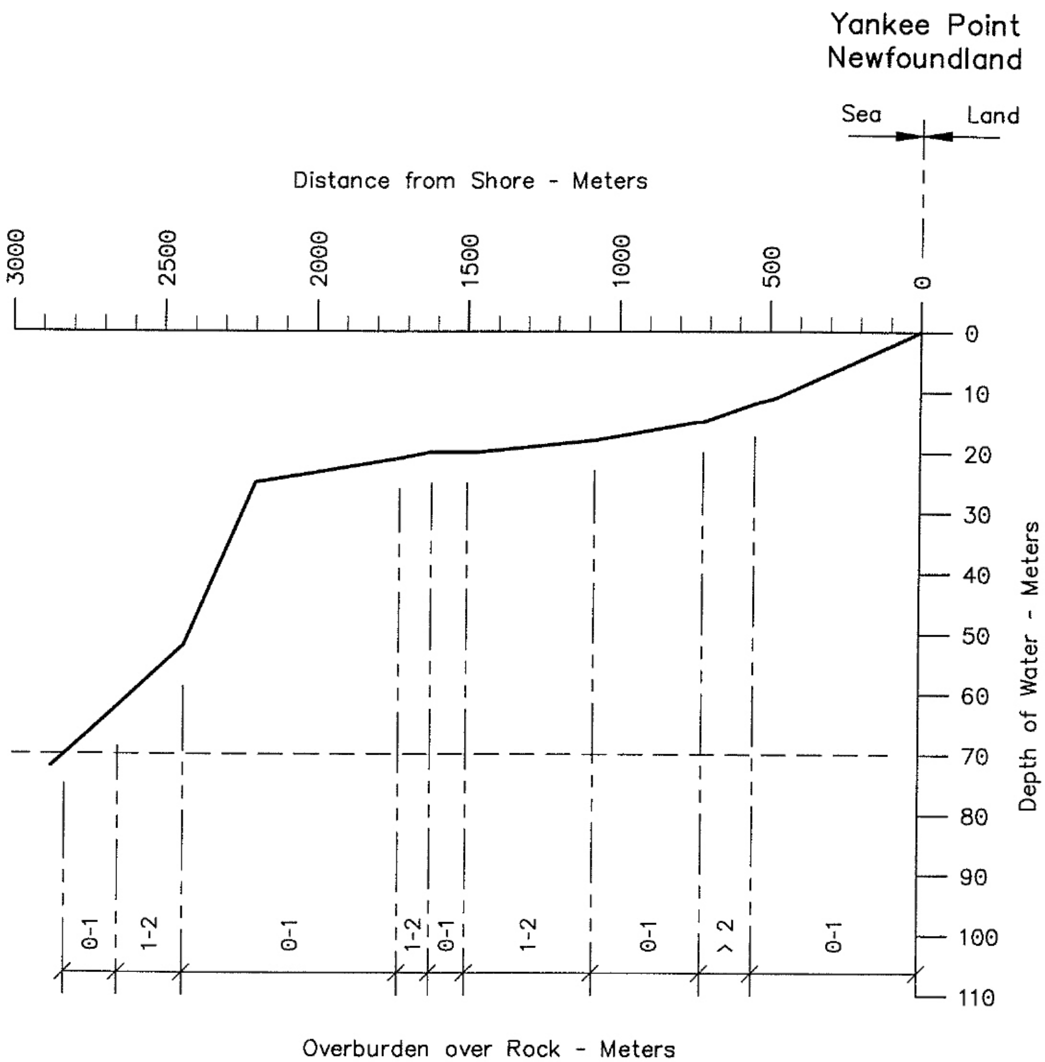
Strait of Belle Isle Submarine Cable
Sea Bottom Profile of Cable Route
Figure 3.4-5

182\10001\a345



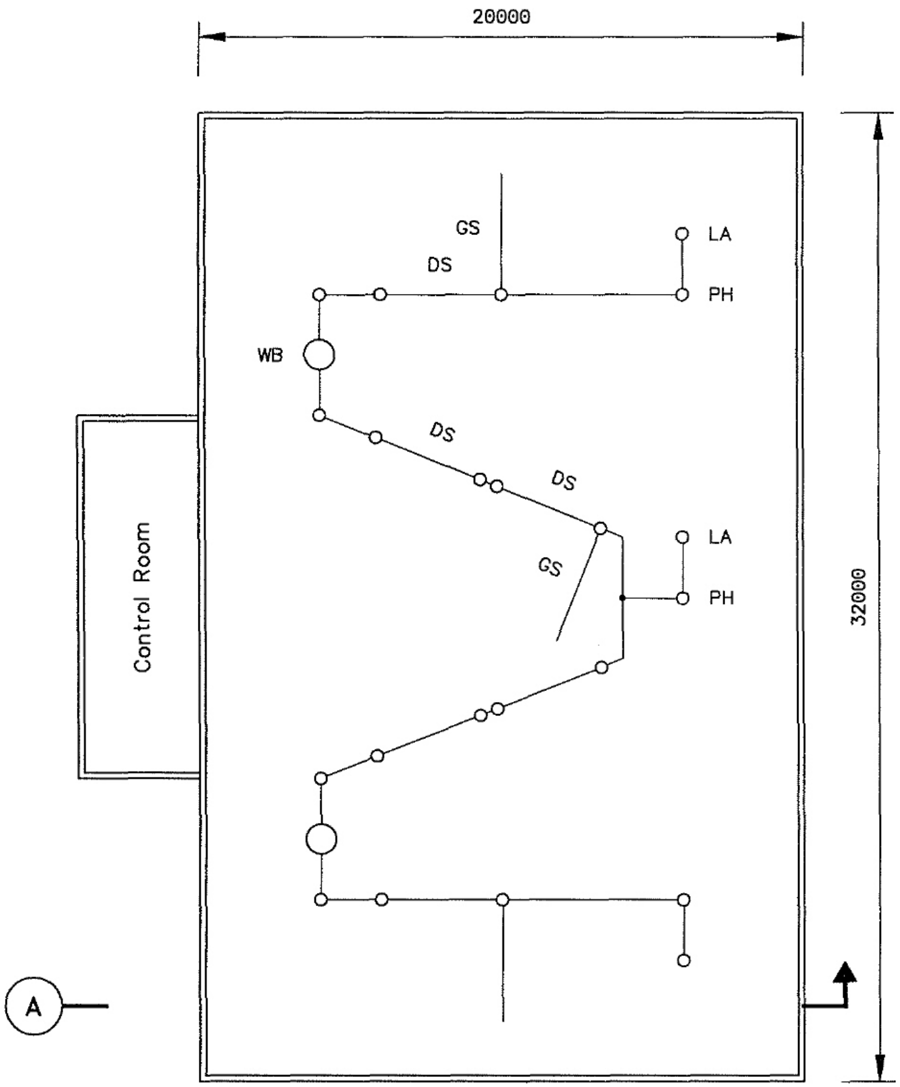
L'Anse au Clair
Submarine Cable Route Profile (near shore)
Figure 3.4-6

182\10001\a346

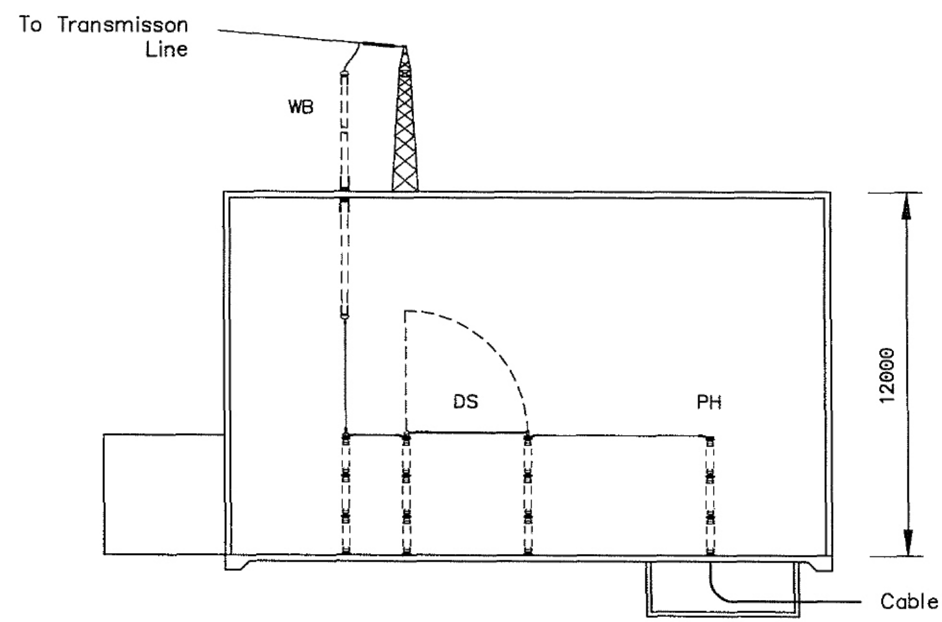


Yankee Point
Submarine Cable Route Profile (near shore)
Figure 3.4-7

Plot 1:25 182\10001\34-7



LAYOUT



SECTION (A)
N.T.S.

Strait of Belle Isle Three Cable Crossing
Terminal Building Layout and Section
Figure 3.4-8

Plot 1:250 182\10001\34-8

3.5 Communications System

3.5.1 General

HVDC transmission systems require highly reliable and secure communications systems. The communication system is needed both for the normal steady state control and for the implementation of modulation functions which can significantly enhance the performance of the AC systems. Voice communication between sites and communications to the SCADA control centre are also needed.

Given the importance to the operation of the HVDC system, the performance of the communications system with respect to availability and quality of service must be very high. Typical specifications are as follows:

a) Circuit availability (annually) 99.9%
b) One way Bit Error Rate - The BER shall not exceed the following values:
   - 1×10^{-3} for no more than (0.054% * L/2500) of any month measured with an integration time of 1 second
   - 1×10^{-6} for no more than 0.4% * L/2500) of any month measured with an integration time of 1 minute

   (L is path length in kilometres.)

The total amount of communications capability required for the HVDC alone is modest and can easily be accommodated on a single microwave or fibre optic communications link. The total requirement is approximately 25 low speed (2400-9600 bps) data circuits. For reliability it is considered that the HVDC control and protection channels (2 channels per pole, 4 in total) should be provided with backup on an alternate path. The performance and quality of the backup communications should be similar to the main communications.

Either microwave or fibre optic communications systems would be suitable. The costs are based on a microwave system.

Satellite communication systems are unsuitable for this HVDC scheme because of the inherent delays in the transmitted signal.

The communications to the cable terminal stations will be entirely on the new microwave system. This will provide a sufficiently reliable communications system as there will be two paths, one to Soldiers Pond one to Gull Island. A total loss of communications to the cable stations would occur only if one of the microwave installations at either cable terminal station were to fail.

Voice circuits will be required among all sites with buildings. Larger sites can be equipped with PBXs interconnected with trunk circuits carried on the main carrier links. Backup voice communications can be provided over central office trunks to the switched telephone network. Smaller sites can be equipped with remote extensions carried over the main carrier backbone to other PBXs in the system.

In addition to the control and other data circuits interconnecting the HVDC converter stations, SCADA data and telephone connections will be required to the L'Anse au Clair and Yankee Point cable terminal stations on the Strait of Belle Isle and the Energy Control Centre in St. John's.

3.5.2 Communication Requirements for the HVDC Transmission System

Communication channels are required between converter stations, the cable terminals and remote control centres for exchange of data and for voice communication. The communications signals fall into two categories, critical control and protection signals including some that require high reliability and security and other less critical signals provided for operator control and monitoring.

While the transmission system can continue to operate at a fixed power transfer even during complete communication outages, the communication outage usually means a significant reduction in the performance of the link and the benefits to the AC systems. Frequently, a communications outage would require a reduction in the power transfer of the DC system to ensure that a fault will not have an unacceptably large impact on the AC systems. Protection and safe shutdown of equipment is not dependent on communications.

Duplicated (main and standby) communication circuits are usually provided for the exchange of important control for each pole. Implementation of main and standby circuits on independent communications links results in a requirement for a total of four circuits per pole.

Single channels are required for the following:

- DC line fault locator. This would require single 2400 bps links between the two converter stations and from each cable terminal station to the converter station on the same side of the Strait of Belle Isle.

- HVDC transient fault recorder (TFR) master station. This would require one 2400 to 9600 bps channel for exchange of data between the TFRs at the two converter stations

- SCADA telemetry and control. This would require at least one 2400 to 9600 bps channel from the control centre in St. John's to each converter station. Monitoring and control of the cable terminal stations would be achieved over a single channel between the cable station and the converter station on the same side of the Strait. An optional high speed channel for exchange of data between the two converter stations would also be desirable since this would allow full operator control status information and control signals from the remote converter station to be available at both converter stations.

These circuits are not required to be backed up on an alternate communications path as they are not critical to operation and performance.

It is assumed that voice communications between the two converter stations and between the converter stations and the control centre in St. John's can be backed up using an alternate communications path. Voice communications is needed for emergency operation of the DC system in the event that the communications are completely out of service.

Voice communications to the cable terminal station does not need to be as reliable since it is anticipated that the cables will be switched very infrequently.

Thus, the primary communications requirements of the DC system can be satisfied with a modest number of low speed data channels that can be accommodated in a single microwave or fibre optic communications system. Four channels on an alternate path are required to be leased for the HVDC control and protection. Backup voice circuits can be obtained by regular dial-up telephone service.

The main backbone link will be required to carry about 25 low-speed (2400 bps) data circuits (i.e., four HVDC control and protection, three or four fault locator, one TFR master and seven SCADA) and about nine voice circuits.

A conceptual overview drawing showing the required communications link is shown in Figure 3.5-1.

Primary multiplexers have a capacity of 24 channels operating at speeds up to 64 kbps. Two multiplexers are required for equipment redundancy and would have a capacity of 48 channels. The additional unused capacity can be used for other purposes.

3.5.3 Communication Options

There are a number of communications technologies which can be considered for the requirements outlined above:

Microwave Radio

Microwave radio was recommended as the main carrier medium in the original report. The advantages of microwave are high performance digital service, medium-to-high channel capacity, independent operation from the HVDC line and concentration of facilities at fixed sites. Microwave technology requires line-of-sight between terminals and special techniques are required to minimize atmospheric fading. Link spans will depend on topography. If repeater sites can be located on elevated sites such as hills or bluffs, longer spacings can be obtained. Over the worst case topography, flat reflective terrain, spacings can vary from 30 to 60 km depending on the height of the antenna towers. Repeater sites located in remote areas can require significant expenditures for remote access roads, power and civil works. If distribution lines are not available, significant ongoing costs will be required to maintain self-contained power supplies such as diesel generators.

Power-Line Carrier

Power-line carrier is a technology employed exclusively by power utilities which uses the power lines as the carrier medium. Long distances can be covered over most lines but channel capacity is limited. Although multiple terminals and sub-multiplexing could be provided to carry the quantity of circuits required for this application, higher carrier frequencies will be necessary for the total number of circuits required. The heavy ice loading conditions can be expected to have a severe effect on signal attenuation which would result in shorter link spans and the requirement for periodic high voltage coupling/decoupling equipment for repeaters and the uncertainty of correct operation over links operating under simultaneous conditions of poor weather and high fault noise.

Fibre Optics

Fibre optics is a technology which is often used on high voltage transmission lines. There are three types of fibre optic cables which are typically used on these lines: Optical Ground Wire (OPGW) which incorporate optical fibres into an overhead shield wire, All Dielectric Self Supporting (ADSS) cables which are fastened to the towers underneath the phase conductors and helically-wound cables which are wrapped around the shield wires or phase conductors.

Fibre optic cables have the advantage of longer spans between repeater sites compared to microwave radio (up to several hundred kilometres as opposed to thirty to sixty kilometres for microwave) with attendant reduced requirements for access, local power and the civil works necessary for the development of such sites. Other advantages are high channel capacity and immunity to fading and electrical noise.

Optical fibres can be incorporated in the shield wire of the DC line. A high strength ground wire would need to be provided considering the expected high wind and ice loadings. If fibre optic communications are selected, it may still prove advantageous to use microwave for crossing the Strait of Belle Isle since it would avoid installing a fibre optic cable.

ADSS cables will have problems with the severe wind and ice loading conditions expected on this route. Helically-wound cables are less common and are usually not used above 110 kV. Another possible design, not normally used on transmission lines, is a steel armoured cable fastened to the transmission line towers but lower than an ADSS cable to ensure sufficient clearances to the DC conductors. Such a cable might be designed to withstand the high wind and ice loads expected. A custom design would be required, however, with a high per metre cost.

3.5.4 Communications System Included in Cost Estimates

The cost estimate is based on construction of a new microwave link for the main communication system and leased circuits for the back-up communication system and will have the following features:

a) The main communications link between the two converter stations is by a digital microwave system. This will have adequate capacity for all the required signals including voice communication between all sites. If microwave is selected, a high capacity system should be installed as the cost will only be slightly higher than a low capacity system which just meets the minimum requirements. The high capacity system would provide sufficient capacity for future expansion and for other functions such as video conferencing, video surveillance, VHF mobile radio and MIS data requirements.

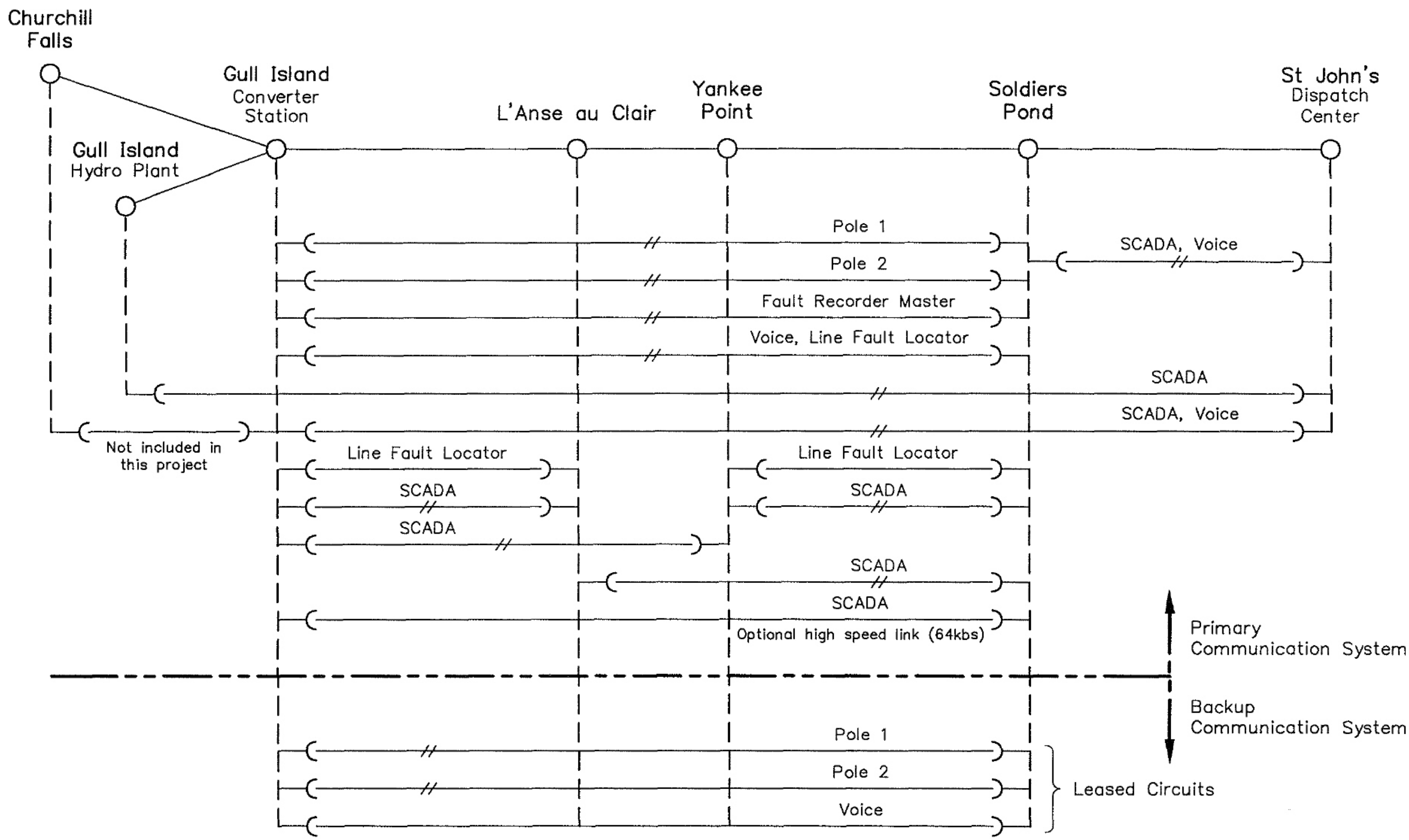
b) Backup communications for the HVDC controls will be provided using leased circuits from private carriers. There is an existing communications carrier between Happy Valley and St. John's. New links between the Gull Island converter station and Happy Valley and the

Soldiers Pond Converter station and St. John's would be required to link up with the existing carrier.

c) The link between Soldiers Pond and St. John's would be via the East Coast microwave system. The cost of this link has not been included in the estimate.

d) Communications to the cable terminal stations will be on the new microwave system. A microwave drop should be provided at each terminal station.

e) SCADA telemetry and remote control of the DC stations and cable terminal stations from the control centre in St. John's would be transmitted on the new digital microwave system.



Note:
Microwave repeater sites not shown

HVDC Transmission System Communications System
Conceptual Overview Diagram
Figure 3.5-1

182\10001\35-1

3.6 Activities Prior to Project Implementation

Some activities should be completed prior to Project Release in order to optimize the design, refine the system performance and maintain the overall project schedule. The results of these activities will not affect the feasibility of the Interconnection but should enable refinements to the design and thus reduce the overall project cost. These activities are as follows:

a) Investigate the integration of the DC system into the Island AC system to establish:

- loss of load probability and overall system reliability
- overload ratings of the DC system
- reactive compensation
- AC system reinforcements
- generation dispatch criteria
- loading shedding scheme
- AC system fault survey

b) Investigate the integration of the DC system into the Labrador AC system including:

- system operation including power interchange with Churchill Falls and Quebec
- reactive power requirements at Gull Island Converter Station
- integration of Muskrat Falls Generating Station

c) Investigate the DC transmission line design in the Long Range Mountains area to establish if there should be two monopolar lines on different routes or a strengthened bipolar line.

d) Investigate the DC transmission line design to establish if it is preferable to use tubular steel towers to reduce the effect of ice loading or use lattice steel towers.

e) Review and finalize the DC transmission line mechanical loading using the additional ice loading information now available.

f) Investigate the use of a compact conductor to provide lower electrical resistance and possible reduced wind loading.

g) Investigate insulator contamination due to salt pollution.

h) Establish the location of electrodes for the Gull Island and Soldiers Pond Converter Stations. At Gull Island, initial investigations are needed to establish if a land electrode is feasible and, if so, locate a suitable site.

i) Establish submarine cable embedment depths in various sea bottom materials.

j) Finalize the submarine cable route by:

   i) establishing if Yankee Point is the most appropriate landing site on the Island by conducting further surveys of the coast south of Yankee Point including determining if there are areas where the rock is easier to trench.

   ii) conducting a detailed survey of the selected route to define the route and provide information for the submarine cable specification. This will include investigation of seabed bathymetry, sub-bottom material and obstacles and debris and will use a narrow beam echo sounder, side scan sonar and high resolution multi-beam sonar and a penetrating echo sounder.

k) Establish if the main communication link for the Interconnection should be by microwave or by fibre optic cable located in the overhead ground wire.

4. COST ESTIMATES

4.1 Basis of Estimates

Cost estimates were prepared for the investigations required prior to project release, DC transmission lines, converter stations, submarine cables, communications system and the associated project management. The cost estimate is in January 1998 Canadian dollars.

Customs duties, if applicable, are included in the cost of equipment and materials.

Transport is included in the cost of equipment and materials to the following major shipping points:

- Goose Bay, Labrador
- Labrador City, Labrador
- St. John's, Newfoundland
- Corner Brook, Newfoundland

Transport from the above shipping points to the sites is estimated as a separate construction cost.

The following costs are excluded from the estimate:

- interest during construction
- construction insurances provided by the Owner.
- applicable sales taxes
- land acquisition, rights-of-way and other land associated costs
- the Owners operational and pre-operational expenses
- the Owners general and administrative contingency and expense items including the obtaining of financing and working capital requirements
- permits and licences
- all previous studies
- environmental studies
- changes to laws or regulations after January 1998.
- native claims

4.2 DC Transmission Lines

4.2.1 Estimating Methodology

A previous report (Reference 3) was used as the base reference document (this in turn had utilized the basic data derived from the original Teshmont studies carried out in the 1970's). This report was used to provide tower quantities, span parameters and insulator quantities (Table 3.2-2). It also provided the percentages of each type of foundation likely to be encountered (Table 3.2-3). It was assumed that any dead end tower encountering very poor foundation conditions, ie silt, clay or bog would be moved to a more suitable location. For estimating purposes, a tower spacing of 200 metres given in Reference 3, for the Long Range Mountain crossing was used to derive the number of towers for that section.

In the initial phase of the work, the tower design types and weights selected were those developed by Teshmont in the original studies. The guyed single conductor vee structure for Section 5 (R6) in Newfoundland is based on the design in Reference 1 (Figures 3.2-1 and 3.2-2). The type designations used were as follows:

Type	**Description**
L1A	Tangent suspension towers with I insulator strings, medium and light loading.
M1A	Tangent suspension towers with V strings, medium and heavy loads.
M1B	Light angle and long span tangent tower up to 10° angle. Use two towers for 20° angle. I and V versions are nominally the same tower used for light and medium loading.
M1C	Strain towers 1-55°, two structures per bipole.
M1D	0-90° angle and terminal towers. Basic tower to be designed for OHSW peak to be bolted on.
Special V	Used for Long Range Mountain crossing, two vee structures per bipole, used with short spans. V suspension.

The foundations are based on the original Teshmont designs. Mast foundations in clay, silt and peat will be constructed on compacted granular fill within a culvert sidewall for the excavation. Guy anchors are of the drilled overburden type. See Figures 3.2-4, 3.2-5 and 3.2-6.

When it was determined that an OHSW would be required on all structures, new conceptual designs were prepared for a tangent tower both without and with an OHSW. The effect of the changes on the weight and cost were determined and the ratio of these changes was applied to the data originally used in the cost estimating spreadsheets for towers, guys, mast foundations and guy anchors. (These spreadsheets had utilized the original Teshmont designs). Similar factors were estimated for each type of tower and foundation. The costs presented in this report correspond to tower types with an OHSW as shown on Figure 3.2-1.

The wind and ice loads are based on the original Meteorological Research Institute data utilized by Teshmont. A review of ice loading and climate data subsequently prepared by Newfoundland and Labrador Hydro using ongoing infield testing did not produce any significant changes to the basic data. Some minor line re-routing was proposed but this did not significantly affect the section calculations. Section 2 (R3) in Labrador could be subject to rerouting and an overall allowance of 5% was allowed to cover this in the cost estimate.

Line sections were grouped together using weather loading and foundation type distribution correspond to the line sections on Figure 4.2-1.

Transmission Line Costs for Each Section

Using the preceding design concepts and cost data provided by the material suppliers and a construction contractor, the costs for each line section were prepared. These costs are given in Tables 4.2-2 to 4.2-10. A summary of the transmission line costs is given in Table 4.2-1.

The format utilized for compiling the cost for each line section is given in Table 4.2-11. Completed sheets for each line section together with all cost details are included in Volume 2. Figure 4.2-2 shows how the cost/km varies along the line.

4.2.2 Price Data

For materials, budgetary price requests were sent to material suppliers of insulators, hardware, conductors, guys, tower and foundation material. These requests provided details of the material together with estimated total quantities. In the case of tower and foundation material, data on production capacity was also requested. Details of the price requests together with all the responses are provided in Volume 2 together with the work sheets used to compile the total cost estimate.

In order to provide a construction cost estimate, assistance was requested from Comstock Canada, a construction company with considerable experience of transmission line construction in harsh environments, including Newfoundland and Labrador.

The following information was provided to Comstock:

- maps showing the proposed transmission line route
- loading and span information, see attached spread sheets
- distribution of each type of tower and foundation on each section of the line
- proposed tower designs, tower weights and proposed foundation types
- estimated foundation weights and excavation quantities
- a mosaic of the terrain along the line
- conductor details
- insulator quantities in each section

Specific costs for work in Labrador and costs for work in Newfoundland were requested as follows:

1. Access road construction ($/km)

2. Line clearing

3. Mobilization assuming the following contracts:

   - one contract in Labrador for 407 km of line, with access from Labrador City, Goose Bay and from the Strait of Belle Isle ferry terminal at Blanc Sablon.
   - two contracts for Newfoundland for 681 km, with access from St. John's and the Strait of Belle Isle ferry terminal at St. Barbe or from Corner Brook.

4. Tower erection including camp, insurance, movement from storage, and all other associated costs.

5. Installation cost per type of mast foundation including all other associated costs.

6. Installation of drilled anchors in overburden with Dywidag anchor material supplied by the purchaser.

7. Conductor stringing including hardware and installation of insulators based on a 54 mm diameter, all aluminum alloy conductor with a unit weight of 5.18 kg/m.

4.2.3 Cash Flows

Information provided by suppliers on their production capabilities together with the schedule requirements were utilized to provide a quarterly cash flow for the transmission line portion of the project. Potential production rates for foundation installation, tower erection and conductor stringing together with the unit costs for these were utilized to provide the quarterly cash flow for these items. The cash flow is given in Table 4.10-2.

4.2.4 Contract Packaging

4.2.4.1 Materials

It is recommended that for the line materials, international bidding take place to enable the following contracts to be awarded with the estimated 1998 values as shown:

Supply and Delivery of Insulators	1 Contract	$27,970,000
Supply and Delivery of Conductor Hardware	1 Contract	$5,250,000
Supply and Delivery of Guy Hardware	1 Contract	$2,970,000
Supply and Delivery of Guy Wire	1 Contract	$3,720,000
Supply and Delivery of Counterpoise & OHGW	1 Contract	$7,890,000
Supply and Delivery of Anchor Rods	1 Contract	$1,510,000
Supply and Delivery of Foundation Steelwork	1 Contract	$3,000,000
Supply and Delivery of Tower Steelwork	2 or 3 Contracts	$23,790,000
Supply and Delivery of Conductors	1 Contract	$41,460,000

4.2.4.2 Construction

It is recommended that the construction of the transmission line be awarded in contracts as follows with the cost values as shown:

Labrador Sections	$92,875/km.	Contract	407 km	$37,800,000
Newfoundland Sections *	$114,427/km.	Contract	201 km	$23,000,000
Newfoundland Sections *	$97,292/km.	Contract	480 km	$46,700,000
Line Clearing & Access Roads	$41,523/km.	Contract	407 km	$16,900,000
Line Clearing & Access Roads	$48,756/km.	Contract	201 km	$9,800,000
Line Clearing & Access Roads	$45,833/km	Contract	480 km	$22,000,000

* The grouping of section data was originally based on type of loading and could possibly be revised to provide a more even contract distribution.

4.2.5 Camp and Support Facilities

The clearing and access road contractor in Labrador will operate from mobile construction camps and may utilize helicopter support for sections of the line. He may briefly utilize any support facilities available at the ends of this section when he is working near the Gull Island site or the cable terminal at L'Anse au Clair.

Construction of the transmission line in Labrador will require the contractor to provide camp facilities which will be moved several times during the construction of this 407 km section. The only support facilities available will be at the Gull Island Converter Station site where a material storage yard will be established for material delivered through Goose Bay and a similar material storage yard at the L'Anse au Clair Cable Terminal Station for line material delivered at that location.

Depending upon the final routing of the line on the Island and its proximity to existing habitation, both the line clearing and line construction contractors may decide to utilize nearby towns/villages to accommodate their construction crews and only for remote sections of the line may it be necessary to employ a mobile construction camp.

Material deliveries will be scheduled for storage yards at convenient locations so as to minimize haul distances to the line. Operation of these storage yards will likely be by staff available locally and these yards should preferably be operated by the Owner with established sign-out procedures for all material.

GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION

TABLE 4.2-1

SUMMARY OF COSTS FOR DC TRANSMISSION LINE
(January 1998 Price Level)

	Cost Canadian Dollars
Foundations	$40,667,000
Towers (including Guys)	$45,728,000
Insulators and Hardware	$33,490,000
Conductors	$80,891,000
Counterpoise and OHGW	$11,145,000
Right-of-Way Clearing	$22,279,000
Access Roads	$26,476,000
Transportation - Port to Storage Yard	$8,196,000
Contractors Transportation and Handling	$4,895,000
Contractors Mobilization	$600,000
Total Direct Transmission Line Costs	$274,367,000
Contingency on Materials and Construction (10%)	$27,348,000
Engineering, Management and Construction Supervision	$36,960,000
Total Transmission Line Cost	$338,675,000
Total T/L Length (km)	1,088

Notes:

1. Contingency is based on 10% of section total materials and transport costs.
2. A total of three transmission line contractors are assumed: one in Labrador and two in Newfoundland.

GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION

TABLE 4.2-2

TRANSMISSION LINE LABRADOR PORTION COST SUMMARY SECTIONS 1 & 2 (January 1998 Price Level)

	Cost Canadian Dollars
Foundations	$13,161,000
Towers (including Guys)	$14,608,000
Insulators and Hardware	$10,670,000
Conductors	$30,425,000
Counterpoise and OHGW	$4,192,000
Right-of-Way Clearing	$8,799,000
Access Roads	$8,140,000
Transportation - Port to Storage Yard	$3,413,000
Contractors Transportation and Handling	$1,706,000
Contractors Mobilization	$200,000
Contingency on Materials (Note 1)	$4,480,000
Allowance for Construction Extras (10%)	$4,962,000
Engineering, Management and Construction Supervision	$12,832,000
Total This Portion	$117,588,000
Portion Length (km)	407

Notes:

1. Contingency is based on 10% of section total materials and transport costs
2. It is assumed that there will be only one transmission line construction contractor for the Labrador portion.

GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION

TABLE 4.2-3

TRANSMISSION LINE NEWFOUNDLAND PORTION COST SUMMARY SECTIONS 3 TO 7 (January 1998 Price Level)

	Cost Canadian Dollars
Foundations	$27,506,000
Towers (including Guys)	$31,120,000
Insulators and Hardware	$22,820,000
Conductors	$50,466,000
Counterpoise and OHGW	$6,953,000
Right-of-Way Clearing	$13,480,000
Access Roads	$18,336,000
Transportation - Port to Storage Yard	$4,783,000
Contractors Transportation and Handling	$3,189,000
Contractors Mobilization	$400,000
Contingency on Materials (Note 1)	$8,550,000
Allowance for Construction Extras (10%)	$9,356,000
Engineering, Management and Construction Supervision	$24,128,000
Total This Portion	$221,087,000
Portion Length (km)	681

Notes:

1. Contingency is based on 10% of section total materials and transport costs
2. It is assumed that there will be two construction contractors for the Newfoundland portion.

GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION

TABLE 4.2-4

TRANSMISSION LINE SECTION COST SUMMARY
TOTAL INSTALLED COST - SECTION 1
(January 1998 Price Level)

	Cost Canadian Dollars
Foundations	$10,377,000
Towers (including Guys)	$10,510,000
Insulators and Hardware	$5,024,000
Conductors	$24,900,000
Counterpoise and OHGW	$3,431,000
Right-of-Way Clearing	$7,264,000
Access Roads	$6,720,000
Transportation - Port to Storage Yard	$2,621,000
Contractors Transportation and Handling	$1,310,000
Contractors Mobilization (Note 1)	$165,000
Contingency on Materials (Note 2)	$3,231,000
Allowance for Construction Extras (10%)	$4,001,000
Engineering, Management and Construction Supervision	$9,745,000
Total This Section	$89,299,000
Section Length (km)	336

Notes:

1. Contractors mobilization is a proportion of total mobilization for Sections 1 and 2: $200,000 total.
2. Contingency is based on 10% of section total materials and transport costs.

GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION

TABLE 4.2-5

TRANSMISSION LINE SECTION COST SUMMARY
TOTAL INSTALLED COST - SECTION 2
(January 1998 Price Level)
(includes allowance of 5% for proposed rerouting)

	Cost Canadian Dollars
Foundations	$2,784,000
Towers (including Guys)	$4,098,000
Insulators and Hardware	$5,646,000
Conductors	$5,525,000
Counterpoise and OHGW	$761,000
Right-of-Way Clearing	$1,535,000
Access Roads	$1,420,000
Transportation - Port to Storage Yard	$792,000
Contractors Transportation and Handling	$396,000
Contractors Mobilization (Note 1)	$35,000
Contingency on Materials (Note 2)	$1,249,000
Allowance for Construction Extras (10%)	$961,000
Engineering, Management and Construction Supervision	$3,087,000
Total This Section	$28,289,000
Section Length (km)	71

Notes:

1. Contractors mobilization is a proportion of total mobilization for Sections 1 and 2: $200,000 total.
2. Contingency is based on 10% of section total materials and transport costs.

GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION

TABLE 4.2-6

TRANSMISSION LINE SECTION COST SUMMARY TOTAL INSTALLED COST - SECTION 3 (January 1998 Price Level)

	Cost Canadian Dollars
Foundations	$1,880,000
Towers (including Guys)	$2,024,000
Insulators and Hardware	$1,913,000
Conductors	$3,112,000
Counterpoise and OHGW	$429,000
Right-of-Way Clearing	$831,000
Access Roads	$1,092,000
Transportation - Port to Storage Yard	$321,000
Contractors Transportation and Handling	$214,000
Contractors Mobilization (Note 1)	$25,000
Contingency on Materials (Note 2)	$589,000
Allowance for Construction Extras (10%)	$595,000
Engineering, Management and Construction Supervision	$1,596,000
Total This Section	$14,621,000
Section Length (km)	42

Notes:

1. Contractors mobilization is a proportion of total mobilization for Sections 1 and 2: $400,000 total.
2. Contingency is based on 10% of section total materials and transport costs.

GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION

TABLE 4.2-7

TRANSMISSION LINE SECTION COST SUMMARY
TOTAL INSTALLED COST - SECTION 4
(January 1998 Price Level)

	Cost Canadian Dollars
Foundations	$4,178,000
Towers (including Guys)	$5,024,000
Insulators and Hardware	$3,565,000
Conductors	$8,448,000
Counterpoise and OHGW	$1,164,000
Right-of-Way Clearing	$2,257,000
Access Roads	$2,964,000
Transportation - Port to Storage Yard	$776,000
Contractors Transportation and Handling	$517,000
Contractors Mobilization (Note 1)	$67,000
Contingency on Materials (Note 2)	$1,383,000
Allowance for Construction Extras (10%)	$1,513,000
Engineering, Management and Construction Supervision	$3,902,000
Total This Section	$35,758,000
Section Length (km)	114

Notes:

1. Contractors mobilization is a proportion of total mobilization for Sections 1 and 2: $400,000 total.
2. Contingency is based on 10% of section total materials and transport costs.

GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION

TABLE 4.2-8

TRANSMISSION LINE SECTION COST SUMMARY
TOTAL INSTALLED COST - SECTION 5
(January 1998 Price Level)

	Cost Canadian Dollars
Foundations	$3,801,000
Towers (including Guys)	$4,002,000
Insulators and Hardware	$3,021,000
Conductors	$3,335,000
Counterpoise and OHGW	$459,000
Right-of-Way Clearing	$891,000
Access Roads	$1,800,000
Transportation - Port to Storage Yard	$457,000
Contractors Transportation and Handling	$305,000
Contractors Mobilization (Note 1)	$26,000
Contingency on Materials (Note 2)	$891,000
Allowance for Construction Extras (10%)	$919,000
Engineering, Management and Construction Supervision	$2,439,000
Total This Section	$22,346,000
Section Length (km)	45

Notes:

1. Contractors mobilization is a proportion of total mobilization for Sections 1 and 2: $400,000 total.
2. Contingency is based on 10% of section total materials and transport costs.

GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION

TABLE 4.2-9

TRANSMISSION LINE SECTION COST SUMMARY
TOTAL INSTALLED COST - SECTION 6
(January 1998 Price Level)

	Cost Canadian Dollars
Foundations	$10,849,000
Towers (including Guys)	$11,496,000
Insulators and Hardware	$6,797,000
Conductors	$23,640,000
Counterpoise and OHGW	$3,257,000
Right-of-Way Clearing	$6,314,000
Access Roads	$8,294,000
Transportation - Port to Storage Yard	$1,940,000
Contractors Transportation and Handling	$1,294,000
Contractors Mobilization (Note 1)	$187,000
Contingency on Materials (Note 2)	$3,343,000
Allowance for Construction Extras (10%)	$4,064,000
Engineering, Management and Construction Supervision	$9,981,000
Total This Section	$91,456,000
Section Length (km)	319

Notes:

1. Contractors mobilization is a proportion of total mobilization for Sections 1 and 2: $400,000 total.
2. Contingency is based on 10% of section total materials and transport costs.

GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION

TABLE 4.2-10

TRANSMISSION LINE SECTION COST SUMMARY
TOTAL INSTALLED COST - SECTION 7
(January 1998 Price Level)

	Cost Canadian Dollars
Foundations	$6,798,000
Towers (including Guys)	$8,574,000
Insulators and Hardware	$7,524,000
Conductors	$11,931,000
Counterpoise and OHGW	$1,644,000
Right-of-Way Clearing	$3,187,000
Access Roads	$4,186,000
Transportation - Port to Storage Yard	$1,289,000
Contractors Transportation and Handling	$859,000
Contractors Mobilization (Note 1)	$95,000
Contingency on Materials (Note 2)	$2,344,000
Allowance for Construction Extras (10%)	$2,265,000
Engineering, Management and Construction Supervision	$6,210,000
Total This Section	$56,906,000
Section Length (km)	161

Notes:

1. Contractors mobilization is a proportion of total mobilization for Sections 1 and 2: $400,000 total.
2. Contingency is based on 10% of section total materials and transport costs.

GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION
TABLE 4.2-11
REDUCED VERSION OF TYPICAL TABLE IN VOLUME 2
SECTION DETAIL COST ESTIMATE

GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION
TRANSMISSION LINE ESTIMATING SHEETS
800 MW 400kV DC BIPOLE LINE

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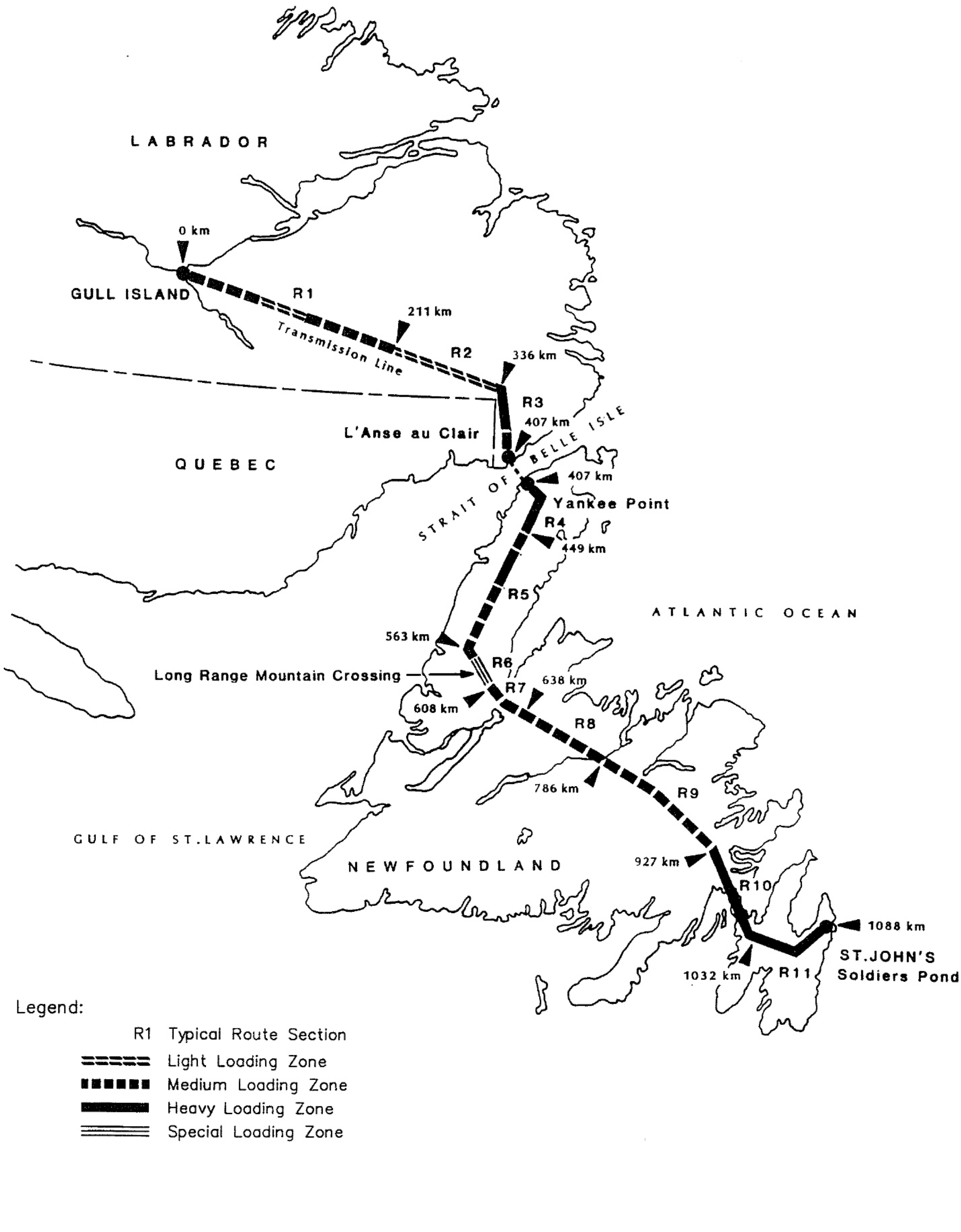
SECTION DETAIL COST ESTIMATE
SECTION 1

SECTION LENGTH: 336 KM **SECTION DESCRIPTION:** R1 & R2 LABRADOR LIGHT LOADING ZONE

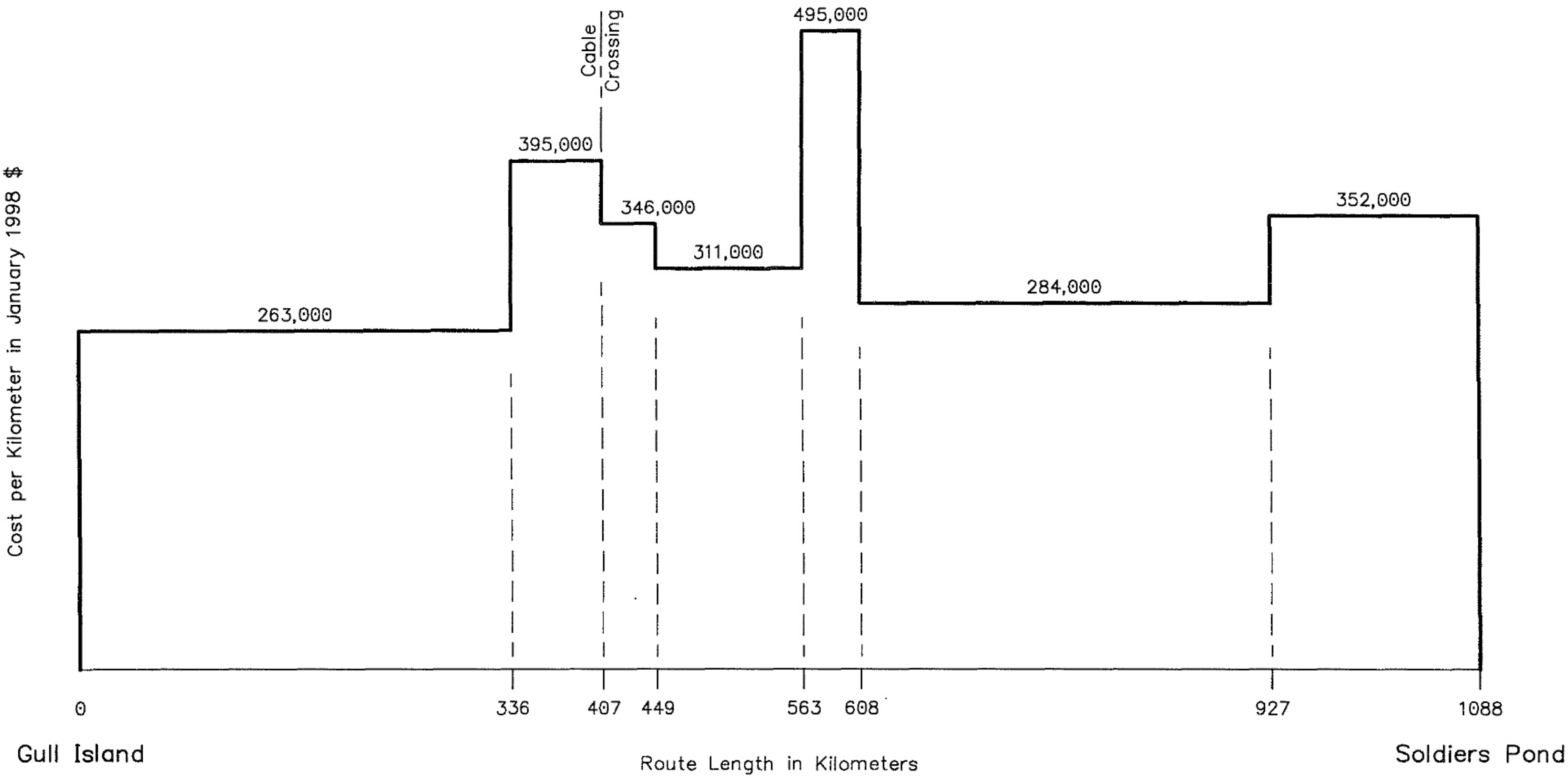
TOWER/FOUNDATION TYPE	UNIT WEIGHT (KG)	QTY	UNIT COST			TOTAL WEIGHT (KG)	TOTAL COST			GRAND TOTAL
			MATERIAL	TRANSP	INSTALL		MATERIAL	TRANSP	INSTALL	
L1A	3231.90	721	4809.1	332.9	3393.5	2,330,200	3,467,337	240,011	2,446,710	6,154,058
FOOTING A (Deep moraine and gravel)	724.90	555	855.0	77.0	3150.0	402,320	474,525	42,735	1,748,250	2,265,510
B (Shallow moraine)	574.20	72	719.0	59.4	3150.0	41,342	51,768	4,277	226,800	282,845
C (Rock)	49.50	36	63.0	5.5	3150.0	1,782	2,268	198	113,400	115,866
D (Clay silt and peat)	724.90	58	855.0	77.0	3150.0	42,044	49,590	4,466	182,700	236,756
GUY ANCHORS A(Deep moraine & gravel)	36.38	2220	80.0	3.8	1473.8	80,753	177,600	8,325	3,271,725	3,457,650
B (Shallow moraine)	25.00	288	61.3	2.5	1013.8	7,200	17,640	720	291,960	310,320
C (Rock)	25.00	144	61.3	2.5	1013.8	3,600	8,820	360	145,980	155,160
D (Clay silt and peat)	91.00	232	190.0	9.1	3685.0	21,112	44,080	2,117	854,920	901,117
GUYS & HARDWARE	75.00	2884	288.0	77.0	INCL. IN TOWER	216,300	830,592	222,068	0	1,052,660
M1A	4139.46	0	6159.5	426.4	4346.4	0	0	0	0	0
FOOTING A (Deep moraine and gravel)	754.60	0	1056.0	92.4	3150.0	0	0	0	0	0
B (Shallow moraine)	574.20	0	876.0	73.7	3150.0	0	0	0	0	0
C (Rock)	49.50	0	75.0	6.6	3150.0	0	0	0	0	0
D (Clay silt and peat)	754.60	0	1056.0	92.4	3150.0	0	0	0	0	0
GUY ANCHORS A(Deep moraine & gravel)	39.29	0	86.4	4.1	1590.3	0	0	0	0	0
B (Shallow moraine)	27.00	0	66.2	2.7	1094.9	0	0	0	0	0
C (Rock)	27.00	0	66.2	2.7	1094.9	0	0	0	0	0
D (Clay silt and peat)	98.28	0	205.2	9.9	3979.8	0	0	0	0	0
GUYS & HARDWARE	75.00	0	288.0	77.0	INCL. IN TOWER	0	0	0	0	0
M2A	4537.00	0	6751.1	467.3	4763.9	0	0	0	0	0
FOOTING A (Deep moraine and gravel)	1331.00	0	1733.0	136.0	3000.0	0	0	0	0	0
B (Shallow moraine)	1044.00	0	1439.0	108.0	3000.0	0	0	0	0	0
C (Rock)	68.00	0	75.0	7.0	3000.0	0	0	0	0	0
D (Clay silt and peat)	1331.00	0	1733.0	136.0	3000.0	0	0	0	0	0
GUY ANCHORS A(Deep moraine & gravel)	29.10	0	64.0	3.0	1179.0	0	0	0	0	0
B (Shallow moraine)	20.00	0	49.0	2.0	811.0	0	0	0	0	0
C (Rock)	20.00	0	49.0	2.0	811.0	0	0	0	0	0
D (Clay silt and peat)	72.80	0	152.0	7.2	2948.0	0	0	0	0	0
GUYS & HARDWARE	150.00	0	576.0	120.0	INCL. IN TOWER	0	0	0	0	0
M1B (I&V TYPES)	6751.20	89	10045.8	695.4	7088.8	600,857	894,075	61,888	630,900	1,586,863
FOOTING A (Deep moraine and gravel)	1530.65	69	1733.0	156.4	3150.0	105,615	119,577	10,792	217,350	347,719
B (Shallow moraine)	1200.60	9	1437.0	124.2	3150.0	10,805	12,933	1,118	28,350	42,401
C (Rock)	78.20	4	75.0	8.1	3150.0	313	300	32	12,600	12,932
D (Clay silt and peat)	1530.65	7	1733.0	156.4	3150.0	10,715	12,131	1,095	22,050	35,276
GUY ANCHORS A(Deep moraine & gravel)	40.74	276	201.6	9.5	3851.4	11,244	55,642	2,628	1,062,986	1,121,256
B (Shallow moraine)	28.00	36	114.8	5.6	2269.4	1,008	4,133	202	81,698	86,033
C (Rock)	28.00	16	114.8	5.6	2269.4	448	1,837	90	36,310	38,237
D (Clay silt and peat)	101.92	28	526.4	26.3	10729.6	2,854	14,739	737	300,429	315,905
GUYS & HARDWARE	150.00	356	576.0	120.0	INCL. IN TOWER	53,400	205,056	42,720	0	247,776
M1C (2 STR PER TOWER)	11276.10	9	16778.8	1161.4	11839.9	101,485	151,010	10,453	106,559	268,022
FOOTING A (Deep moraine and gravel)	1397.55	14	1733.0	142.8	3000.0	19,566	24,262	1,999	42,000	68,261
B (Shallow moraine)	1096.20	2	1439.0	113.4	3000.0	2,192	2,878	227	6,000	9,105
C (Rock)	57.75	0	75.0	7.4	3000.0	0	0	0	0	0
D (Clay silt and peat)	1397.55	2	1733.0	142.8	3000.0	2,795	3,466	286	6,000	9,752
GUY ANCHORS A(Deep moraine & gravel)	106.25	56	215.0	10.6	4298.8	5,950	12,040	595	240,730	253,365
B (Shallow moraine)	50.13	8	102.5	5.0	2026.3	401	820	40	16,210	17,070
C (Rock)	50.13	0	102.5	5.0	2026.3	0	0	0	0	0
D (Clay silt and peat)	455.00	8	890.0	45.3	18423.8	3,640	7,120	362	147,390	154,872
GUYS & HARDWARE	150.00	72	576.0	120.0	INCL. IN TOWER	10,800	41,472	8,640	0	50,112
M1D DE TOWER	18148.00	24	27004.2	1869.2	19055.4	435,552	648,101	44,862	457,330	1,150,293
FOOTING A (Deep moraine and gravel)	2264.00	18	2947.0	232.0	3000.0	40,752	53,046	4,176	54,000	111,222
B (Shallow moraine)	1815.00	4	2504.0	186.0	3000.0	7,260	10,016	744	12,000	22,760
C (Rock)	68.00	2	94.0	7.0	3000.0	136	188	14	6,000	6,202
SPECIAL V (2 STR PER TOWER)	4990.70	0	7426.2	514.0	5240.2	0	0	0	0	0
FOOTING A (Deep moraine and gravel)	854.70	0	1056.0	87.2	3000.0	0	0	0	0	0
B (Shallow moraine)	666.75	0	876.0	68.3	3000.0	0	0	0	0	0
C (Rock)	57.75	0	75.0	6.3	3000.0	0	0	0	0	0
D (Clay silt and peat)	854.70	0	1056.0	87.2	3000.0	0	0	0	0	0
GUY ANCHORS A(Deep moraine & gravel)	36.38	0	80.0	3.8	1473.8	0	0	0	0	0
B (Shallow moraine)	25.00	0	61.3	2.5	1013.8	0	0	0	0	0
C (Rock)	25.00	0	61.3	2.5	1013.8	0	0	0	0	0
D (Clay silt and peat)	91.00	0	190.0	9.1	3685.0	0	0	0	0	0
GUYS & HARDWARE	75.00	0	288.0	77.0	INCL. IN TOWER	0	0	0	0	0
INSULATORS										
SUSP 160 kN UNITS	10.70	17423	68.000	1.739	INCLUDED	186,426	1,184,764	30,299	0	1,215,063
210 kN UNITS	11.20	608	87.000	1.739	IN	6,810	52,896	1,057	0	53,953
300 kN UNITS	11.50	14048	170.000	1.739	CONDUCTOR	161,552	2,388,160	24,429	0	2,412,589
STRAIN 300kN UNITS	11.50	1196	170.000	1.739	STRINGING	13,754	203,320	2,080	0	205,400
OHGW LINE.KM	1719.00	336	4950.000	0.000		577,584	1,663,200	0	0	1,663,200
COUNTERPOISE LINE.KM	3500.00	336	2300.000	0.000	2960.0	1,176,000	772,800	0	994,560	1,767,360
CONDUCTOR HARDWARE										
COND & JMP CLAMPS	18.00	1676	275.000	0.982	INCLUDED	30,168	460,900	1,646	0	462,546
SUSP STRINGS 160 kN	4.00	782	115.000	0.411	IN	3,128	89,930	321	0	90,251
210 kN	5.00	32	115.000	0.411	CONDUCTOR	160	3,680	13	0	3,693
300 kN	6.00	894	160.000	0.571	STRINGING	5,364	143,040	510	0	143,550
STRAIN STRINGS	50.00	68	800.000	1.357		3,400	54,400	92	0	54,492
SUSP YOKE PLT	12.00	16	225.000	0.803		192	3,600	13	0	3,613
VIBRATION DAMPERS: @ 1/Span/Pole	10.50	0	112.000	1.100		0	0	0	0	0
@ 2/Span/Pole	10.50	3348	112.000	1.100		35,154	374,976	3,683	0	378,659
CONDUCTOR LINE.KM (2 Conductors)	11039.00	336	35480.000	2626.000	36000.0	3,709,104	11,921,280	882,336	12,096,000	24,899,616
TOTALS PER SECTION						10,483,000	26,716,000	1,665,000	25,860,000	54,241,000



Transmission Line Distances and Weather Sections

Figure 4.2-1

182\10001\42-1



Gull Island - Soldiers Pond HVDC Interconnection
Graphical Representation of Transmission Line Costs
Figure 4.2-2

Plot 1:5 182\10001\42-2

4.3 Converter Stations

4.3.1 Price Data

Budget price data was obtained from the following sources:

a) Equipment suppliers
b) Teshmont's database of equipment budget prices and bid data from recent projects
c) Installation costs based on Teshmont's experience and bid data from previous projects
d) Civil and building construction costs were developed from cost data adjusted for Newfoundland and Labrador conditions.

Mini-specifications were written for the following in order to obtain budget prices from equipment suppliers:

a) DC converter equipment
b) Synchronous condensers
c) AC switchyard apparatus

The mini specifications specified the ratings and requirements, the point of delivery and defined the scope of the budget price. The mini-specifications requested prices in 1998 Canadian dollars including custom duties and excluding taxes.

4.3.2 Estimating Methodology

A typical DC system single line diagram, DC converter layout and converter building conceptual design were developed. The DC single line diagram is the basis for the DC converter mini-specification. The DC layout and converter building conceptual design are the basis for construction cost estimates for civil work and building costs respectively.

Single line diagrams of the AC switchyards were developed to determine the quantities of various AC switchyard components.

Budget prices from equipment suppliers were analysed and used in the estimate. Budget price and bid data from previous projects were used to check the budget prices to verify they were in the expected range and to break down the prices between components which would be imported and components which could be supplied in Canada. Table 4.3-1 lists equipment which must be imported and also equipment which could be supplied by Canadian suppliers.

Installation costs for DC equipment are based on manhour estimates and labour rates. Installation labour rates are blended to cover all labour classifications for a typical installation crew. These include all the contractor's overhead costs, payroll burden and contractor's profit. Installation costs for AC equipment are in general based on costs per item of equipment developed for previous projects.

Electrical equipment installation costs for Gull Island have been adjusted by a factor of 1.2 to reflect additional costs due to the remote location. Camp cost and shipping costs are estimated as separate items to the installation costs.

Building construction costs have been adjusted to reflect additional costs in St. John's and Gull Island due to the remote location by a factor of 1.4 and 2.0 respectively compared to typical mainland costs.

Civil work costs have been adjusted by a factor of 1.3 in general and 2.4 for concrete for St. John's compared to typical mainland costs. Costs of Gull Island are increased a further factor of 1.25 over St. John's costs.

4.3.3 Cash Flows

A cash flow for the converter stations is shown on Table 4.10-2. The cash flow is based on the construction described below and assumes progress payments are made on the value of work performed.

A construction schedule has been developed for Gull Island and Soldiers Pond based on experience on other similar sized projects. The construction activities at the two stations are carried out at the same time with minor differences due to the winter shipping limitations at Goose Bay, Labrador. Figure 5.2-2 shows the converter station construction schedule.

The major activities are as follows:

a) System Studies

Specification Studies

Specification studies include studies by the Utility required to define system parameters and to obtain parameters for the specification of the HVDC equipment, AC circuit breakers, and other major equipment.

These studies must be completed before the respective specification can be issued.

Implementation Studies

These are operational studies performed by the Utility which will determine how the DC system will react during certain faults and how the DC system can be operated to best advantage. These studies are carried out as information on the design is provided by the contractor and may carry on after the scheme is in service.

b) Environmental Studies and Regulatory Approvals

Converter Stations

It is anticipated that an environmental impact report will be required addressing issues such as audible noise, electric fields, radio interference and visual impact.

Electrodes

It is anticipated that environmental reports and interference studies will be necessary for the electrode sites and electrode lines.

c) Preparation of Converter Equipment Specifications

The converter equipment specifications are required to define the converter equipment requirements and obtain competitive bids for the converter equipment.

d) HVDC Converter Equipment Supply and Install

General

The schedule for HVDC converter equipment allows time in the design periods for adequate discussion between the utility and the contractor. The manufacture and installation periods have float to accommodate unforeseen contingencies. Five months are provided for system commissioning which allows for a thorough test program.

Control System Tests

Tests for the controls generally fall into two categories, optimization of performance and hardware verification.

Performance tests are performed using a DC simulator and do not require the production hardware. These tests can take from 3 to 5 months depending on the complexity of the study. Manufacturers may have access to more than one DC simulator and these tests can be expected to be scheduled without major delays.

Final tests carried out in the factory must be made on the simulator using the actual DC controls. These tests are usually not a problem, but can be affected by items such as lateness of other contracts held by the manufacturer or special requirements for complex system representation.

e) Converter Station

This work includes site improvement for the entire station, plus foundations and structures for the DC yard and trenches for the AC and DC yards.

f) Converter Building

The converter building must be complete in the first quarter of Year 5 to allow the installation of control equipment and erection of the valves.

g) Ground Electrode and Electrode Line

The electrode is required for the start of HVDC system tests. The time required to specify, obtain material and construct the electrode and electrode line is approximately 16 months. However the design and site selection should be carried out early in the project to ensure all possible problems are identified and a suitable site can be found.

h) AC Switchyard

The 230 kV AC connection to the power system is required for the start of the system tests in the last quarter of Year 5.

i) DC Transmission Line

The DC transmission line is required for the start of system tests in the second quarter of Year 5.

4.3.4 Construction Packaging

4.3.4.1 Types of Contracts

The contracts can be divided into four basic types:

a) Supply and Installation Contracts

These contracts can be used where the equipment is complicated and the specialized skills and resources required are best provided by the manufacturer. They are also used where it is important to ensure unified responsibility, or in a few cases, such as for pre-fabricated buildings, where it is customary that the supplier deliver an assembled unit.

b) Supply Contracts

These contracts cover equipment and material which usually:

- require detail design to a technical specification and/or
- require a long delivery time or
- are supplied in large quantities

A variation is where the manufacturer supervises the erection which is carried out by a third party and commissions the equipment to clarify responsibility and protect warranties.

c) Installation Contracts

These contracts are used to install equipment or material that is purchased under supply type contracts. These contracts may include the supply of equipment and material which require little lead-time for delivery.

d) Service Contracts

These contracts are used mainly for support facilities. Where convenient, one contractor may be engaged to provide general services such as camps or catering, first aid, water supply or the like in order to avoid the cost of individual installation contractors setting up such facilities. The provision of electrical energy or telephone services are also service contracts.

4.3.4.1 Contract Scope Description

The contract packages assumed for in the project are as follows:

a) Supply and Installation Contracts

The following contracts apply to both converter stations except as noted:

- HVDC Equipment

  The contract includes thyristor valve assemblies, valve cooling equipment, converter transformers, DC switchgear, DC measuring apparatus, controls, supervisory and protection equipment, AC and DC filters and ancillary items.

- Synchronous Condensers at Soldiers Pond

  Associated cooling equipment, controls, starting and protection equipment are included.

- Converter Building Structural Steel

- Converter Building Superstructure

  Cladding, roofing and building electrical and mechanical services are included.

- Switchyard Structures

  AC and DC switchyards and filters areas are included.

b) Supply Contracts

- Converter Station

  - Building mechanical equipment
  - Building electrical equipment
  - Electrical station services
  - Power and control cables
  - 230/4.16 kV station services transformers
  - AC switchyard equipment and material

- AC control and protection components
- Building for switching stations
- Electrode materials

- Electrode Line

  - Towers
  - Foundations - Steelwork
  - Foundation - Timber mats
  - Conductor
  - Insulators
  - Hardware
  - Accessories

c) Installation Contracts

At each of the two converter stations the following contracts were assumed:

- Site Improvements and General Services

  This includes clearing, site draining, grading, fencing and fence grounding, landscaping, site water supply and distribution, site fire protection and a sewage treatment system.

- Building Substructure

  This includes the foundations for the converter transformers due to the proximity of the transformers to the converter buildings.

- Switchyard Foundations

  This includes foundations required for equipment and structures in the following areas:

  - AC Switchyard
  - AC Filters
  - DC Switchyard
  - DC Filters
  - Synchronous Condenser

  Also included are the outdoor cable trenches and vaults.

- Electrical/Mechanical

  This includes the installation of all electrical and mechanical equipment not included in the "Supply and Installation Contracts" noted above.

- Construction Facilities

  This includes the provision of camp quarters at Gull Island (not required at Soldiers Pond), administration buildings and workshops, water supply and distribution, sewage, roads and streets, electrical distribution and communication circuits

- Electrode Line Clearing of Right-of-Way

- Electrode Line Construction

- Electrode Construction

d) Service Contracts

For the construction of facilities required for the converter stations, service contracts were assumed in the estimate for:

- operation and maintenance of the buildings and sites at Gull Island
- catering at Gull Island
- provision of electrical power
- provision of communication facilities

4.3.5 Camp and Support Facilities

It is assumed that the Gull Island Power Station Camp facilities would be available for the converter station construction. Incremental costs for the converter station construction personnel have been included in the estimate. The peak requirements are estimated to be 23 supervisory personnel and 65 tradesmen. There would be a significant work force for approximately two years.

4.3.6 Staffing Requirements

The estimated staffing requirements for the construction of each converter station is shown in Table 4.6-1.

4.3.7 Cost Estimate of DC Converter Stations

The cost estimate, expressed in January 1998 Canadian dollars, is given in Table 4.3-2 and 4.3-3 for Gull Island and Soldiers Pond respectively. A summary for both stations including Engineering and Management is given on Table 4.3-4.

The following costs which cover material, installation, commissioning and supervision are included:

a) Civil Work

- Clearing
- Surveying

- Cut and fill to level site
- Foundation and trench excavation in soil and rock
- Crushed rock surface
- Roads and parking lot
- Chain link fence
- Water and sewage
- AC and DC switchyard equipment foundations
- AC and DC switchyard bus and equipment support structures
- Station ground grid
- Switchyard lighting

b) Buildings

- Converter building
- Relay buildings, (distributed type, 1 per 2 bays)
- Warehouse building
- Pumphouse
- Synchronous condenser building including machine and unit transformer foundations (at Soldiers Pond)

c) DC Equipment

- Two 400 kV, 400 MW valve groups with short time and continuous overload ratings
- Pole equipment consisting of smoothing reactor, arresters, measuring devices, wall bushings, DC filters, control and protection circuit equipment and associated buswork
- Converter transformers including spares
- DC line switching
- DC filters
- AC filters consisting of capacitors and air cooled reactors
- Transmission line disconnects
- Ground disconnects
- Electrode line switching including metallic return switching
- Electrical and mechanical services associated with DC equipment including valve cooling

d) DC Electrode and Electrode Line

- Sea electrode
- Electrode line

e) AC Substation Equipment

- Circuit breakers
- Arresters
- Potential transformers

- Current transformers
- Disconnect switches
- Ground switches
- Cables
- Bus work
- Control and protection circuit equipment

f) Two 230 kV transmission lines from Gull Island Converter Station to Gull Island Hydro Plant.

g) Two 230 kV circuit breakers and associated equipment at Gull Island Hydro Plant Substation.

h) Synchronous Condensers

- Machines including cooling equipment
- Unit transformers
- Control and protection equipment

i) Communication System

- Microwave system
- SCADA type control system

j) Auxiliary Services

- Electrical and mechanical services
- Station service transformers
- Fire protection

k) Construction Services

- Transportation
- Camps (at Gull Island)

GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION

TABLE 4.3-1

ESTIMATE OF FOREIGN AND DOMESTIC SUPPLY OF CONVERTER STATION EQUIPMENT

Item	Foreign Supply	Domestic Supply
Civil works, equipment and structure foundations, structures and buildings		21,888,000
Converter valves, controls, measuring devices, wall bushings, active DC filters and surge arresters	215,600,000	
Converter transformers		80,920,000
DC disconnects	100,000	
AC filters		8,640,000
High speed switches	1,200,000	
Electrical mechanical services		11,640,000
Electrode, electrode line and AC tie lines		6,440,000
Circuit breakers	8,446,000	
Arresters, potential transformers and current transformers		2,880,000
AC disconnect switches		3,240,000
Cable and buswork		3,650,000
AC control and protection	2,750,000	
Synchronous condenser		54,200,000
Auxiliary services		6,500,000
Construction services		2,204,000
Total	$228,096,000	$202,202,000

GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION

TABLE 4.3-2

GULL ISLAND CONVERTER STATION
SUMMARY OF COST ESTIMATES
(January 1998 Price Level)

	Cost Canadian Dollars (Millions)
Civil Works	2.90
Equipment and Structure Foundations	3.70
Structures	2.01
Buildings	16.46
DC Equipment	170.09
Ground Electrode and Electrode Line	10.78
AC Substation Equipment	15.16
230 kV AC Transmission Line Converter Station to Gull Island Power Plant	1.00
Gull Island Hydro Plant Equipment	1.89
Auxiliary Services	3.93
Construction Services	5.51
Contingency 10%	23.34
Total	256.77

GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION

TABLE 4.3-3

SOLDIERS POND CONVERTER STATION
SUMMARY OF COST ESTIMATES
(January 1998 Price Level)

	Cost Canadian Dollars (Millions)
Civil Works	2.51
Equipment and Structure Foundations	6.08
Structures	2.46
Buildings	12.76
DC Equipment	168.71
Ground Electrode and Electrode Line	1.88
AC Substation Equipment	17.76
Synchronous Condenser	58.40
Auxiliary Services	4.00
Construction Services	0.50
Contingency 10%	27.51
Total	302.57

TABLE 4.3-4

CONVERTER STATIONS
SUMMARY OF COST ESTIMATES
(January 1998 Price Level)

	Cost Canadian Dollars (Millions)
Gull Island Converter Station	233.43
Soldiers Pond Converter Station	275.06
Subtotal	508.49
Contingency	50.85
Management and Engineering	67.12
Total	626.46

4.4 Submarine Cable Crossing

4.4.1 Price Data

Budget price data was obtained from the following sources:

a) Cable suppliers
b) Teshmont's data base of budget prices and bid data from recent projects
c) Installation costs based on Teshmont's experience and bid data from previous projects.

A mini-specification was written to specify the rating and requirements of the submarine cable. Budget prices were requested for a three cable system and a four cable system. Questions were also asked regarding installation and overload ratings of cables. The mini-specification also specified the point of delivery and defined the scope of the budget price. The mini-specifications requested prices in 1998 Canadian dollars including custom duties and excluding taxes.

4.4.2 Estimating Methodology

Previous studies which had investigated the L'Anse au Clair to Yankee Point route were reviewed. This route was confirmed to be the preferred route and is used as the basis for the estimate. Quantities of cable, embedment in overburden and trenching in rock were estimated from previous submarine cable studies.

The cost estimates are based on three 400 kV, 1500A cables.

A single line diagram for the cable switching station and switching station building conceptual design were developed. The single line diagram and the building conceptual design are the basis for the switching station equipment requirements and the building costs respectively.

Budget prices from cable suppliers for the supply and installation of the submarine cable were analysed and used in the estimate. Budget price and bid data from previous submarine cable projects were used to verify the prices were in the expected range.

4.4.3 Cash Flows

The cash flow for the Strait of Belle Isle submarine cable crossing is given in Table 4.10-2. The cash flow is based on the construction schedule described below and assumes progress payments are made on the value of work performed.

A construction schedule has been developed for the Strait of Belle Isle submarine cable based on all three submarine cables being installed in Year 4. A large cable laying ship could deliver and lay the cables in one trip. For example the cable ship Skagarak based in Norway can carry the three 40 km 1500A cables at once.

An alternative is to ship the cables in a cargo ship and transfer the cables to a barge for laying. This operation may require two seasons. Figure 5-4 shows the submarine cable and cable terminal construction schedule.

The major activities are described as follows:

Route Optimization Investigation

This investigation is carried out prior to tendering the submarine cable supply and installation to select an optimum route for the submarine cable crossing. The optimization should avoid or minimize areas of hard rock and rock ledges.

Detailed Marine Survey

This survey is done by the submarine cable contractor after the award of the submarine cable contract and is the basis for negotiations to the cable installation price.

Near Shore Rock Excavation

Excavation of trenches in rock is required in water depths down to 70m in areas where the overburden over the rock is less than 2m.

This excavation is time consuming and would be carried out in the year prior to the laying of the cable.

Cable Delivery

The cable would be delivered by the cable laying ship or cargo ship. Cable laying would start about a week after arrival of the cable laying ship at the cable crossing location to allow for mobilization and preparation for cable laying. If shipped by cargo ship the cable would be transferred to a barge for laying.

Laying and Embedding

Cable laying and embedding would be carried out in Year 4 to allow a season of float in the event of some unforseen problem. The cable laying would be completed in a few weeks unless delayed by weather or sea conditions. The embedding of the cable by jetting or ploughing would be slower but would be completed in one season.

Cable Terminal Building

The cable terminal building and the terminal equipment would be installed in Year 4.

4.4.4 Construction Packaging

The submarine cable system will be provided under a supply and installation contract. The responsibility for the successful implementation of the submarine cable contract must be with the cable contractor. However, it is usual to share some of the risk between the Contractor and the Owner and so reduce the overall price of the Contract.

Examples of risk sharing are:

- bad weather days
- adjustment to length of embedment in various types of sea bottom materials

The cutting of rock trenches at Yankee Point could be in the cable contract or in a separate contract.

The construction of the cable termination building, supply of equipment other than cable terminations and installation of the equipment could be separate contracts from the submarine cable contract.

The supply and installation of the DC switching equipment could be part of the DC equipment contract.

4.4.5 Cost Estimate of Submarine Cable

The estimate of cost for the submarine cable crossing is given in Table 4.4-1. A summary of the cable crossing cost including Management and Engineering and Inspection is given in Table 4.4-2.

The following costs are included:

- route optimization investigations
- detailed route survey by cable contractor
- design, manufacture, testing and delivery of submarine cable, including 3 km of spare cable
- excavation of rock trenches near shore
- removal of rock ledges
- laying of submarine cable
- embedding of submarine cable, including some contingency for concrete mattresses
- backfill of rock trenches
- termination of submarine cable
- land cable trenches and chases
- installation of land cable and accessories
- civil costs associated with the terminal site and associated equipment
- termination building
- electrical equipment which includes switchgears, surge arresters, pot heads, wall bushings and dead ends along with associate controls
- auxiliary services

GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION

TABLE 4.4-1

STRAIT OF BELLE ISLE SUBMARINE CABLE COST ESTIMATE (January 1998 Price Level)

	Cost Canadian Dollars (Millions)
Terminal Stations (L'Anse au Clair and Yankee Point)	
Civil Work	7.22
Electrical Equipment	2.91
Auxiliary Services	0.05
Submarine Cable	
Route Investigation	3.00
Survey	1.50
Cable	108.60
Land Cable	7.99
Laying Cable	12.60
Embedding Cable	39.38
Near Shore Embedding	
• in overburden	7.18
• in rock	45.88
Backfill of Trench in Rock and Cleanup	15.74
Concrete Mattresses	3.60
Ledge Removal	37.05
Land Cable Trenching	4.67
Diving Support	2.00
Total	299.37

GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION

TABLE 4.4-2

STRAIT OF BELLE ISLE
SUBMARINE CABLE
SUMMARY OF COST ESTIMATES
(January 1998 Price Level)

	Cost Canadian Dollars (Millions)
Submarine Cable	299.4
Contingency	39.5
Management and Engineering 5%	16.9
Inspection 3%	10.2
Total	366.0

4.5 Communications

4.5.1 Price Data

The cost estimate of a digital microwave system and leased circuits was provided by Newfoundland and Labrador Hydro. The cost of remote sites in Labrador and on the Great Northern Peninsula is based on Quebec Hydro estimates for similar parts of Labrador and Northern Quebec.

4.5.2 Cost Estimate for Communications System

Figure 4.5-1 shows the microwave system route and the locations of the microwave sites assumed for the estimate.

The cost estimate includes 18 new sites in Labrador and on the Great Northern Peninsula. These sites will require their own power supplies (diesel and solar panels) and do not have access roads. There are three existing sites on the island of Newfoundland which will require rebuilding as they are 25 to 30 years old. Ten new island sites are assumed to have access and power.

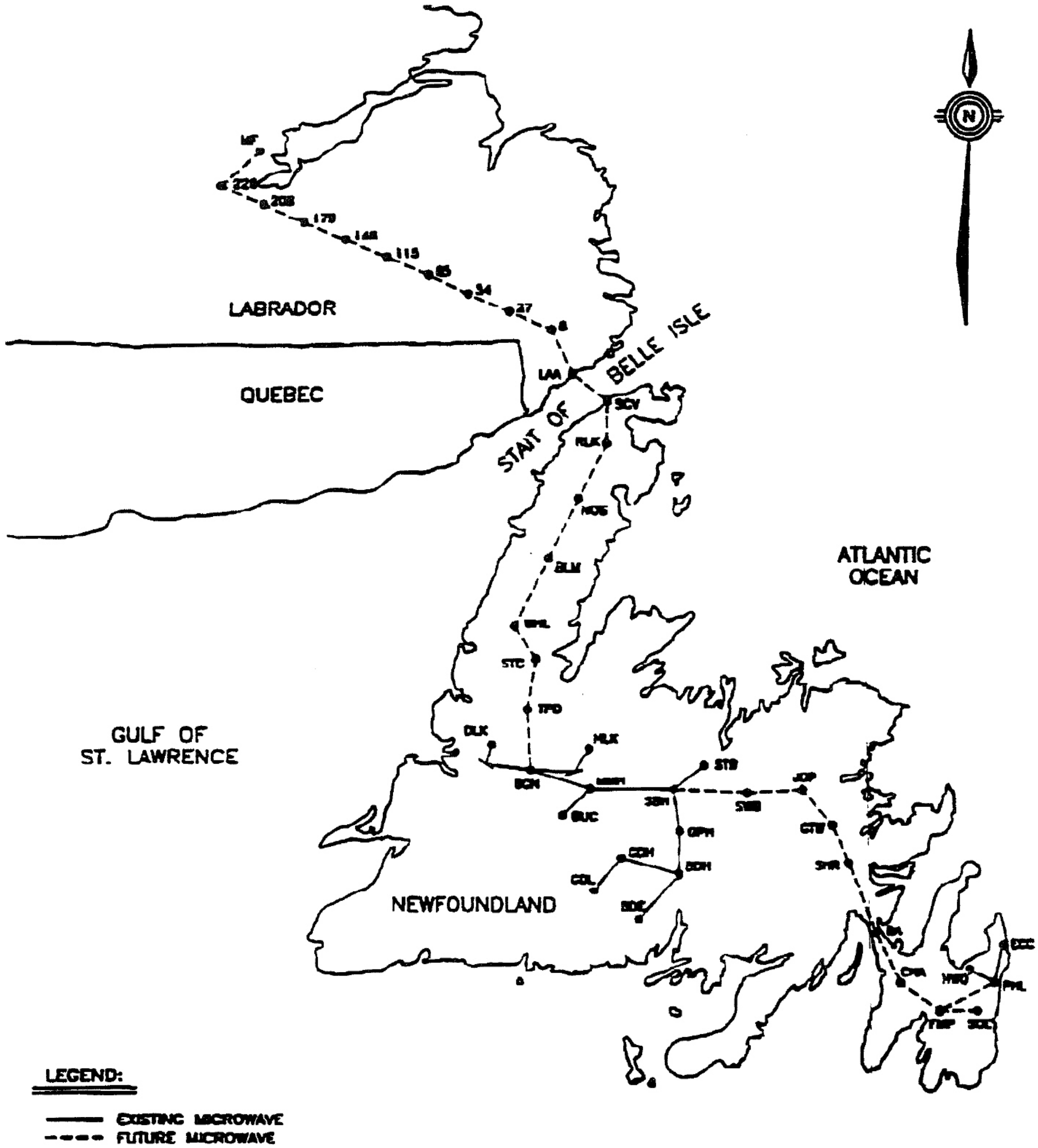
The estimated cost of the communications system is in Table 4.5-1.

The estimated cost of leased circuits is $5,000 per month.

TABLE 4.5-1

GULL ISLAND TO SOLDIERS POND COMMUNICATIONS SYSTEM SUMMARY OF COST ESTIMATES (January 1998 Price Level)

		Cost Canadian Dollars (Millions)
New microwave sites in Labrador and on Great Northern Peninsula	18 Sites	62.19
Island Sites	13 Sites	19.76
Subtotal		81.95
Contingency 10%		8.20
Engineering		2.13
Management (50% of Engineering)		1.06
Total		93.34



HYDRO	NEWFOUNDLAND AND LABRADOR HYDRO		
SCALE N.T.S.	PROPOSED HVDC MICROWAVE ROUTING	DATE: 1993-06-10	
DRAWN W.B.		W.O. NO.	
CHECKED		DWG.NO. 600-E-93	REV. 0
APPROVED			

Figure 4.5-1

4.6 Project Staffing Requirements

Project staffing requirements for the Gull Island to Soldiers Pond HVDC Interconnection have been estimated to total 26,000 person months. Details of the staffing requirement estimate are shown in Table 4.6-1.

The construction personnel requirements for the transmission lines are based on production rates and crew sizes required to complete each task in the given times.

The construction personnel requirements for converter stations, cable terminal stations and the communication system are derived from construction and installation labour cost data. Manufacturing personnel and manufacturers supervisory personnel have not been included in the staffing requirements.

The construction personnel requirements for the submarine cable installation are based on construction cost data and estimates of the Canadian labour content. Foreign labour is not included in Table 1-1.

The management and engineering staffing includes the personnel who will be stationed in the consultant's offices and/or at the appropriate sites of the installation work. The Owner's personnel have not been included.

The staffing requirements for the operation and maintenance of the Project after it has been placed in service, are shown separately in Section 4.10.

GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION

TABLE 4.6-1

STAFFING ESTIMATE
PERSON MONTHS

Activity Description	Years 1	2	3	4	In Service Date ↓ 5	6	Person Months
Pre-Project Release Investigation 1)							144
Transmission Line 2) 3)	144	908	4044	3095	348	0	8539
Converter Stations 2) 3)	0	0	373	3044	2779	0	6196
Cable and Cable Terminals 2)	10	45	524	410	0	0	989
Communications 2)	0	30	127	153	0	0	310
Subtotal	154	983	5068	6702	3127	0	16178
Management & Engineering 1)	850	1919	3094	2738	1075	194	9870
Total Person Months/Year	1004	2902	8162	9440	4202	194	
				Total Person Months			26048

Notes:

1) Calculation of person months is based on 160 hr/month
2) Calculation of person months is based on 237 hr/month in Labrador and remote areas of Newfoundland
3) Calculation of person months is based on 194 hr/month at Soldiers Pond and in accessible areas of Newfoundland

4.7 Management and Engineering

The Management and Engineering services would be provided by Consultants on the Owner's behalf. Figure 4.7-1 shows the assumed Consultant's management organization. The roles of each of the managers are outlined briefly below.

Project Manager

The Project Manager is responsible to the Owner for the overall management and engineering services including the budget and schedule. He is also responsible for ensuring that the Owner is apprised of the performance of all elements of the Project. Initially the project manager would probably be stationed in the Consultants head office, then locate to a project office in St. John's. The duties of the Project Manager include:

- providing high level reports directly to the Owner and supporting the Owner in interfacing with outside entities.
- directing the work of the Consultant to ensure coordination of the activities of the engineering divisions and the work with contractors.
- participating in the negotiation and approval process of major contracts on the Project.
- directing the activities of the Engineering Manager and the Construction Manager. He also has direct responsibility for the operations of the Project Services and Administration Services Divisions.

Assistant Project Manager

The Assistant Project Manager provides support to the Project Manager, acting on his behalf during absences of the Project Manager and undertaking specific assignments as required.

Manager of Engineering

The Manager of Engineering plays a major role in the design, administration and implementation of the Project. His initial task will be to form a multi-discipline engineering group to determine the overall parameters and engineering requirements of the Project. His duties include:

- coordinating all aspects of engineering so as to provide the full engineering input required in a timely manner.
- providing advice to the Owner on technical and design issues and contributing to the progress reporting on the Project.
- coordinating all Project engineering departments which report to the Manager of Engineering.
- liaison with engineering and design groups of the DC equipment and submarine cable manufacturers.

At first the Manager of Engineering would be located in the Consultants head office, with frequent visits to the Owner's office in St. John's, later locating to the project office.

Systems Engineer

In conjunction with the Owner's engineers, the Systems Engineer is responsible for determining the design parameters of the electrical system including the converter stations, transmission lines and cables. His duties will include:

- carrying out investigations and system studies to establish design criteria.
- preparing technical portions of major specifications.
- carrying out a detailed review of selected portions of the tenders for the HVDC contract especially those sections dealing with system performance issues.
- providing technical review of manufacturer's HVDC design reports.
- providing technical support throughout the Project.
- witnessing and reporting on specific equipment type tests.
- providing commissioning support on site

Stations Engineer

The Stations Engineer heads a major engineering group, responsible for the complete design of the two HVDC converter stations and cable terminal stations. His duties include:

- preparing the specification and evaluation of tenders for the HVDC equipment supply contract.
- monitoring the HVDC equipment supply contract, including approval of engineering reports and drawings, which will be a major aspect of the work.
- ensuring the cooperation of the civil, mechanical and electrical departments to see that all design aspects are coordinated.
- preparing designs and specifications and evaluating tenders for the civil and mechanical work such as foundations, buildings, building services and fire protection, as well as electrical work such as the communication systems, power supply systems and alarm systems..

Transmission Line Engineer

The Transmission Line Engineer is responsible for the complete design of the HVDC transmission line including the interface to the cable terminal stations and the converter stations. His duties include:

- determining the transmission line route in conjunction with a survey contractor.
- preparing drawings including plans and profiles, tower locations, and right-of-way boundaries.
- designing a family of transmission towers, together with required foundations.
- preparing specifications and tender documents for the manufacture and supply of transmission towers, conductors, insulators and hardware, and for clearing and erection.
- evaluating bids, and providing assistance with the administration of contracts.

Submarine Cable Engineer

The Submarine Cable Engineer is responsible for determining the electrical and mechanical parameters of the cable, in conjunction with the Systems Engineer. His duties include:

- preparing the specifications and tender documents for the marine survey and for the cable manufacture and its installation.
- evaluating tenders and participating in the contractor selection process.
- providing engineering support throughout the manufacture and installation of the cable, including witnessing of key tests.

Construction Manager

This position is a major responsibility that would be established at an early date in the project office in St. John's.

The Construction Manager is responsible for establishing the construction requirements and contract packaging for all aspects of the Interconnection including converter stations, transmission lines, submarine cables and communications facilities. His duties include:

- developing construction policies and procedures as well as the preparation of construction tender documents in conjunction with the Transmission Line Engineer and the Stations Engineer.
- assisting the Project Manager in communication with the Owner on all construction matters during the course of the project.
- coordinating all construction activities so that the Project is completed in a timely manner.

All construction engineering departments report to the Construction Manager. The staff of such departments could include engineers transferred from the staff of the Engineering Manager.

Transmission Line Construction Engineer

The Transmission Line Construction Engineer is responsible for all transmission line construction activities and ensures that construction contracts are carried out according to the terms of the contracts. His duties include:

- ensuring that contractors follow specified construction procedures and environmental requirements.
- overseeing the construction of access roads and the contractors construction camps.
- coordinating between different transmission line and stations contractors.

Stations Construction Engineer

The Stations Construction Engineer is responsible for construction at both converter station and cable terminal sites and is represented by a resident engineer at each converter station. Initially the work is concentrated on the civil aspects of the work in preparation for the delivery and installation of the HVDC equipment. His duties include:

- supervising the installation of the auxiliary equipment and the AC switchyards.
- participating in the testing and commissioning of the installation in conjunction with the HVDC equipment supplier and the Owner's maintenance and operating staff.

Submarine Cable Construction Engineer

The Submarine Cable Construction Engineer is responsible for ensuring that the cable installation including embedment is carried out to the requirements of the specification. His duties include:

- witnessing of the cable laying and embedding operations.
- ensuring that the cable termination installations meet the requirements of the contract.
- witnessing of the manufacturer's tests on the completed cable installation.

He would be assisted by cable experts from the submarine cable engineering group.

Project Services Manager

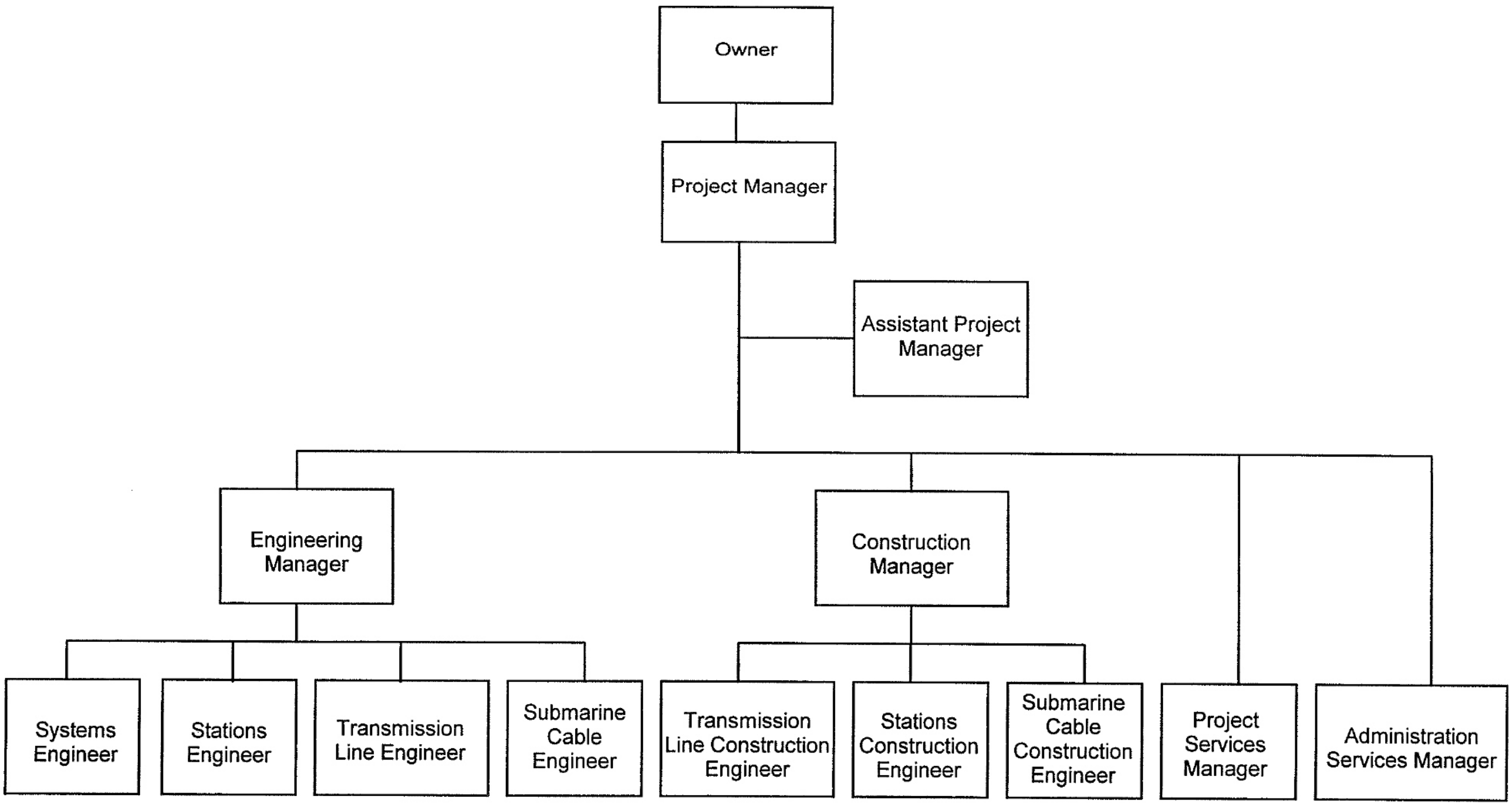
Reporting direct to the Project Manager in the St. John's office, the Project Services Manager has the principle responsibility for ensuring the project services systems are in place and operational to provide cost, scheduling and control information to all the engineering departments. His duties include:

- developing, maintaining and operating computer programs that provide the required project management information and control reporting to the Owner and the management team.
- establishing and administering a document control system and ensuring a consistent approach to project procedures.
- coordinating inspection and expediting of contractors' activities.

Administration Services Manager

The Administration Services Manager reports to the Project Manager in the St. John's office and has a wide range of responsibilities to ensure the smooth running of the Project. His duties include:

- establishing and administering project accounting and purchasing.
- administering human resources, coordinating staff, and moving and transportation of personnel.
- arranging of insurance and controlling the use of company vehicles and communication systems.



Gull Island to Soldiers Pond HVDC Interconnection
Management and Engineering Services Organization Chart
Figure 4.7-1

4.8 Transportation and Logistics

4.8.1 Transmission Line

An estimated 13,000 tonnes of material for the Labrador portion of the transmission line is expected to be delivered either by truck to Labrador City or by sea to Happy Valley - Goose Bay. It is assumed that the Owner will arrange transportation to the Owner's storage yard. An estimated 22,000 tonnes of material is required for the Newfoundland portion of the transmission line. Insulators will probably be delivered in containers from offshore. Steel and other material may be sent via truck and ferry to St. John's or delivered in containers to other ports in Newfoundland such as Corner Brook, Shoal Harbor, Lewisport, etc. From there the Owner will arrange transport by truck to the Owner's yards.

With two separate line contractors in Newfoundland a suitable storage yard can be provided at both ends of the southern section and at one end and at an intermediate point in the northern section.

The estimate includes all transportation costs including the cost of transportation to the Owner's storage yard.

4.8.2 Converter Stations

Seven converter transformers weighing up to 200 tonnes each will have to be transported to each converter site. Approximately 3500 tonnes of other materials will be required at each site. Synchronous condenser stators and rotors (weighing less than 200 tonnes) will be transported from St. John's to Soldiers Pond.

Gull Island

Primary access to the Gull Island power Station site will be via the Trans-Labrador Highway from either Labrador City or Happy Valley-Goose Bay. Access roads from the Trans-Labrador Highway to the Gull Island Power Station Site are included in the power station estimates and are assumed to be available for converter station access. Access to the converter station during its construction prior to completion of the main dam in Year 5 will be via the power station access road which crosses the Churchill river on the lower cofferdam at elevation 155 ft. (47m). The Trans-Labrador highway and the access road across the cofferdam will be sufficient to transport 200 Tonne loads.

The converter station is located approximately 3 km from the power house at elevation 200 ft. (65m). The road to the converter station will most likely take off from an access road designated as road 2 (Plate 26, Construction Roads from the Gull Island Report) in the vicinity of Big Spillway Creek. The road would then generally parallel the shoreline of the Churchill River approximately 1.5 km to the converter station. A crossing will be required over Big Spillway Creek. No information is available on Big Spillway Creek regarding the location or size of the required crossing which must be suitable for loads up to 200 tonnes. An allowance of $1,000,000 has been made for the Big Spillway Creek crossing.

The permanent road to the converter station will cross the main dam and join the converter station access road crossing Big Spillway Creek.

Off loading facilities (consisting of ramps) suitable for 200 tonne loads are assumed to be constructed at Goose Bay as part of the power station project. No allowance is made in the HVDC Transmission System estimates for unloading facilities.

Churchill Falls Labrador Corporation's transformer transporter, located in Churchill Falls will be used and the cost is included in the estimate.

Goose Bay is generally open between June and December and will be used as the main delivery point for imported materials to the converter station. The port of Sept Isles is open throughout the year and will provide access during the winter. Domestically supplied materials, except for heavy loads, will be transported direct from the source by truck to Labrador City and thence by the Trans-Labrador Highway to Gull Island.

Soldiers Pond

Soldiers Pond is adjacent to the Trans-Canada Highway approximately 35 km from the St. John's wharf. Loads of up to 200 tonnes can be transported through St. John's and on the Trans-Canada highway. An access road approximately 1.5 km in length suitable for 200 tonnes is required from the Trans-Canada highway to the converter station site.

St. John's port is open all year and will be used as the main delivery point for materials to the Soldiers Pond converter station. St. John's has facilities to handle loads of 200 tonnes.

4.8.3 Submarine Cable

As discussed in Section 4.4.3 above the submarine cable is usually delivered by the cable laying ship. Facilities for unloading and storage of the spare cable are required at a location near the cable crossing.

Materials for both cable terminal stations would be delivered to Corner Brook. Materials would be transported from Corner Brook to Yankee Point by truck and Corner Brook to L'Anse au Clair by truck and ferry.

4.9 Operation and Maintenance

An estimate of the annual operation and maintenance costs of the Interconnection are shown in Table 4.9-1.

At the Gull Island and Soldiers Pond Converter Stations, the estimate is based on operators working shifts. Soldiers Pond Converter Station requires additional maintenance personnel because of maintenance required for synchronous condensers.

For the transmission lines, the estimate is based upon a four week survey per year by an engineer and a helicopter. In addition, every 10 years, three 4 person crews would spend six months maintaining the right-of-way.

The estimate for the cable and terminal stations is based upon a two month survey of the cable being performed once every five years. In addition, four personnel would maintain the equipment at the cable terminal stations annually over a two week period.

The cost estimates include allowances for the purchase of consumable spares not covered by the capital estimates.

GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION

TABLE 4.9-1

OPERATION AND MAINTENANCE COSTS PER ANNUM

Category	Refer to Note	Average Hours/Year	No. of Personnel	Average Cost ($/hr)	Cost per Annum Dollars (thousands)	
					Unit	Total
Gull Island Converter Station						
Operators		2000	6	80	960	
Maintenance Personnel		2000	15	80	2400	
Material and Equipment					800	
Subtotal					4160	4160
Soldiers Pond Converter Station						
Operators		2000	6	80	960	
Maintenance Personnel		2000	25	80	4000	
Material and Equipment					800	
Subtotal					5760	5760
Transmission Lines						
Engineer		1500	1	100	150	
Maintenance Crews	1	1000	10	60	600	
Helicopter Rental	1	240	-	800	192	
Vegetation Clearing (Ave)	2	100	12	50	60	
Subtotal					1002	1002
Cable and Terminals						
Cable Survey (Ave)	3	60	Ship	3,333	200	
Terminal (Ave)	4	100	4	80	32	
Repair Allowance	5	-	-	-	666	
Material Allowance	6	-	-	-	20	
Storage Allowance	7	-	-	-	10	
Subtotal					928	928
TOTAL						11850

Notes:

1. The transmission lines are assumed to be maintained over a six month period each year with one 5 person crew each in Newfoundland and Labrador. Helicopter rental includes the pilot.
2. The right-of-way is assumed to be maintained every 10 years and this would require three crews of four persons for a period of six months.

3. A cable survey assumed once every five years, taking two months to complete.
4. Cable terminals assumed to be maintained once each year over a period of two weeks.
5. Submarine cable repair allowance is based on an estimated failure rate of 0.1 failures per 100 km per year. (This number based on historic submarine cable failures was developed for another submarine cable project). The estimated cost per failure for an embedded submarine cable is 6 million dollars. The spare cable is included in the submarine cable estimate.
6. The allowance for material is $30,000 per year.
7. Storage cost for the spare cable is $10,000 per year.

4.10 Overall Cost Estimate

The estimated cost of the Gull Island to Soldiers Pond HVDC Interconnection is $1425 million. The cost estimates have an accuracy of ±10%. The cost estimates include contingencies. The costs are given based on a January 1998 price level.

Table 4.10-1 gives the estimate cost of the major components of the Interconnection. Management and Engineering is shown separately.

The estimated cash flow for the construction of the Interconnection is given by quarter in Table 4.10-2. The cash flow is based on the project schedule provided with this report.

GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION

TABLE 4.10-1

PROJECT COST ESTIMATE
(January 1998 Cost Level)

Item	Amount (Million $)
Pre-Project Release Investigations	4
Transmission Line	275
Converter Stations	508
Submarine Cable	299
Communications	82
Continency	126
Project Management and Engineering	134
Total	1428

GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION

TABLE 4.10-2

PROJECT ESTIMATED CASH FLOW
(MILLION $)
(January 1998 Cost Level)

Item	Amount	Year 1				Year 2				Year 3				Year 4				Year 5				Year 6			
		Quarters				Quarters				Quarters				Quarters				Quarters				Quarters			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Transmission Line	302				12	22	33	33	36	42	30	15	11	17	15	13	11	9	3						
Converter Stations	559								10	36	47	50	52	53	60	65	66	58	53	9					
Submarine Cable	339		2	2			1	1		35	63	71	44	38	33	38	11								
Communications	90									1	6	7	2	2	12	12	5	7	15	15	6				
Project Management and Engineering	138 *	2	2	3	3	4	5	8	9	10	10	10	10	10	10	10	10	7	5	2	2	1	1		
Total	1428	2	4	5	15	26	39	42	55	124	156	153	119	120	130	138	103	81	76	26	8	1	1	0	0

Notes:

1. Pole 1 in service January, Year 6
2. Pole 2 in service March, Year 6
3. Cash flow amounts include contingency

* Includes $4 million for pre-project release investigations.

4.11 Risk Evaluation and Contingency

The estimates for major equipment were developed based on mini specifications and in-house cost data bases. Contingencies are included for these items as the requirements may not be fully defined and the manufacturers may have not developed fully competitive estimates.

The contingency included in the project cost estimates is the maximum of:

- risk evaluation
- normal 10% project cost

A contingency of 10% is included in the project cost estimates for the DC transmission line and converter stations. For the submarine cable cost estimates the contingency is 13% based on the results of the risk evaluation.

Tables of risk identification for the DC transmission line, converter stations and submarine cable crossing are given in Tables 4.11-1, 4.11-2 and 4.11-3 respectively.

GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION

TABLE 4.11-1

RISK IDENTIFICATION
TRANSMISSION LINE

Items	% of Item Cost at Risk	Risks	Exposure $	Risk Probability %	Risk Contingencies $
Foundation and Anchors	50%	type, quantity & price change	2,245,000	50	1,122,500
Towers (including Guys & Hardware)	25%	type, quantity & price change	7,350,000	50	3,675,000
Insulator & Conductor Hardware	10%	type, quantity & price change	3,322,000	50	1,661,000
Overhead Shield Wire	10%	type & price change	500,000	50	250,000
Counterpoise	10%	type & price change	300,000	50	150,000
Conductors	10%	quantity & price change	4,146,000	50	2,073,000
Clearing	30%	amount & price change	2,230,000	100	2,230,000
Access Roads	40%	amount & price change	2,650,000	100	2,650,000
Line Construction	10%	quantity & price change	10,796,000	100	10,796,000
Total					24,607,500

GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION

TABLE 4.11-2

RISK IDENTIFICATION
CONVERTER STATIONS

Item		Exposure $	Probability %	Contingencies $
Gull Island Converter Station				
Access Road	Length & Conditions	675,000	50	337,000
Big Spillway Creek Bridge	Size	1,000,000	50	500,000
Site Levelling	Cut and Fill	374,000	50	187,000
Well and Water Supply	Source	1,000,000	50	500,000
Foundations	Type	3,700,000	50	1,850,000
Switchyard Structures	Type & Amount	500,000	30	150,000
Converter Building Foundations	Type	3,000,000	50	1,500,000
Converter Building Structure	Design	3,000,000	20	600,000
DC Converter Equipment	Define Requirements	20,000,000	40	8,000,000
Electrode & Electrode Line	Electrode Site Location	14,000,000	50	7,000,000
AC Switchyard Equipment	Design	3,000,000	30	900,000
AC Transmission Line to Gull Island Power Plant	Length & Design	300,000	30	90,000
Auxiliary Services	Design	500,000	20	100,000
Transportation	Amount	2,500,000	50	1,250,000
Subtotal				22,964,000
Soldiers Pond Converter Station				
Access Road	Length & Conditions	675,000	50	337,000
Site Levelling	Cut and Fill	440,000	50	220,000
Well and Water Supply	Source	1,000,000	50	500,000
Foundations	Type	6,000,000	20	1,200,000
Switchyard Structures	Type & Amount	600,000	30	180,000
Converter Building Foundations	Type	3,000,000	20	600,000
Converter Building Structure	Design	3,000,000	20	600,000
Indoor DC Switching	Requirement	4,300,000	80	3,440,000
DC Converter Equipment	Define Requirements	20,000,000	40	8,000,000
Electrode & Electrode Line	Electrode Site Location	1,000,000	50	500,000
AC Switchyard Equipment	Design	3,000,000	30	900,000
Synchronous Condensers	Define Requirements	30,000,000	20	6,000,000
Auxiliary Services	Design	500,000	20	100,000
Transportation	Amount	500,000	50	250,000
Subtotal				22,827,000
Total				45,791,000

GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION

TABLE 4.11-3

RISK IDENTIFICATION
SUBMARINE CABLE CROSSING

Item		Exposure $	Probability %	Contingencies $
Submarine Cable				
Submarine Cable	Amount	25,000,000	30	7,500,000
Laying Cable	Amount	4,000,000	30	1,200,000
Embedding Cable 2.0m in Overburden in 70m of Water	Overburden Conditions	7,000,000	50	3,500,000
Trenching in Rock in Water up to 70m Deep	Rock Conditions	20,000,000	50	10,000,000
Embedding Cable 0.6m in Overburden in 70m of Water	Overburden Conditions	20,000,000	50	10,000,000
Concrete Mattresses	Amount	3,600,000	50	1,800,000
Land Cable Trenching	Amount & Conditions	4,600,000	50	2,300,000
Mobilization	Location of Equipment	4,300,000	50	2,150,000
Subtotal				38,450,000
Submarine Cable Terminals L'Anse au Clair and Yankee Point				
Access Road	Length & Conditions	200,000	50	100,000
Site Levelling	Cut and Fill	400,000	50	200,000
Well and Water Supply	Source	20,000	20	4,000
Building Foundations	Type	1,000,000	50	500,000
Electrical Equipment	Design	500,000	50	250,000
Auxiliary Services	Design	25,000	50	12,000
Subtotal				1,066,000
Total Contingency				39,516,000

The Total Contingency corresponds to 13% of the submarine cable crossing cost estimate.

4.12 Activities Prior to Project Release

The estimate cost and duration of activities required to be completed prior to Project Release are given in Table 4.12-1.

The activities are described in more detail in Section 3.6 of this report.

GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION

TABLE 4.12-1

COST ESTIMATE OF ACTIVITIES PRIOR TO PROJECT RELEASE

		Estimate Cost (dollars)	Duration of Study (months)
a)	Investigation of Integration of the Interconnection with the Island AC System	300,000	6
b)	Investigation of Integration of the Interconnection into the Labrador AC System	60,000	3
c)	DC Transmission Line Design for Long Range Mountain Area	10,000	1
d)	DC Transmission Line Tubular Steel or Lattice Steel Structures	40,000	3
e)	Review and finalize DC Transmission Line Loading	50,000	2
f)	Investigate the Use of Compact Conductor on DC Transmission Line	30,000	1
g)	Salt Contamination Study	100,000	24
h)	Determine location of Electrodes for Gull Island Converter station and Soldiers Pond Converter Station. Work includes Field Measurements to Establish Possible Electrode Sites in Labrador	550,000	6
i)	Embedment Studies of Cable	350,000	9
j)	Finalize Submarine Cable Route Across Strait of Belle Isle		
	i) establish the most suitable landing location on the Island	1,000,000	6
	ii) carry out a detailed survey of the selected cable route	1,500,000	8
k)	Establish if DC System Communication Link should be Microwave or Fibre Optic	20,000	2
	Total Estimated Cost	**$4,010,000**	

5. PROJECT SCHEDULE

The project schedule starts at the beginning of Year 1 and has a duration of five years and three months. Year 1 corresponds to Year 01 in the Gull Island Hydro Plant Review and Cost Estimate. The HVDC system is complete and in service shortly after the first Gull Island generators are available. Figure 5-1 shows the master schedule for the project.

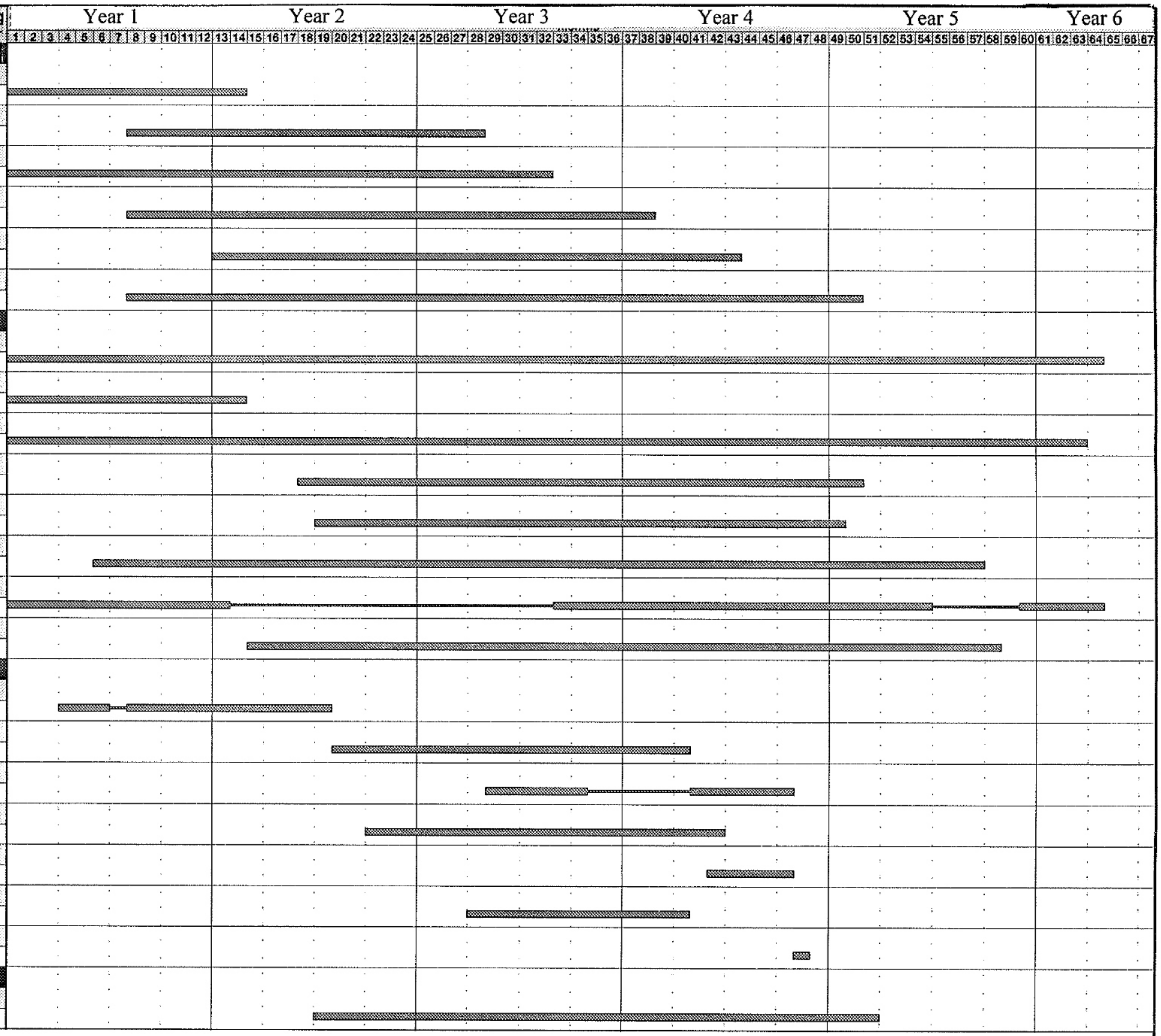
The DC transmission line schedule, shown on Figure 5-2, is a five year programme starting at the beginning of Year 1. The transmission line is complete in the second quarter of Year 5 in time for converter station commissioning tests. Construction activities continue throughout the year with sufficient time to concentrate specific activities in summer or winter months whichever is most favourable for the activity. For example, access to some areas of the transmission line may be better in the winter.

The HVDC converter station schedule, shown in Figure 5-3, starts the beginning of Year 1. Commissioning of the first pole starts with the availability of the first Gull Island Generator in the third quarter of Year 5. Commissioning of the second pole follows the first pole by three months and is complete in the first quarter of Year 6. The Gull Island and Soldiers Pond converter station schedules are similar except for activities related to the synchronous condensers which are only required at Soldiers Pond.

Although construction of the DC electrode and electrode line do not start until Year 3, it is necessary to identify a suitable site for the DC equipment specification. The Owner's implementation studies and electrode commissioning tests may continue after the DC system is in commercial operation.

The submarine cable crossing schedule is shown in Figure 5-4. In Year 1 the cable route is optimized to minimize the amount of rock trenching and the cable tender documents are written and issued. Marine work such as rock trenching, ledge removal and cable laying and embedding must be carried out in a May to October construction period when sea conditions in the Strait of Belle Isle are suitable. The schedule assumes the three cables are laid in one year. The cable installation is complete by the end of Year 4, although the cables are not required for service until the fourth quarter of Year 5 which is the start of pole 1 commissioning. The proposed schedule can be modified to provide for unforseen problems and if necessary accommodate the laying of cables over a two year period.

Activity Description	Orig Dur
400 KV HVDC SINGLE BIPOLE TRANSMISSION LINE	
+ Survey	14
+ Clearing & Access Roads	21
+ Foundations & Anchors	32
+ Towers	31
+ Conductor	31
+ Construction Contract	43
HVDC CONVERTER STATION	
+ System Studies	64
+ Environmental & Regulatory	14
+ HVDC Converter Equipment Supply/Install	63
+ Converter Station	33
+ Converter Building	31
+ Synchronous Condensers & Auxiliaries	52
+ Ground Electrode & Electrode Line	64
+ AC/DC Switchyards	44
SUBMARINE CABLE CROSSING	
+ Preliminary Work	16
+ Cable Manufacturing	21
+ Cable Laying	18
+ Termination Buildings	21
+ Shore Cable	5
+ Cable Storage Facility	13
+ Testing Cable	1
COMMUNICATIONS	
+	33



Project Start	01-JAN-98
Project Finish	30-APR-03
Data Date	01-JAN-98
Plot Date	23-MAR-98

Early Bar
Progress Bar

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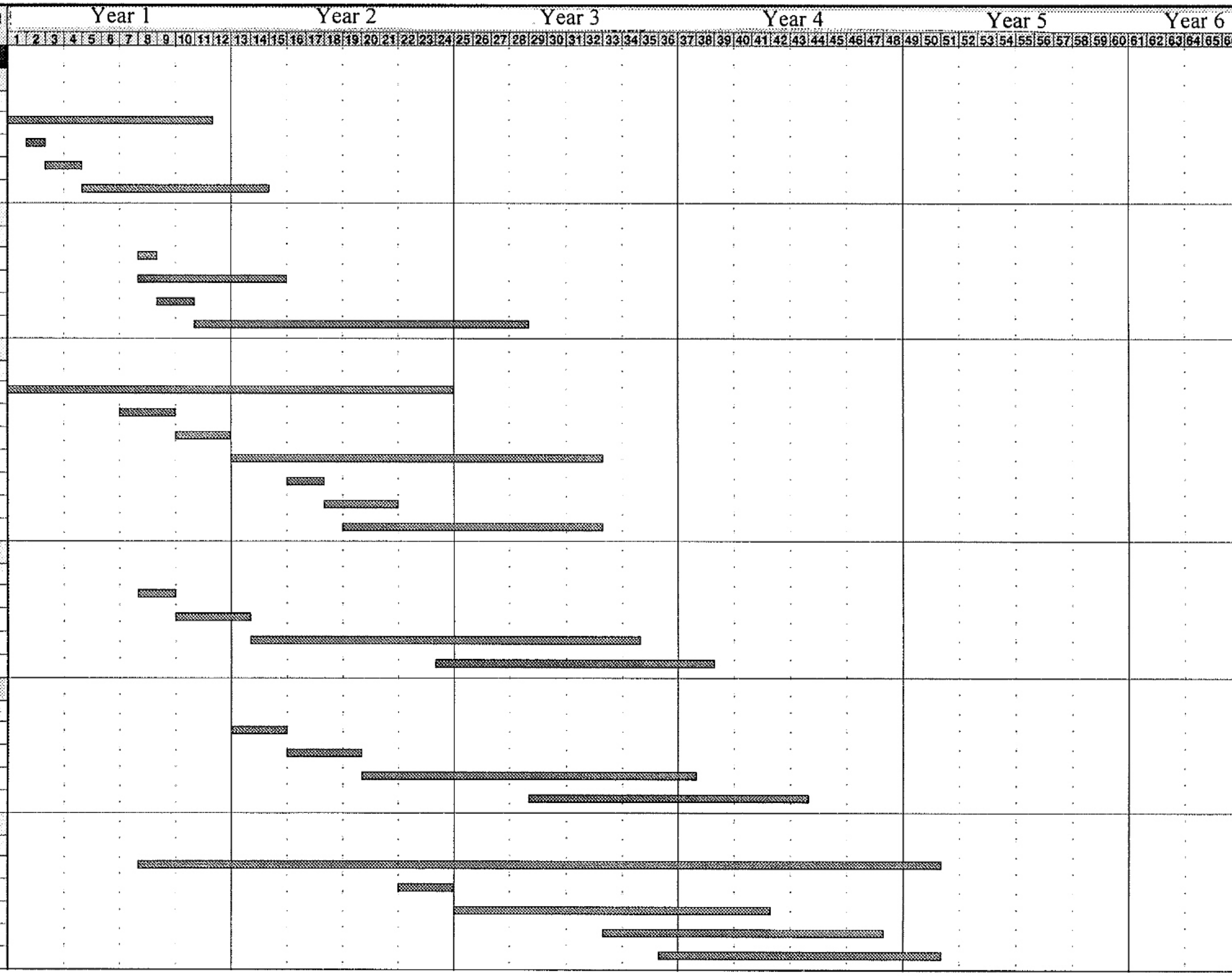
Sheet 1 of 1

GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION
Master Project Schedule
Figure 5-1

Activity Description	Orig Dur
400 KV HVDC SINGLE BIPOLE TRANSMISSION LINE	
Survey	
Engineering-Survey	11
Control Point	1
Bid/Evaluate/Award	2
Survey	10
Clearing & Access Roads	
Control Point	1
Engineering-Clearing	8
Bid/Evaluate/Award	2
Clearing & Access Roads	18
Foundations & Anchors	
Eng-Foundations/Anchors Towers, Conductor	24
Control Point	3
Bid/Evaluate/Award	3
Manufacture Foundations & Anchors	20
Control Point	2
Bid/Evaluate/Award	4
Deliver Foundations & Anchors	14
Towers	
Control Point	2
Bid/Evaluate/Award	4
Fabricate tower Steel	21
Deliver Tower Steel	15
Conductor	
Control Point	3
Bid/Evaluate/Award	4
Fabricate Conductor	18
Deliver Conductor	15
Construction Contract	
Engineering-Construction Contract	43
MOB - Construction Contract	3
Install Foundations & Anchors	17
Assembly & Erect Towers	15
String Conductor & Test	15



Project Start	01-JAN-98
Project Finish	30-APR-03
Data Date	01-JAN-98
Plot Date	23-MAR-98

Early Bar
Progress Bar

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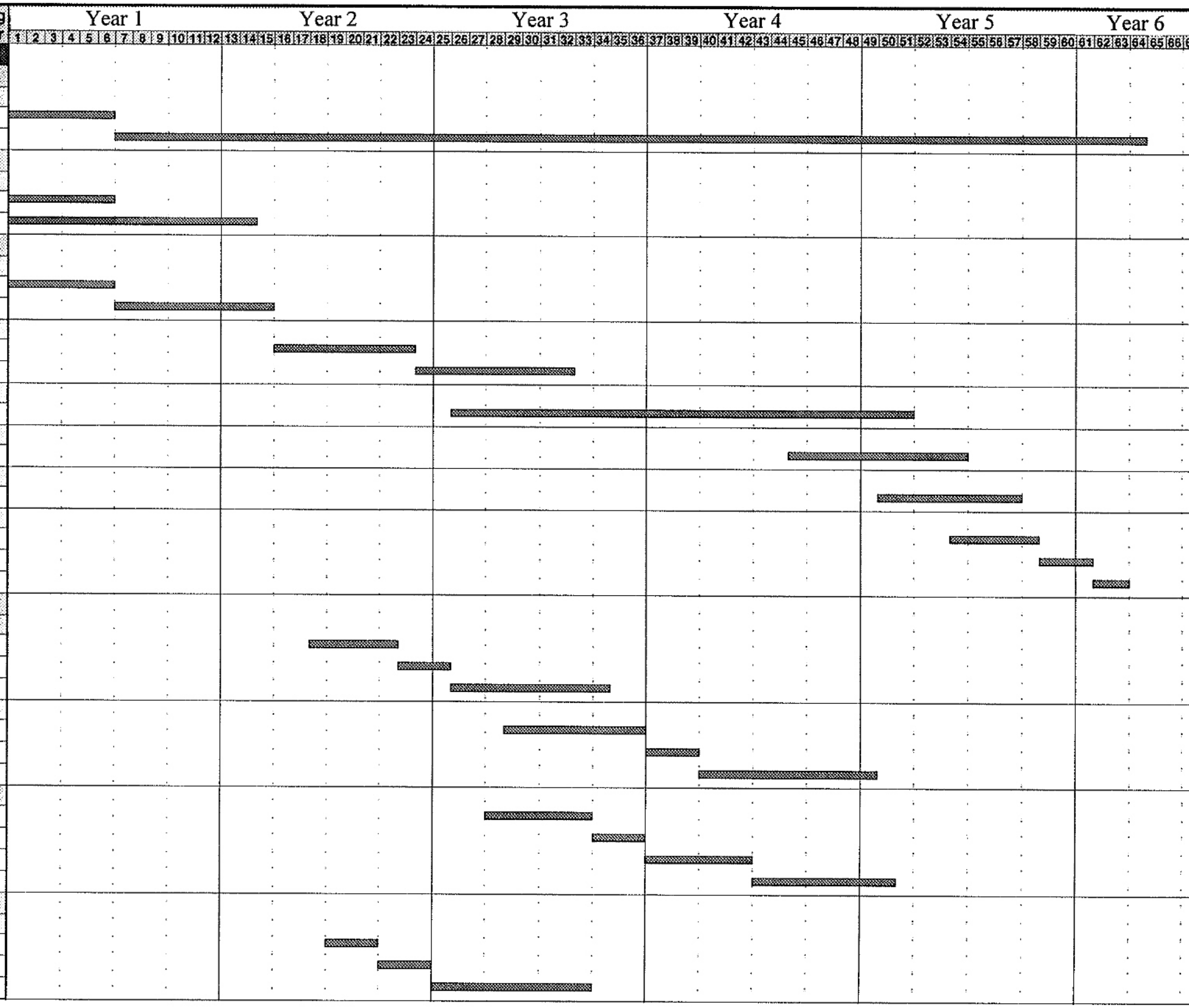
Sheet 1 of 1

GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION
Transmission Line Schedule
Figure 5-2

Activity Description	Orig Dur
HVDC CONVERTER STATION	
System Studies	
Specification Studies	6
Implementation Studies	58
Environmental & Regulatory	
Converter Stations	6
Electrodes	14
HVDC Converter Equipment Supply/Install	
Specification	
Prepare Spec	6
Tender	9
Design	
System Design	8
Equipment Design	9
Manufacture	
Procure materials, manufacture, factory testing	26
Deliver	
Deliver to Site	10
Install	
Installation of Equipment	8
Commission	
Subsystem Tests	5
System Tests Pole 1	3
System Tests Pole 2	2
Converter Station	
Site Improvements	
Design & Spec	5
Tender	3
Construction	9
Foundations & Trenches	
Design & Spec	8
Tender	3
Construction of foundations, cable treches etc.	10
Structures	
Design & Spec	6
Tender	3
Manuf. & Deliver	6
Construction	8
Converter Building	
Design	
Spec.	3
Tender	3
Design	9



Project Start	01-JAN-98
Project Finish	30-APR-03
Data Date	01-JAN-98
Plot Date	04-MAR-98

Early Bar
Progress Bar

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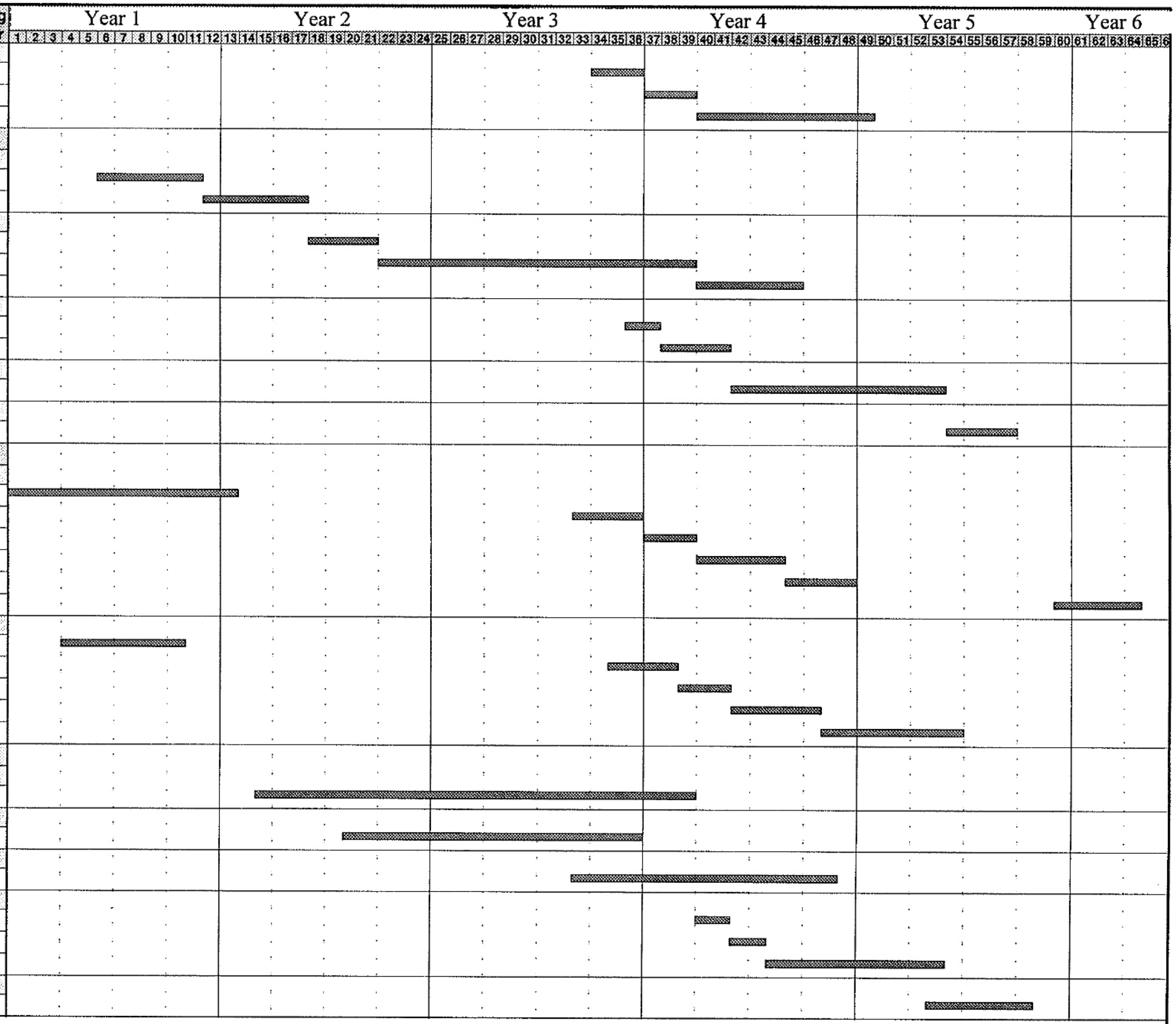
Sheet 1 of 2

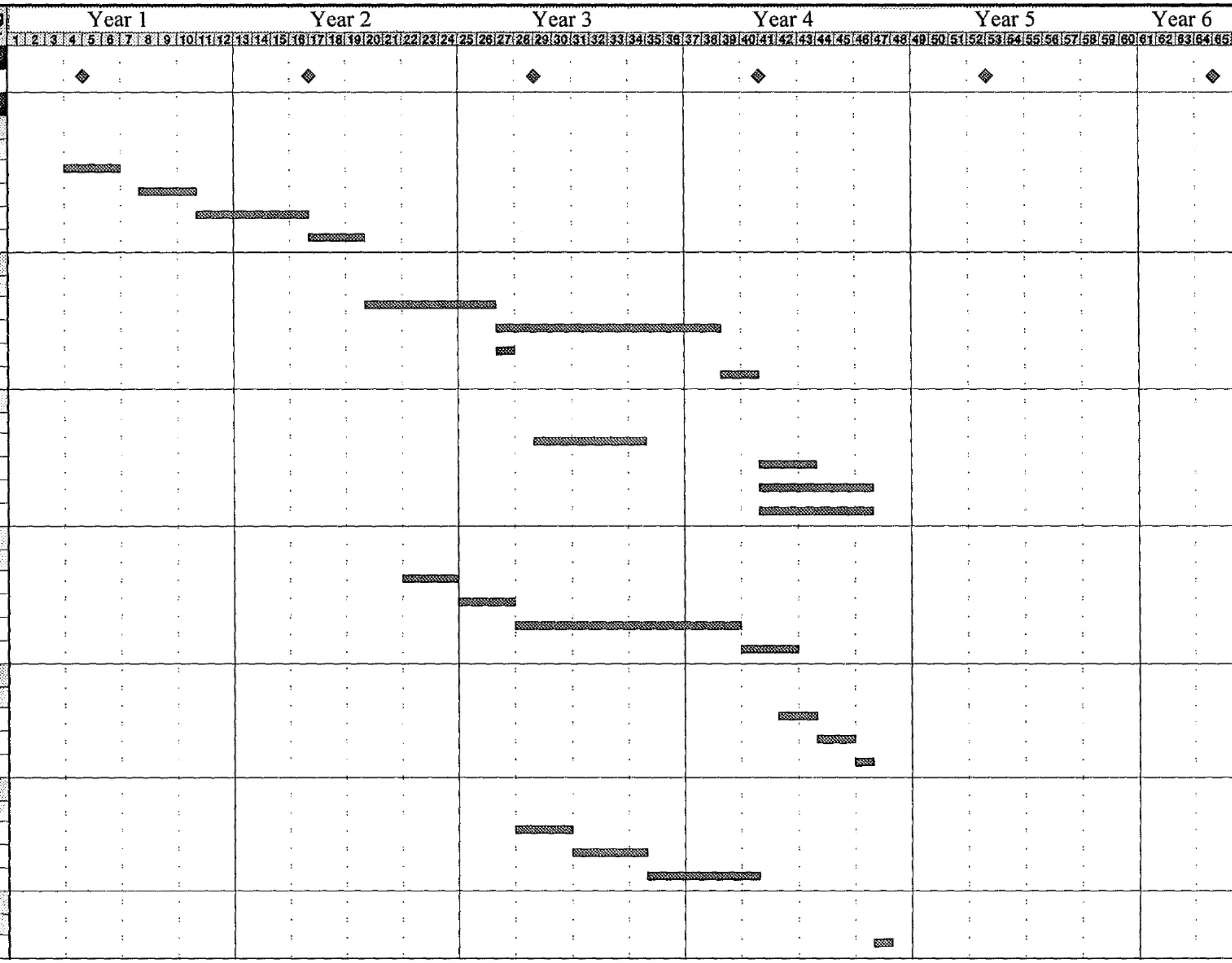
GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION
Converter Station Schedule
Figure 5-3 **Sheet 1 of 2**

Activity Description	Orig Dur
Construction	
Spec.	3
Tender	3
Construction	10
Synchronous Condensers & Auxiliaries	
Specification	
Prepare Spec.	6
Tender	6
Manufacture & Deliver Equipment	
Design	4
Manufacture	18
Delivery	6
Building & Foundations	
Design	2
Construction	4
Installation	
Installation	12
Commission	
Test	4
Ground Electrode & Electrode Line	
Ground Electrode	
Design & Site Selection	13
Specify	4
Tender	3
Material Delivery	5
Construction	4
Tests	5
Electrode Line	
Design & route Selection	7
Specify	4
Tender	3
Material Delivery	5
Construction	8
AC/DC Switchyards	
Design & Specification	
Design& spec of AC swyd inclding bldgs& sitework	25
Award Supply Contracts	
Tender	17
Manufacture & Deliver Equipment	
Manufacture & delivery of equip bldgs& structure	15
Installation Contracts	
Spec	2
Tender	2
Sitework & building equipment installation	10
Commission	
Commissioning	6



GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION
Converter Station Schedule
Figure 5-3 **Sheet 2 of 2**

Activity Description	Orig Dur
+ MILESTONES See Note	
	60
SUBMARINE CABLE CROSSING	
Preliminary Work	
Route Optimization	3
Submarine Cable Specification	3
Tender / Evaluate / Award	6
Detailed Marine Survey	3
Cable Manufacturing	
Design	7
Manufacture	12
Cable Testing	1
Transport	2
Cable Laying	
Submerged Rock Trenching	6
Laying Cable	3
Embedding Cable	6
Concrete Mattress	6
Termination Buildings	
Design	3
Tender	3
Construction	12
Electrical Equipment Instalation	3
Shore Cable	
Trenching	2
Laying Cable	2
Cable Termination	1
Cable Storage Facility	
Design	3
Tender	4
Construction	6
Testing Cable	
Testing Cable	1



Note: Six Month Marine Construction Period Starting May 1

Project Start	01-JAN-98
Project Finish	30-APR-03
Data Date	01-JAN-98
Plot Date	04-MAR-98

Early Bar
Progress Bar

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Sheet 1 of 1

GULL ISLAND TO SOLDIERS POND HVDC INTERCONNECTION
Submarine Cable Crossing Schedule
Figure 5-4

6. LIST OF REFERENCES

1. Teshmont, Report No. ER-133-61200-1, Gull Island Transmission Facilities, "Design Transmittal Transmission Towers ±400 kV HVDC Transmission Line", August 1975.

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3. SNC-Lavalin, Engineering Report No. 11.99.13, "Transmission of Electricity from Labrador to Newfoundland Single Pole 400 kV DC", March 1980.

4. Lower Churchill Development Corporation Limited, "Strait of Belle Isle Crossing HVDC Transmission, Submarine Cable Scheme 1984 Program", December 1984.

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11. Power Technologies Inc., "HVDC Link Reliability Studies", June 12, 1981.