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THE FOLLOW-ON METEOROLOGICAL EVALUATION OF THE PROPOSED GULL ISLAND TRANSMISSION LINE NETWORK

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SUMMARY

In 1973, a study was conducted of the possible meteorological problems involved in constructing a transmission line network from the Gull Island Hydro Site in Labrador to the Avalon Peninsula of Newfoundland. That report was presented in November, 1973. During the winter of 1974-1975, a second phase of the study was conducted to validate and refine the values of wind and ice load determined during the previous year. This study consisted of data acquisition, field surveys, analysis of field and climatological data, and revision of line sector values developed during the earlier study. Meteorological measurements were recorded at one site in the high terrain of Labrador, two sites in the Long Range Mountains of Newfoundland, and one site east of the mountains. Data from these sites were correlated with that recorded at nearby weather service stations, and probabilities of occurrence of specific ice and wind loadings were extrapolated to 16 route segments.

This year's data did not result in any revision of the icing estimates given in the 1973 report. It appears that the winter of 1974-1975 was a relatively light icing season throughout Newfoundland.

Wind speeds over the ridge of the Long Range Mountains were much greater than previously believed. The 50-year return period value was increased from 98 mph in the 1973 report to 140 mph in this study. The prevailing direction of the extreme winds has been changed from north-northwesterly to easterly. Measurements taken in Labrador have shown the 1973 estimates of return period wind speeds on the mainland to be somewhat low. The 50-year return period value for the higher elevations just north of the Strait of Belle Isle was increased from 93 mph to 100 mph.

The shifting of the proposed route eastward at the crossing of the Long Range Mountains will result in some decrease in ice and wind loads along most of this portion of the line. However, portions of the segment are exposed to the east and should be subject to the same extreme loadings as predicted by the past winter's measurement program.

I. INTRODUCTION

Teshmont Consultants, Ltd., is in the process of designing a 500-kv transmission line for Newfoundland and Labrador Hydro. The proposed line will extend from the Gull Island Hydro Site southwest of Goose Bay, Labrador, to near Holyrood on the Avalon Peninsula of Newfoundland.

It was known that portions of the line would be subjected to some of the highest wind and ice loads to be experienced in Canada. Northeastern Newfoundland was known to be especially susceptible to damaging icing storms in recent years. The proposed routes were to cross through that area as well as uninhabited areas where no past experience or reports were available. Two preliminary meteorological evaluations of the area and potential routes were conducted during the fall of 1973 and the summer of 1974. Those studies were based on the existing climatological records of the few weather stations located throughout the area supplemented by storm damage reports and conversations with personnel having first-hand experience with the winds and icing in the various regions of the province. It was readily apparent that existing data were not available from the remote areas most susceptible to high winds and/or icing. The need to collect meteorological data at some of the more vulnerable locations and to develop relationships between these locations and existing weather stations was recognized. A data collection program was established and data collected at four sites during the winter of 1974-1975. If necessary, the wind and ice loadings predicted for these remote portions of the proposed route could be refined to reflect the results of the measurement program.

There have been some changes in the proposed route since the two previous studies were made. The portion of the route in Labrador has not changed significantly since the November, 1973, report. After crossing the Strait of Belle Isle, the route will then run south-southwestward along the west coastal plain of the northwest peninsula of Newfoundland, remaining at elevations near or below 500 feet except where the route runs between the High Lands of St. John and the Long

Range Mountains. The elevation in this region briefly reaches 1500 feet. When the sites for the 1974-1975 meteorological program were chosen, the proposed route was expected to run between Portland Creek Pond and Inner Pond, stay on the coastal plain on the west side of West Hill, and then veer southeastward as it rapidly ascended to the ridge of the Long Range Mountains. One of the weather station sites was located near the highest point of the ridge. The current route also runs between Portland Creek Pond and Inner Pond, but then immediately begins a more gradual climb east of West Hill and crosses the mountains at slightly lower elevations. The new crossing of the Long Range Mountains should be slightly less exposed than the earlier route. South of the Main River the descent into the Upper Humber Valley is along the original route described in the November, 1973, report. However, the latest route then turns south of the original, running south of Sheffield Lake and close to the northern edge of the Top-sails. South of Gander the original and current routes become one again and remain essentially so, with only minor variations, until the terminus northeast of Holyrood.

This report presents the analysis of the data collected during the winter of 1974-1975. The scope of the study and data sources are described in Sections II and III. The four remote data collection sites are described in Section IV, and the results of the field program are analyzed in Section V. The wind and ice loading estimates given in the two previous reports are updated by line segment in Section VI. Finally, significant results and conclusions are summarized in Section VII.

II. SCOPE OF STUDY

This transmission line study consisted basically of three phases, as follows:

- Data acquisition (field program)
- Reduction and analysis of data
- Refining of segment values

The data acquisition phase consisted of making measurements of wind, temperature, and ice accumulations at four sites previously identified as being apparent critical locations to determine ice and wind loading extremes. These locations were selected as being representative of the highest and/or most exposed portions of the proposed route. Site locations and equipment installed are described in Section IV. Measurements were made from October 1974 through June 1975.

In the data reduction and analysis phase, the data gathered from the four instrumented sites and the corresponding weather records from the six area weather stations listed in Section III were processed together. They were related to the historical data for those stations to develop probabilities of occurrence of specific ice, wind, and combined ice and wind loads for the measurement sites.

Results of the analysis phase were used to refine the route segment values previously developed.

III. DATA SOURCES

A. Climatological Data

Historical meteorological data for twelve Department of the Environment stations in the area were available from previous studies conducted in 1973 and 1974. For six of the stations most nearly related to the instrumented sites, microfilms or photocopies of the hourly weather observations taken during the period 1 October 1974, through 30 June 1975, were procured from the Atmospheric Environment Service (AES). The twelve stations for which the historical data were available and their period of record are listed below. The stations for which hourly data during the past winter were acquired are designated by the asterisks.

* St. John's-Torbay, Nfld.	1953-1971
Argentia, Nfld.	1953-1969
* Gander, Nfld.	1953-1971
Buchans, Nfld.	1953-1964
* Deer Lake, Nfld.	1966-1971
Stephenville, Nfld.	1953-1971
* Daniels Harbour, Nfld.	1966-1971
* Battle Harbour, Labrador	1958-1971
* Goose Bay, Labrador	1953-1971
Wabash Lake, Labrador	1961-1971
Schefferville (Knob Lake), Quebec	1953-1971
Lake Eon, Quebec	1961-1971

Periods with wind speeds greater than 20 mph and/or peak gusts greater than 30 mph were extracted from wind charts obtained from Hawke Bay, Nfld., for the period November, 1974, through April, 1975. In addition, Monthly Climatological Summaries were available from St. John's Airport and Gander International Airport for the October, 1974, through May, 1975, period.

B. Field Data

Recorded data were obtained from four instrumented sites along the proposed route during the period from mid-October, 1974, through early June, 1975. The locations of these remote sites are shown in Figure III-1 and descriptions of their locations and instrumentation installed are detailed in Section IV.

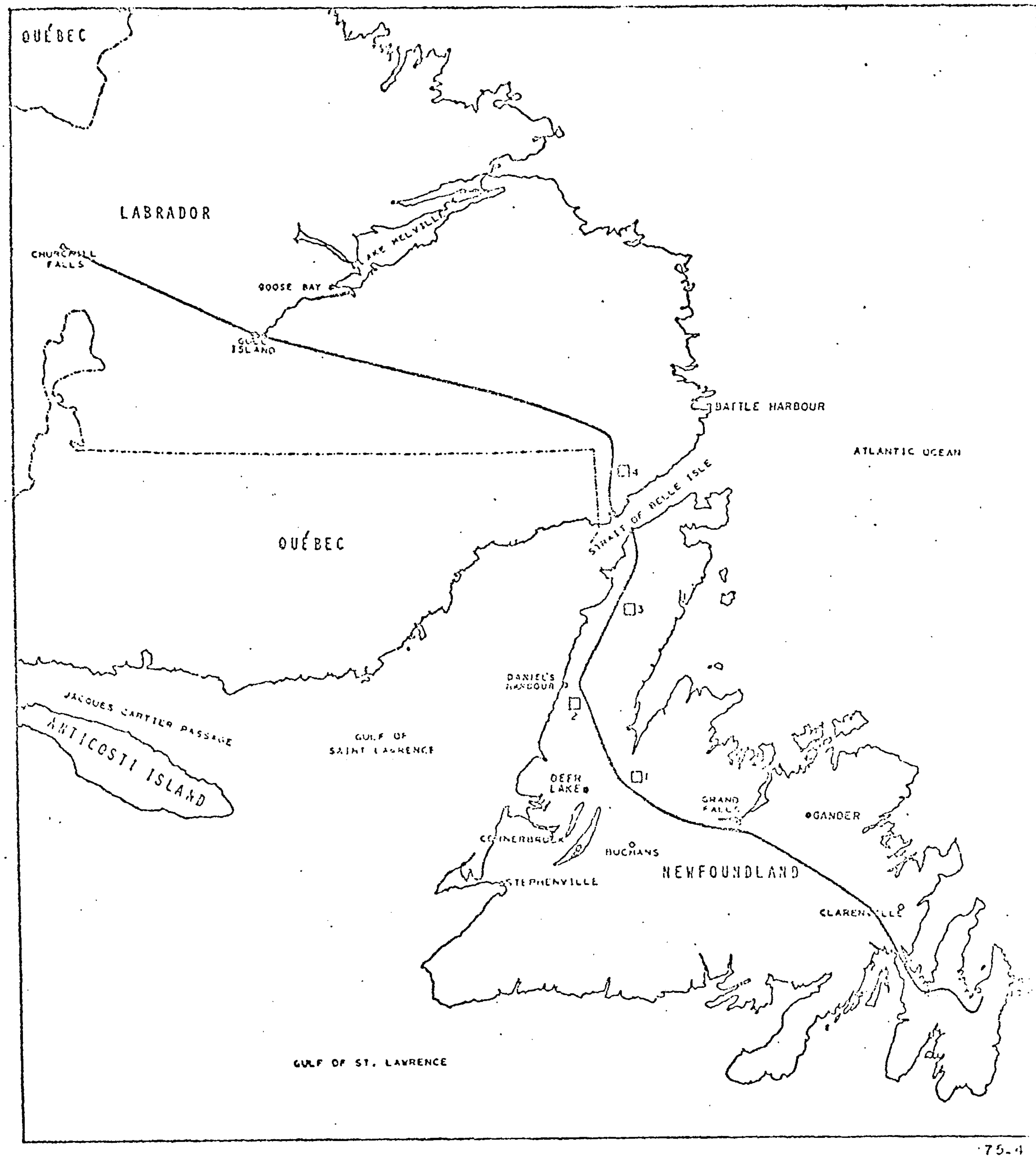

Fig. III-1. PROPOSED GULL ISLAND TRANSMISSION LINE SYSTEM. Measurement Sites are Indicated by the Squares.

IV. SITE DESCRIPTIONS

Site 1 was located near the microwave tower on a hill north of Sheffield Lake. At an elevation of 1500 feet, this station, approximately 1000 feet above the lake, was well exposed to the gradient wind flow from all directions. This site was chosen to represent the maximum exposure in an area where no regular observations are available. Of special interest was northeast winds coming off the Atlantic Ocean.

Site 2 was located eight miles south-southeast of Portland Creek on a ridge 2000 feet above sea level. This site, located near the area where the proposed route was expected to cross the ridge, is well exposed in all directions.

Site 3 was located between the High Lands of St. John and the Long Range Mountains, approximately eleven miles east of Barr'd Harbour. At an elevation of 1500 feet, the site is sheltered by higher terrain to the west. The possibility of channelling of north-northeast or south-southwest winds led to the selection of this site.

Site 4 was located on the mainland on a plateau about twenty-six miles north of the Strait of Belle Isle crossing point at an elevation of 1800 feet. It is well exposed in all directions and representative of high terrain in this area.

At each site two 30-foot towers were erected approximately 54 feet apart, spanned by a cable 1.338 inches in diameter. An ice rate meter (IRM) that measures increased tension due to ice loading was connected to the cable. Atop each tower was a Mechanical Weather Station (MWS) that recorded wind direction, wind run, temperature, and relative humidity. In addition, power was available at Site 1 which allowed for the installation of heat lamps atop one of the towers in an attempt to reduce the heavy ice accumulations that were expected at the site.

The IRM's began service in mid-October, 1974, and the MWS's in mid-November, 1974. All of the sites were deactivated in June, 1975.

V. ANALYSIS OF FIELD PROGRAM RESULTS

Mechanical Weather Station data recovery percentages by parameter were calculated for each site. The value of having two MWS's at each site is reflected in the comparison of the recovery percentages of each MWS. By station, only 73.4 percent of the data was recovered, yet, by site, 90 percent was recovered. These percentages include data that was questionable due to the likelihood of icing (e.g. wind speeds very low for several consecutive days with a constant wind direction during the same period). However, these data are still useful in that they give a good indication of the duration of severe icing conditions. One parameter not included in these recovery percentages was relative humidity. The somewhat delicate humidity element could not withstand the severity of the many winter storms that passed through Newfoundland and, thus, the resulting data were, at best, suspect during most of the season.

A. Winds

The Mechanical Weather Stations used at Sites 1 through 6 measure "wind run," the number of miles of wind which pass the station. Normal data reduction of MWS recordings results in hourly average winds, the total number of miles of wind which passed the station between 30 minutes before the hour and 30 minutes after the hour. The winds extracted from the microfilmed hourly weather reports of six stations in Newfoundland and Labrador are "hourly wind" speeds. The hourly wind consists of a one-minute average wind speed observed sometime during the ten minutes prior to the hour. Thus, if the actual maximum one-minute average does not occur in that ten minutes, it is not recorded. The fastest "hourly wind" values represent only samples of the wind conditions for each hour. The sample covers a period of from one to ten consecutive minutes just before the hour, depending upon the observer and the recording or indicating equipment used for the observation. Such a sample ignores the winds that occur during at least 5/6 of each hour and possibly as much as 59/60 of each hour. Thus, there is a consistent tendency for hourly wind values to understate the fastest wind occurrence during the hour. The degree of understatement is directly proportional to the variability of the wind speed.

Studies of the relationships between maximum wind speed values derived from different averaging times have resulted in a considerable range of conversion factors to be used. These relationships have been studied under the general category of wind gusts and gust factors.

1. Wind Gusts

Gusts are sudden brief increases in the speed of the wind resulting from eddies superimposed on the basic flow of air. Many studies of the relationship of gusts to the steady wind and their variation with speed, height, thermal stratification, and terrain have culminated in general agreement concerning the nature of these relationships (Davis and Newstein, 1968; Camp, 1968; Shellard, 1965; Mitsuta, 1962; Boyd, 1965; Brook and Spillane, 1970; Sissenwine et al., 1973; and others). However, quantitative results have varied, depending on the data and analytical methods used.

Most studies of gustiness are from micrometeorological research. Though measurements obtained from such experiments are generally superior to operational data because of refined anemometry, such studies hardly ever provide data for the very high wind speeds important in design of transmission towers and conductors. Sissenwine et al., 1973, analyzed a more meaningful spectrum of wind speeds and this work appears to be one of the better recent efforts in this field. Their study included the analysis of 548 wind observations taken at anemometer heights varying from 10 to 85 feet, with one-minute steady wind speeds varying from 20 to over 70 knots, and locations varying from tropical Pacific islands to Alaska and Greenland. Since recorder charts of steady winds greater than 70 knots were scarce (only 10 cases of the 548 studied), they also used 26 observations of gust factors for five-minute steady winds ranging from 71 to 163 knots taken at Mt. Washington, New Hampshire, and four values derived from wind data taken during hurricanes that passed close to the Blue Hill Observatory near Boston, Massachusetts. Actually, accurate data on short period gusts are quite rare. In weather station climatological records the steady state wind speed corresponding to maximum peak gusts is usually not available. The maximum hourly wind speed and maximum peak gust for the station frequently did not occur in the same storm and are related only in a qualitative sense.

2. Gust Factors

In discussion of gust relationships, a "gust factor" equal to G/V is commonly employed. In this expression G is the maximum gust speed and V is the maximum sustained wind speed. While there is general agreement that gust factors tend to decrease with increasing wind speed and height above the surface, past studies have resulted in a variety of gust factor relationships with as many different values as studies. There has been little apparent effort to standardize the type of wind speed used as the sustained wind or the duration of the gusts involved.

Sissenwine et al. found that a least-squares relationship (G. F. = $1 + 0.55\ e^{-0.0093V}$) best fit the median (50 percentile) two-second gusts related to five-minute steady speeds. Two-second gusts thus derived ranged from 1.46 times a five-minute steady speed of 25 knots to 1.22 times a five-minute steady speed of 100 knots. Table V-1 and Fig. V-1 show the relationship of other gust durations to five-minute steady speeds.

One of the most widely used relationships for computing gust speeds was derived by Boyd. His formula, $G = 5.8 + 1.29\ V$, gives gust speeds (G) in miles per hour based on hourly wind speeds (V) in miles per hour. At the time he derived this formula, the gust data used were thought to be of approximately three-second duration. Recently, Mr. Boyd stated that he now believes the response time of the pressure tube anemometer and its recorder, which his data were collected from, to be of the order of five to eight seconds.

Another often referenced authority, Durst (1960), developed a statistical model based on samples taken with a high speed recorder. Although his empirical data were taken at speeds less than 42 miles per hour, he applied his model to class intervals of speeds up to 80 mph. As Table V-2 shows, his probable gust factors for various duration gusts are nearly the same for all speed classes.

If the Durst relationships for hourly speeds to five-minute gusts (interpolated) are combined with the Sissenwine et al. relation of five-minute to two-second speeds, the resulting gust factors for two-second gusts from hourly winds vary from 1.6 at 20 mph to 1.4 at 80 mph. This is nearly exactly what the Boyd formula of $G = 5.8 + 1.29\ V$ results in for five-second gusts.

In 1964, the Bonneville Power Administration published gust factors for 52 stations in their area of operation (Bonneville Power Administration, 1964). These gust factors comparing maximum gusts to one-minute wind speeds ranged from 1.23 to 1.67 with a mean of 1.35. They detected no variation of gust factor with wind speed in the data used in their study.

Gust factors tend to decrease with height above the terrain. This decrease with height is generally accepted as theoretically reasonable in a qualitative sense; however, there is limited experimental data to develop firm quantitative values from. It is apparent that, since this variation with height is a function of eddy size, it must also be related to terrain roughness, wind speed, and atmospheric stability. Wind near the earth's surface is very sensitive to the terrain; consequently, any particular location is likely to have its own gust characteristics. It is certainly well within the state of the art in anemometry to experimentally develop gust factor height dependence values applicable to a selection of typical topographic and

TABLE V-1

GUST FACTORS VERSUS 5-MINUTE STEADY WIND SPEED

5-Minute Speed (knots)	Gust Factor (GF)		
	60-sec	30-sec	2-sec
20	1.120	1.172	1.4566
30	1.105	1.151	1.4160
40	1.094	1.134	1.3791
50	1.085	1.121	1.3454
60	1.077	1.111	1.3147
80	1.066	1.095	1.2613
100	1.057	1.081	1.2170
125	1.049	1.069	1.1719
150	1.042	1.059	1.1363
175	1.035	1.050	1.1080
200	1.028	1.040	1.0856

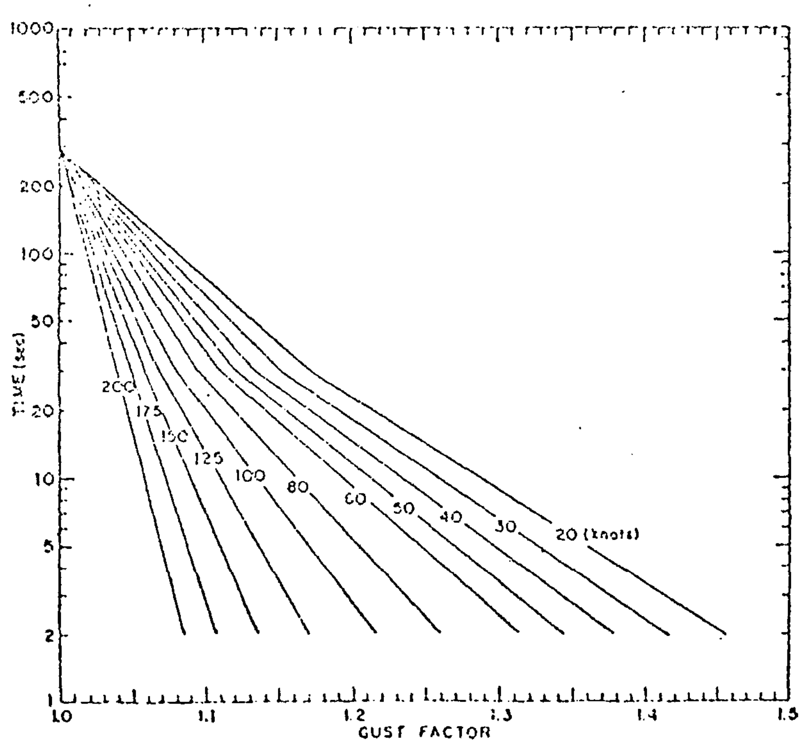

Fig. V-1. GUST FACTORS VERSUS 5-MINUTE STEADY WIND SPEED

TABLE V-2

PROBABLE (50 PERCENT) GUST FACTORS FOR 20- TO 80-MPH AVERAGE HOURLY SPEEDS USING DURST'S MODEL

Mean Hourly Speed (mph)	Gust Factor (GF)					
	600 sec	60 sec	30 sec	20 sec	10 sec	5 sec
20	1.05	1.25	1.30	1.35	1.40	1.50
30	1.07	1.23	1.33	1.37	1.43	1.47
40	1.07	1.25	1.32	1.35	1.42	1.48
50	1.06	1.24	1.32	1.36	1.42	1.48
60	1.07	1.24	1.32	1.35	1.42	1.48
70	1.06	1.24	1.31	1.36	1.41	1.49
80	1.06	1.24	1.33	1.36	1.43	1.48

geographic locales; however, this has not been pursued on any organized basis.

It is apparent from the above discussion of the currently most frequently referenced sources that there are no hard and fast relationships to use in relating speeds of different averaging times. Observations at high wind speeds in the range to be expected to occur in Newfoundland were included in the derivation of the relationship developed by Sissenwine, et al. For this reason, Sissenwine's least squares relationship is used in the estimation of peak gusts in this study. This formula may tend to underestimate gusts at lower one-minute speeds, but it appears to be more realistic for the higher wind speeds. In order to be consistent, the same formula was used throughout.

3. Results From 1974-1975 Measurement Program

Table V-3 lists the maximum hourly wind speeds and the peak gusts reported at the six weather stations this winter.* The peak gust is the

* Daniel's Harbour did not record gusts.

TABLE V-3

MAXIMUM STATION WINDS REPORTED DURING WINTER OF 1975-1975

(Wind Speeds in Miles Per Hour)

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
St. John's								
Max. Hourly*	WSW 35	SSW 40	NNE 45	SE 50	W 45	WSW 52	NNW 46	N 63
Peak Gust	S 55	WSW 56	NE 65	S 71	NNW 61	WSW 72	S 70	N 91
G.F.	1.57	1.40	1.44	1.42	1.35	1.38	1.52	1.44
Gander								
Max. Hourly	S 45	SSW 32	E 28	SSW 41	W 28	W 35	NNW 30	N 40
Peak Gust	SSW 80	SSW 49	E 44	SSW 69	NNW 45	W 58	S 43	N 58
	1.78	1.53	1.57	1.68	1.61	1.66	1.43	1.45
Deer Lake								
Max. Hourly	SSW 35	SW 20	ENE 25	NNE 25	W 25	SW 23	ENE 23	NW 21
Peak Gust	SSW 80	WSW 35	ENE 45	NNE 45	W 35	SW 37	ENE 40	WNW 32
	2.29	1.75	1.80	1.80	1.40	1.61	1.74	1.52
Daniel's Harbour								
Max. Hourly	SW 64	ESE 42	WSW 36	WSW 45	WSW 36	ENE 36	ENE 41	SSW 32
Battle Harbour								
Max. Hourly	SW 35	SW 40	N 50	N 45	SSE 25	NNW 40	S 35	NNW 46
Peak Gust	SW 50	ENE 57	N 53	N 68	SSE 40	NNW 48	S 46	NNW 56
	1.42	1.43	1.06	1.51	1.60	1.20	1.31	1.22
Goose Bay								
Max. Hourly	WSW 27	ENE 58	NNE 26	W 40	SW 30	W 37	SW 35	NW 23
Peak Gust	WSW 45	ENE 70	NNE 40	W 52	SW 40	W 53	SW 55	NW 29
	1.67	1.21	1.54	1.30	1.33	1.43	1.57	1.26
Hawke Bay**								
Max. Hourly	--	NW 32	ESE 28	N 39	W 29	W 30	SW 26	--
Peak Gust	--	E 61	E 50	N 62	WSW 46	W 46	E 48	--
		1.90	1.79	1.59	1.59	1.53	1.85	

* Maximum Hourly Wind Speeds are one-minute averages
** Period of Record November through April

highest "instantaneous" wind speed recorded at a station during a specified period. Depending on the response time of the anemometer and recorder used, this value may represent anything from a two-second to an eight-second gust, or, if the wind is not gusting, simply the highest wind speed recorded. It should be noted that the maximum hourly winds and peak gusts are not necessarily associated. They frequently occur on different days.

Winds were generally lighter than normal at reporting weather stations in Newfoundland and Labrador during the winter and spring of 1974-1975. In November, an hourly wind speed of 58 mph was recorded at Goose Bay surpassing the previous all-time record by 6 mph. May was an exceptionally windy windy month over much of the province. St. John's recorded a peak gust of 91 mph, the highest ever recorded in May, but well below the all-time record of 120 mph. The average wind speed for the month was also a record 18.8 mph. At Gander, total wind mileage was above normal in May.

In contrast, February was relatively calm, with no wind storms during the month. For the remaining winter and spring months, the average wind speed was near or slightly below normal.

The maximum hourly average wind speeds recorded at each of the observation sites during this past winter are listed in Table V-4. The values in parentheses are the estimated maximum one-minute averages computed at 1.25 times the maximum hourly average and estimated peak gusts (two-second average) computed using the relationship of Sissenwine et al. Table V-5 breaks down the wind data into speed categories, both by number of hours and percentage of recovered data. By far, the highest wind speeds were recorded at Site 2. Over 15 percent of the wind data recovered at that site showed speeds in excess of 40 mph; over 8 percent of the data indicated average hourly wind speeds exceeding 50 mph. The highest speed recorded was from the east at 101 mph, on March 3. It is likely that this figure was equalled or exceeded during storms that resulted in damage to the MWS or that occurred when both stations were iced up. On December 18 the cups on both stations were blown off at wind speeds in excess of 80 mph from the east. One storm of note occurred between April 26-28 when one of the stations at Site 2 recorded 38 consecutive hours of winds above 50 mph and 14 consecutive hours of winds in excess of 80 mph. This highest wind speed recorded during this period was 93 mph. Once again, the prevailing direction of these winds was from the east. Although the site is well exposed in all directions, less than 10 percent of the winds in excess of 50 mph were from directions other than northeast through southeast. This would seem to indicate that the extreme winds at Site 2 are prevalent when the low pressure systems move to the south of Newfoundland.

TABLE V-4

MAXIMUM SITE WINDS RECORDED
WINTER OF 1974-1975
(Wind Speeds in Miles Per Hour)

	Nov.†	Dec.	Jan.	Feb.	Mar.	Apr.	May†
Site 1							
Max. Hourly Avg.	29*	33*	44	45	40	45	46
Est. 1-Min. Avg.	(36)	(41)	(55)	(56)	(50)	(56)	(58)
Est. Peak Gust	(46)	(52)	(68)	(70)	(63)	(70)	(72)
Site 2							
Max. Hourly Avg.	37*	95*	89*	50*	101	93*	75
Est. 1-Min. Avg.	(46)	(119)	(111)	(63)	(126)	(116)	(94)
Est. Peak Gust	(58)	(136)	(129)	(77)	(144)	(134)	(112)
Site 3							
Max. Hourly Avg.	54*	50*	55	57	49*	60	47
Est. Max. 1-Min. Avg.	(68)	(63)	(69)	(71)	(61)	(75)	(59)
Est. Peak Gust	(83)	(77)	(85)	(87)	(75)	(91)	(73)
Site 4							
Max. Hourly Avg.	54	60	58	50	57	54	70
Est. Max. 1-Min. Avg.	(68)	(75)	(73)	(63)	(71)	(68)	(88)
Est. Peak Gust	(83)	(91)	(89)	(77)	(87)	(83)	(106)

† Period of record began mid-November, ended mid-May
* Partial month of data due to equipment problems.

TABLE V-5

Number of Hours

Avg. Hourly Wind Speed (mph)	Site: 1	2	3	4
40-49.5	19	171	227	268
50-59.5		97	30	85
60.69.5		59	1	7
70-79.5		21		1
80-89.5		17		
90-99.5		7		
≥ 100		1		
Total	19	373	258	361

Percentage of Recovered Data

	Site: 1	2	3	4
40-49.5	0.47	6.93	5.13	6.08
50-59.5		3.93	0.68	1.93
60-69.5		2.39	0.02	0.16
70-79.5		0.85		0.02
80-89.5		0.69		
90-99.5		0.28		
≥ 100		0.04		
Total	0.47	15.11	5.83	8.19

On the mainland at Site 4, wind speeds exceed 40 mph over 8 percent of the period; however, speeds in excess of 50 mph occurred on only 85 hours, or little more than 2 percent of the period of record. The highest wind speed recorded was from the northwest at 70 mph on May 17. One storm of note occurred between December 3-5. Wind speeds exceeded 35 mph for 39 consecutive hours and 50 mph for 25 consecutive hours. The wind direction was north-northeast, changing to north later in the storm. Unlike Site 2, the extreme winds at Site 4 showed no obvious preference for any direction, although a majority of the strong winds were from the northwest through northeast. However, there were indications that the wind vane on one or both of the stations may have been shaken loose on one or more occasions and lost its orientation. Thus, more of a pattern to the direction of the extreme winds may have existed without being apparent.

The stations at Site 3 recorded winds in excess of 50 mph less than one percent of the time. A maximum wind speed of 60 mph from the northeast occurred on April 1. However, most of the strongest winds were from the southwesterly quadrant, indicative of low pressure systems passing to the north of the region.

Site 1 at Sheffield Lake did not record any winds above 50 mph, and very few of the wind speeds exceeded 40 mph. There did not appear to be any prevalent wind direction associated with the stronger wind speeds.

It was evident from a comparison of all four sites that the strongest winds at each location were not generally the result of the same storm systems. As noted earlier, the strong easterly winds at Site 2 were apparently due to storm systems passing to the south of the region, but at Site 3 the strong southwesterly winds resulted from the storm centers passing to the north. On only two occasions was one storm responsible for very high winds at more than one site. On January 19 southerly winds approaching 90 mph struck Site 2, while at Site 4 south-to-southwesterly winds reached 58 mph. The winds at Site 1 did not exceed 37 mph, and at Site 3 they peaked at only 31 mph. During the storm of April 26-28 described earlier for Site 2, northeasterly winds at Site 4 peaked at 53 mph, while at Site 3 the highest hourly wind speed recorded was 42 mph. The winds at Site 1 did not exceed 30 mph. However, during several severe storms at Site 2 the anemometer cups at one or more of the other sites were partially or completely frozen, and thus, were not recording the true wind speed.

A total of 30 wind storms were analyzed and the strongest winds recorded during each storm at the four sites were correlated with corresponding winds at the most representative reporting station in the area. The stronger winds at Site 1 were approximately 50 percent higher than the corresponding winds at Gander. The magnitude of the strong winds at Site 4 were, on the average, twice that of Battle Harbour, although the actual ratios of Site 4 winds to Battle Harbour winds ranged from 1.00 to 2.86. For winds above

40 mph at Battle Harbour, the range of ratios fell to between 1.00 and 1.91.

There was little correlation found between Site 2 and any of the six stations. The station nearest Site 2, Daniel's Harbour, is very sheltered from easterly winds by the ridge upon which Site 2 is located. At times, the winds at Site 2 were almost four times stronger than the winds at Battle Harbour, a station well-exposed to all directions, as was Site 2.

On March 3, the maximum wind speed recorded at Battle Harbour was 30 mph, while at Site 2 a one-minute average speed of 120 mph likely occurred during the hour when the average wind speed was 101 mph. On other occasions, Site 2 winds were less than twice the magnitude of the winds at Battle Harbour, but, on the average, the maximum wind speeds at Site 2 were approximately three times those at Battle Harbour. Unfortunately, during those days when the strongest winds were recorded at Battle Harbour, the anemometers at Site 2 were either frozen or otherwise not functioning. At these extreme wind speeds, the correlation between the two locations would probably be easier to ascertain.

Although Daniel's Harbour is sheltered from the east, strong winds from the east-northeast or east-southeast are occasionally recorded. At the same time, the winds at Site 2 are very strong. Generally, when Daniel's Harbour recorded winds from the easterly quadrant at speeds greater than about 30 mph, the average hourly wind speed at Site 2 exceeded 65 mph and has approached 100 mph this past season. This would indicate an estimated one-minute wind speed of 80 mph and above.

4. Height Factors

The wind speeds obtained from the MWS's have not been extrapolated from the measurement level of 30 feet up to an approximate conductor level of 80 to 100 feet above the ground. Wind speed generally increases with height above the surface of the earth. The rate of increase is dependent on the speed of the wind, the variation with height of the air temperature, and the roughness of the terrain over which the wind is flowing.

There have been many studies undertaken and theories presented on the variations of wind speed with height above the surface. There is general agreement that wind profiles tend to obey a power law (De Marris, 1959; Johnson, 1959; and Munn; 1966). This relationship is normally used when neutral stability exists. The power law is of the form $V_2/V_1 = (Z_2/Z_1)^P$ where V_1 is the wind speed at some known level, Z_1, and V_2 is the wind speed at the desired level, Z_2. The exponent, P, is dependent on the atmospheric temperature lapse rate, wind speed and ground roughness. There is less agreement as to what the value of P should be. It is larger under a stable vertical temperature gradient and smaller for neutral and unstable conditions; it decreases with increasing wind speeds and increases with terrain roughness (De Marris, 1959; Davenport, 1968). The typical value used for P is 1/7 or 0.143 (Sherlock, 1952). However, Sherlock recognized that this P value was applicable to steady or mean winds and that guests were better described with a value of P = 0.0625. Shellard (1963), in the Tables of Surface Wind Speed and Direction Over the United Kingdom, used P values of 0.17 for mean hourly wind speeds and 0.085 for three-second gusts.

The majority of studies of wind profiles are made under regimes of light to moderate wind speeds and P values resulting from such studies may not be applicable to high wind speeds. Sissenwine et al. (1973), using high wind speed data collected at the Argonne National Laboratory instrumented tower in Argonne, Illinois, derived the empirical equation $P = 0.077 + 1.56/V_1$ where the limiting P value approaches 0.077 as V_1 becomes very large.

The Argonne National Summaries presents a percentage frequency of P values versus the ten-minute average wind speeds. The data for the table contains about 35,000 observations. For wind speeds greater than 24 mph the median P value is about 0.125. It now appears that a P value of 0.125 should be used for wind speeds up to approximately 50 mph, and 0.080 for wind speeds above that, and for all gust speeds. However, one must be cautious when extrapolating the wind speeds recorded at Site 2, and to a lesser extent Site 4, to the approximate conductor level. The depth of the air mass streaming over the exposed ridge at Site 2 is not known, and thus, the vertical wind profile is uncertain. If it is relatively shallow, the wind speed at 100 feet may even be less than that at 30 feet. Conversely, a deep layer may result in higher wind speeds at 100 feet than at 30 feet. It is likely that the layer of streaming air is at least 100 feet deep. Although the depth of the layer is not known, it is readily apparent that the wind speeds in the layer are much greater than in the free air at 2000 feet above sea level at some distance from the ridge.

B. Temperatures

Ambient air temperatures were recorded at the four sites and extracted from station data. Tables V-6 and V-7 show the minimum temperatures by month recorded at these locations. Temperatures at the station were generally near or slightly below normal during the entire winter, except for quite cold weather during the last two weeks of January and all of February. Both Gander and St. John's reported February to be the coldest month on record. On the fourth, Gander recorded -24°F, setting an all-time record by eight degrees. Goose Bay recorded -33°F in January and -31°F in February, only a few degrees off the records for each month. Battle Harbour also came close to setting new low standards.

TABLE V-6
MINIMUM STATION TEMPERATURES
RECORDED DURING WINTER OF 1974-1975
(Temperatures in Degrees Fahrenheit)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
St. John's	26	22	14	- 5	-10	9	14	26
Gander	23	18	2	-15	-24*	1	12	25
Deer Lake	17	15	-10	-22	-27	-20	- 5	22
Daniel's Harbour	25	20	- 2	-13	-14	- 2	9	24
Battle Harbour	19	9	- 2	-28	-24	- 6	12	21
Goose Bay	5	1	-15	-33	-31	-23	3	18

* New all-time low temperature

TABLE V-7
MINIMUM SITE TEMPERATURES
RECORDED DURING WINTER OF 1974-1975
(Temperatures in Degrees Fahrenheit)

	Nov	Dec	Jan	Feb	Mar	Apr	May
Site 1	**	8*	8*	- 7	0	13	16
Site 2	**	0*	-24	-25	- 7	7	17
Site 3	- 3	3*	-30*	-23	- 8*	12	14
Site 4	- 5	- 9	-25	-23	- 3	3	10

Period of record began mid-November, ended mid-May
** Missing data due to equipment problems
* Partial month of data due to equipment problems

Temperature measurement was difficult at times due to the temperature elements frequently being covered with ice and thus recording a constant temperature for days at a time. However, enough data was recovered to make several observations. Temperatures below 0°F were quite common at Sites 2, 3 and 4. During the cold wave in January and February, the temperature seldom rose above 0°F at Site 2.

Often these cold temperatures were accompanied by relatively strong winds. Some examples of this are shown below:

Site 1:	-3°F with 37 mph (46)*, -7°F with 28 mph (35)
Site 2:	+12°F with 101 mph (126), +8°F with 89 mph (111), -23°F with 52 mph (65), -24°F with 45 mph (56)
Site 3:	-12°F with 56 mph (70), -15°F with 53 mph (66)
Site 4:	-25°F with 47 mph (59)

* Values in parentheses are corresponding estimated one-minute averages.

No precise correlation was established between temperatures at the sites and any of the stations in Newfoundland and Labrador. However, some generalizations can be made. The temperatures at Sites 2 and 4 were usually 5° to 15°F lower than the corresponding temperature at Battle Harbour, except during extremely cold temperatures when there was little or no correlation.

C. Icing

In general, the number of hours of freezing precipitation was below normal at the six weather stations in Newfoundland and Labrador during the 1974-1975 measurement period. However, with the exception of Battle Harbour, the totals at each station were within one standard deviation of the mean. Table V-8 shows the number of hours of freezing rain and total freezing precipitation for the six stations from October, 1975, through May, 1975. The number of hours of freezing rain was near normal for most stations. The frequency of occurrence of freezing precipitation was near or above normal in November, but in December it was below normal at all stations except St. John's. January was well below normal at all stations except St. John's. Battle Harbour and Goose Bay reported no freezing precipitation during the entire month of January. This continued into February, a month characterized by clear, relatively calm, and extremely cold weather. All stations had less freezing precipitation than normal, with Battle Harbour and Goose Bay once again receiving none. No definite pattern existed during March. St. John's and Battle Harbour were well below normal, but Goose Bay was well above normal, and Gander was near normal. April was also quite variable. Gander recorded 47 hours of freezing precipitation, compared to an average of 21 hours. Almost half

TABLE V-8
HOURS OF FREEZING PRECIPITATION AT STATIONS
DURING WINTER OF 1974-1975
(Number of Hours of Freezing Rain in Parentheses)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	1974-75 Total	Avg.	Yrs. of Record
St. John's	0	1(0)	14(0)	39(12)	20(9)	19(7)	23(12)	6(0)	122(40)	153(46)	19
Gander	0	12(1)	11(0)	11(2)	19(10)	33(8)	47(22)	0	133(43)	158(31)	19
Deer Lake	1(1)	19(13)	6(1)	2(2)	3(3)	2(2)	0	0	33(22)	43(22)	6
Daniel's Harbour	2(2)	6(6)	0	2(2)	2(2)	6(4)	2(0)	0	20(16)	22(15)	6
Battle Harbour	0	0	0	0	0	4(1)	13(3)	3(3)	20(7)	49(17)	12
Goose Bay	3(2)	3(3)	2(2)	0	0	13(5)	13(0)	0	34(12)	35(15)	19

of the precipitation was freezing rain. Battle Harbour and Goose Bay were also above normal, but St. John's was slightly below normal. Only St. John's and Battle Harbour recorded freezing precipitation during May.

Significant amounts of ice were measured frequently at Sites 2 and 4. Site 1 did not record any substantial icing during the entire winter season. At Site 3, minor icing occurred on four occasions. On December 21, approximately 140 pounds of ice were recorded. Unfortunately, the MWS at Site 3 was iced up, and thus very low wind speeds were recorded. At Battle Harbour, northerly winds of 20 mph with peak gusts of 30 mph were blowing. The cloud bases were around 3000 feet, with only occasional light snow and snow flurries. This suggests that the ice was rime. Temperatures were too low to suggest wet snow to be the cause.

On the three other occasions, less than 100 pounds of ice were recorded. During the day preceding one of those icing periods, on March 24, wind speeds peaked at 35 mph; it is likely that the wind speeds were at least as high during the ice accumulation as the ice built up on the MWS's throughout the day.

At Site 2 there were 12 periods ranging in duration from 1 to 166 hours when ice accumulations exceeded six pounds per foot of cable. Maximum amounts occurred at the end of the longest icing period, between January 13-20, when 14.5 pounds per foot was recorded. On the average, about 540 pounds of ice remained on the cable during the entire period. The cloud bases at Daniel's Harbour were less than 2000 feet, and the temperature at Site 2 was generally less than 0°F; therefore, it is likely that most of the ice was in the form of rime.

Upon examination of the Ice Rate Meter Chart for the afternoon of January 19, is appears that the tower and IRM were vibrating and the rime ice was being blown off the cable by the winds whose peak gusts undoubtedly exceeded 100 mph. This would account for a gradual decrease of ice until early evening, when 150 pounds of ice remained on the line. This ice was probably a glaze coating that is not easily removed by wind and vibration. The ice then began to increase again, during which time the wind was vibrating the instrument, and another 570 pounds of ice, again likely to be rime, accumulated in only 14 hours. Late in the morning, this new ice dropped off the cable, again leaving the 150 pound glaze ice base. Assuming a density of $0.5 g/cm^3$ for the 570 pounds of rime and $0.9 g/cm^3$ for the glaze base, the 720 pounds of ice translates into 4.1 radial inches of ice. By this time the MWS's were gradually icing up; although the recorded wind speed was only 25 mph, the erratic IRM trace indicates that the winds were quite high. If the winds peaked at 50 mph during the period of maximum icing (not an unreasonable assumption), the transverse wind load would be almost five pounds per lineal foot (the diameter of the cable used was 1.338 inches).

Unfortunately, wind speeds during most periods of maximum ice loads were not recorded due to the inability of preventing ice build-up on the instrumentation. Maximum combined wind and ice loads may have occurred on December 18. The hourly average wind speed was 70 mph before the cups blew off; this is equivalent to a one-minute wind speed near 90 mph. The winds at Daniel's Harbour were from the east-northeast at speeds up to 34 mph, which could indicate that the average hourly wind speed at Site 2 approached 100 mph. The IRM recorded 460 pounds of ice during this time before malfunctioning. At a density of 0.5 g/cm^3, this weight is equivalent to 3.0 radial inches. At 70 mph, the average transverse wind load was 7.6 pounds per lineal foot. It is likely that wind gusts were much higher, and that more ice accumulated on the cable after the recorder failed.

The climate in the vicinity of Site 4 is more continental than that at Site 2. This results in colder, drier winters, and hence less icing during late December, January, and February, as reflected by the icing data at Site 4. Icing that occurs in the fall and spring is usually in the form of glaze ice that results from freezing rain. In mid-November 400 pounds of ice was recorded. The MWS's were not in operation at this time; however, Battle Harbour reported light rain and fog with winds gusting as high as 40 mph. Freezing rain could have been falling at Site 4, with 400 pounds of ice translating into two radial inches of glaze. Significant ice loadings were not recorded again until December 27, when 525 pounds accumulated on the cable. This ice was likely in the form of rime, because cold temperatures were prevalent over the entire area. January and February were very cold and virtually ice-free. Temperatures rarely exceeded 0°F. Finally, on February 25, the temperature rose into the teens and 650 pounds of mostly rime ice, equivalent to 3.8 radial inches, was recorded. Up to three radial inches remained on the cable when the site was serviced on February 28. Ice remained on the cable in varying amounts through March. On March 14-15, approximately 340 pounds, or three radial inches, of rime combined with a wind speed of 56 mph to produce an average transverse wind load of 4.8 pounds per foot. Higher wind gusts undoubtedly resulted in higher transverse loads. Ice recorded on March 25 appears to be glaze. Temperatures in the mid-20's were too cold for wet snow to occur. Freezing rain and drizzle was reported at several Newfoundland stations, including Goose, and this was likely responsible to the 490 pounds of ice which was equivalent to slightly over two radial inches of glaze. Icing was frequent throughout April and May, reaching a peak on May 7, when 650 pounds of ice was recorded. The synoptic situation on this day suggested that freezing rain was falling in the area. Battle Harbour reported light rain, light snow, and ice pellets, with temperatures near freezing during this period. At Site 4, average hourly winds accompanying the precipitation were as high as 45 mph. However, one of the two MWS's at the site was completely frozen, suggesting that the other station may have been partially iced up. Thus, it is possible that wind speeds could have been even higher.

The winds at Site 4 tend to be very steady at high speeds. It has been observed that this steadiness can result in a resonant frequency being set up in the guys, cable, and towers. This violent shaking may have been responsible for a shifting in the base line of the IRM recorder. It is uncertain as to what effect this had on the magnitude of the tension recorded by the IRM.

VI. REFINED LOADING ESTIMATES

Not all loading estimates were changed as a result of the 1974-1975 measurement program. Also, several estimates have been revised because of changes in the proposed route since the previous reports.

A. Changes in Route Segments

Segments 1, 2, 3, and 8 remain essentially unchanged. Segment 4, the higher elevations west of Gander Lake, is no longer necessary since the latest version of the proposed route crosses lower terrain to the south. Segments 5 through 7, the portion of the route running from Grand Falls to Buchans and up through the Humber Valley, have been eliminated and are replaced by Segment 20, previously an alternate route. Segment 9 now runs from the top of the ridge of the Long Range Mountains to the west coastal plain east-southeast of Portland Creek. Segment 10 still runs along the west coastal plain, but it now extends from east of Portland Creek north to 51°N. The elevation is generally less than 500 feet. A new segment, 10a, covers the portion of the route east of the high lands of St. John, where the elevation ranges from 500 to 1700 feet. Segments 11 and 12 remained virtually unchanged. Segment 13, defined as that portion of Segment 12 with elevations between 500 and 1500 feet, has been shifted slightly west of the original route, resulting in slightly lower elevations with less exposure to the east. The remaining portions of the proposed route are still described by Segments 14 through 17, 20, and 23. The alternate routes to Goose Bay (Segments 18 and 19) and to Stephenville (Segments 21 and 22) are no longer being considered in this report.

B. Refined Loading Estimates by Route Segment

1. Icing

The results of the 1974-1975 measurement program have not indicated that a change in the icing estimates from the previous reports is necessary. With the exception of Site 2, no unusual ice loads were recorded or observed during a winter when icing appeared to be below normal at most Newfoundland stations. Site 2 did record severe ice buildups during the past winter, but this was to be expected, and the estimates presented in the November, 1973, report reflect this expectation. However, the proposed route has been shifted from its previous location near Site 2 to an area further east. The elevation is generally lower, which affords some sheltering from the east. This should result in less icing, although there are several points along the new route that are well exposed to easterly winds, which would be nearly perpendicular to the proposed route. It is difficult to estimate the impact of this channelling effect on the icing amounts in an area where slight changes in elevation or exposure can result in large wind and icing differences. Two areas in question are the high elevations on the west end of Inner Pond and a point on the route almost directly east of Site 2. It is likely that the icing in these areas is similar to that at Site 2, and thus the November, 1973, estimates for Segment 9 are still valid. The remaining portion of the route segment crossing the ridge should have perhaps ten percent less ice for each of the return periods.

2. Winds

The maximum gusts for all segments have been recalculated using the relationship of Sissenwine et al. (1973) as was discussed in Section V. A. 1. This will result in slightly lower gust factors than were used in the November, 1973 report. The sustained winds from which these estimated gusts were calculated are one-minute average wind speeds. The wind speeds listed under the combined wind and ice loads were derived using only the winds associated with icing. The method was described in detail in the September, 1974, report. These winds will generally be associated with rime icing.

The one-minute average winds assigned to Segments 1 through 3, 8, 11, and 20, should remain unchanged from those appearing in the earlier reports. The return period winds for Segment 13, the higher elevations north of the Strait of Belle Isle, were increased due to information gained from Site 4. Although the highest hourly average wind speed recorded during the past winter at the site was "only" 70 mph, eight percent of the winds were above 40 mph. This suggests a more gradual slope to the return period plot than was used in the November, 1973, report. Thus, while the 50-year return period wind speed for Segment 13 was increased by less than ten percent, the ten-year wind speed was increased by 20 percent. The winds for Segments 14 through 17 and 23 were increased only slightly, also based on the winds recorded at Site 4.

The peak winds recorded at Site 2 during the past winter were much stronger than was previously expected. It is obvious from these results that hourly average wind speeds in excess of 90 mph (or one-minute wind speeds in excess of 110 mph) occur there almost every year. The slope of the return period plot should be small, like that of Segment 13. With these facts in mind, the ten-year return period value for Segment 9 was increased by almost 60 percent to 126 mph, while the 50-year value of 140 mph is over 40 percent higher than the 98 mph given in the earlier report. The prevailing direction has been changed to easterly from the north-northwest given previously. Virtually all of the strongest winds recorded at Site 2 were from the eastern quadrant.

Tables VI-1 through VI-4 give the 10-, 25-, 50-, and 75-year return period values for wind, ice, and combined wind and ice for the 16 remaining segments of the Gull Island Transmission Line System. Wherever possible, the segment numbers from the November, 1973, report were retained in this report. They are listed in order running from Holyrood in the east to Gull Island in the west.

TABLE VI-1: 10-YEAR RETURN PERIOD VALUES

Seg. No.		Maximum Wind: Wind Dir.	Maximum Wind: Wind Speed (mph)	Maximum Wind: Max. Gusts (mph)	Maximum Ice Loads: Glaze Rad. in	lb/ft	Maximum Ice Loads: Rime Rad. in	lb/ft (0.9)	Maximum Ice Loads: Wet Snow Rad. in	lb/ft (0.5)	Combined Wind and Ice Loads: Wind Speed (mph)	Glaze Rad. in	lb/ft (0.9)	Rime Rad. in	lb/ft (0.5)
1	Holyrood to Whithouse (< 500 ft)	W	75	91	2.9	17.4	3.8	15.0	0.8	1.5	40	2.2	11.3	2.4	7.2
2	Whitbourne to 10 miles west of Clarenville (< 500 ft)	W	80	97	3.5	23.6	4.3	13.4	0.8	1.5	43	2.8	16.5	2.8	9.1
3	10 miles west of Clarenville to Grand Falls (≤ 800 ft)	WSW	70	86	2.4	12.9	3.1	10.8	1.2	2.6	36	1.7	7.7	1.7	4.3
20	Grand Falls to north end of Humber Valley	NNE	80	97	2.7	15.5	3.5	13.1	1.7	4.3	43	2.0	9.8	2.1	5.9
8	North end of Humber Valley to top of ridge of Long Range Mountains on north side of Main River ~ 49°50'N (300 ft to 1200 ft)	NNW	62	77	2.2	11.3	1.7	4.3	1.4	3.2	36	1.4	5.8	1.0	2.0
9	Crossing Long Range Mountains (1200 ft to 1800 ft)	E	126	143	3.5	23.6	7.3	46.2	1.7	4.3	67	2.8	16.5	5.8	30.8
10	Along west Coastal Plain (≤ 500 ft)	SW	68	83	2.7	15.5	2.1	5.9	0.9	1.8	36	2.0	9.8	1.3	2.9
10a	East side of High Lands of St. John (500-1700 ft)	SW	80	97	2.7	15.5	4.3	13.4	1.7	4.3	44	2.0	9.8	2.3	9.1
11	51°N to Strait of Belle Island (≤ 500 ft)	NNE	75	91	2.9	17.4	3.8	15.0	2.2	6.3	40	2.2	11.3	2.4	7.2

TABLE VI-1: 10-YEAR RETURN PERIOD VALUES (Continued)

Seg. No.		Maximum Winds: Wind Dir.	Maximum Winds: Wind Speed (mph)	Maximum Winds: Max. Gusts (mph)	Maximum Ice Loads: Glaze Rad. in	Maximum Ice Loads: Glaze lb/ft	Maximum Ice Loads: Rime Rad. in	Maximum Ice Loads: Rime lb/ft (0.9)	Maximum Ice Loads: Wet Snow Rad. in	Maximum Ice Loads: Wet Snow lb/ft (0.5)	Combined Wind and Ice Loads: Wind Speed (mph)	Combined: Glaze Rad. in	Combined: Glaze lb/ft (0.9)	Combined: Rime Rad. in	Combined: Rime lb/ft (0.5)
12	Strait of Belle Isle to 30 miles inland from coast near corner of Quebec (≤ 500 ft)	NNW	75	91	2.7	15.5	2.1	5.9	2.2	[illegible]	40	2.0	9.8	1.3	2.9
13	Same area (500-1500 ft)	NNW	90	108	2.9	17.4	4.8	22.2	3.1	10.8	44	2.2	11.3	3.4	12.5
14	30 miles inland to 58°40'W (1000 to 1400 ft)	NNW	62	77	1.3	5.3	1.7	4.3	1.4	3.2	36	0.6	1.9	1.0	2.0
15	58°40'W to 60°05'W (≥ 1500 ft)	NNW	62	77	1.5	6.4	3.1	10.8	1.7	4.3	36	0.8	2.7	1.7	4.3
16	60°05'W to 60°30'W (≤ 1300 ft and protected from north)	W	53	66	0.6	1.9	1.1	2.3	1.2	2.6	32	0.5	1.5	0.7	1.3
17	60°30'W to Gull Lake Valley (> 1400 ft)	NW	68	83	1.3	5.2	3.1	10.8	1.4	3.2	36	0.6	1.9	1.7	4.3
23	Gull Lake to Churchill Falls (500-1600 ft)	NNW	68	83	0.6	1.5	2.1	5.1	0.8	1.3	36	0.5	1.2	1.3	2.5

TABLE VI-2: 25-YEAR RETURN PERIOD VALUES

Seg. No.		Maximum Winds			Maximum Ice Loads						Combined Wind and Ice Loads				
					Glaze		Rime		Wet Snow			Glaze		Rime	
		Wind Dir.	Wind Speed (mph)	Max. Gusts (mph)	Rad. in	lb/ft	Rad. in	lb/ft (0.9)	Rad. in	lb/ft (0.5)	Wind Speed (mph)	Rad. in	lb/ft (0.9)	Rad. in	lb/ft (0.5)
1	Holyrood to Whitbourne (< 500 ft)	W	85	102	3.4	22.5	5.0	23.8	1.0	2.0	44	2.5	13.8	3.0	10.2
2	Whitbourne to 10 miles west of Clarenville (< 500 ft)	W	90	108	4.0	29.4	5.5	28.1	1.0	2.0	47	3.1	19.4	3.5	13.1
3	10 miles west of Clarenville to Grand Falls (≤ 800 ft)	WSW	80	97	2.9	17.4	4.0	16.3	1.5	3.6	40	2.1	10.5	2.0	5.4
20	Grand Falls to north end of Humber Valley	NNE	90	108	3.2	20.4	4.4	19.2	2.0	5.4	47	2.3	12.1	2.4	7.2
8	North end of Humber Valley to top of ridge of Long Range Mountains on north side of Main River ~ 49°50'N (300 ft to 1200 ft)	NNW	70	86	2.5	13.8	2.0	5.4	1.8	4.7	40	1.5	6.4	1.1	2.3
9	Crossing Long Range Mountains (1200 ft to 1800 ft)	E	134	161	4.0	29.4	8.5	60.8	2.0	5.4	78	3.1	19.4	6.4	36.6
10	Along west Coastal Plain (≤ 500 ft)	SW	75	92	3.2	20.4	2.8	9.1	1.3	2.9	40	2.3	12.1	1.5	3.6
10a	East side of High Lands of St. John (500-1700 ft)	SW	90	108	3.2	20.4	5.5	28.1	2.0	5.4	48	2.3	12.1	3.5	13.1
11	51°N to Strait of Belle Isle (≤ 500 ft)	NNE	85	102	3.4	22.5	5.0	23.8	2.5	7.7	44	2.5	13.8	3.0	10.2

TABLE VI-2: 25-YEAR RETURN PERIOD VALUES (Continued)

Seg. No.		Maximum Winds			Maximum Ice Loads						Combined Wind and Ice Loads				
		Wind Dir.	Wind Speed (mph)	Max. Gusts (mph)	Glaze Rad. in	Glaze lb/ft	Rime Rad. in	Rime lb/ft (0.9)	Wet Snow Rad. in	Wet Snow lb/ft (0.5)	Wind Speed (mph)	Glaze Rad. in	Glaze lb/ft (0.9)	Rime Rad. in	Rime lb/ft (0.5)
12	Strait of Belle Isle to 30 miles inland from coast near corner of Quebec (< 500 ft)	NNW	65	102	3.2	20.4	2.8	9.1	2.5	7.7	44	2.3	12.1	1.5	3.6
13	Same area (500-1500 ft)	NNW	96	114	3.4	22.5	6.0	32.7	3.5	13.1	48	2.5	13.8	4.0	16.3
14	30 miles inland to 58°40'W (1000 ft to 1400 ft)	NNW	70	86	1.7	7.7	2.0	5.4	1.8	4.7	40	0.7	2.3	1.1	2.3
15	58°40'W to 60°05'W (≥ 1500 ft)	NNW	70	86	1.9	9.1	3.8	15.0	2.0	5.4	40	0.9	3.2	1.8	4.7
16	60°05'W to 60°30'W (≤ 1300 ft and protected from north)	W	60	74	1.0	3.7	1.4	3.2	1.5	3.6	36	0.5	1.5	0.8	1.5
17	60°30'W to Gull Lake Valley (≥ 1400 ft)	NW	75	91	1.7	7.7	4.0	16.3	1.8	4.7	40	0.7	2.3	2.0	5.4
23	Gull Lake to Churchill Falls (500-1600 ft)	NNW	75	91	1.0	3.1	2.8	8.2	1.0	1.7	40	0.5	1.2	1.5	3.1

TABLE VI-3: 50-YEAR RETURN PERIOD VALUES

Seg. No.		Maximum Winds			Maximum Ice Loads						Combined Wind and Ice Loads				
					Glaze		Rime		Wet Snow			Glaze		Rime	
		Wind Dir.	Wind Speed (mph)	Max. Gusts (mph)	Rad. in	lb/ft	Rad. in	lb/ft (0.9)	Rad. in	lb/ft (0.5)	Wind Speed (mph)	Rad. in	lb/ft (0.[illegible])	Rad. in	lb/ft (0.5)
1	Holyrood to Whitbourne (< 500 ft)	W	93	110	3.8	27.0	5.7	29.9	1.2	2.6	48	2.8	16.5	3.4	12.5
2	Whitbourne to 10 miles west of Clarenville (< 500 ft)	W	98	116	4.4	34.5	6.2	34.6	1.2	2.6	51	3.4	22.5	3.9	15.7
3	10 miles west of Clarenville to Grand Falls (≤ 800 ft)	WSW	88	106	3.3	21.4	4.7	21.4	1.8	4.7	44	2.3	12.1	2.4	7.2
20	Grand Falls to north end of Humber Valley	NNE	98	116	3.6	24.7	5.1	24.6	2.3	6.7	51	2.6	14.7	2.8	9.1
8	North end of Humber Valley to top of ridge of Long Range Mountains on north side of Main River ~ 49°50'N (300 ft to 1200 ft)	NNW	76	92	3.1	19.4	2.2	6.3	2.0	5.4	44	2.0	9.8	1.2	2.6
9	Crossing Long Range Mountains (1200 ft to 1800 ft)	E	140	157	4.4	34.5	9.5	74.4	2.3	6.7	87	3.4	22.5	6.8	40.7
10	Along west Coastal Plain (≤ 500 ft)	SW	80	97	3.6	24.7	3.2	11.3	1.5	3.6	44	2.6	14.7	1.8	4.7
10a	East side of High Lands of St. John (500-1700 ft)	SW	93	116	3.6	24.7	6.2	34.6	2.3	6.7	51	2.6	14.7	3.9	15.7
11	51°N to Strait of Belle Isle (≤ 500 ft)	NNE	93	110	3.8	27.0	5.7	29.9	2.7	8.6	48	2.8	16.5	3.4	12.5

TABLE VI-3: 50-YEAR RETURN PERIOD VALUES (Continued)

Seg. No.		Maximum Winds			Maximum Ice Loads						Combined Wind and Ice Loads				
		Wind Dir.	Wind Speed (mph)	Max. Gusts (mph)	Glaze		Rime		Wet Snow		Wind Speed (mph)	Glaze		Rime	
					Rad.	In lb/ft	Rad.	In lb/ft (0.9)	Rad.	In lb/ft (0.5)		Rad.	In lb/ft (0.9)	Rad.	In lb/ft (0.5)
12	Strait of Belle Isle to 30 miles inland from coast near corner of Quebec (< 500 ft)	NNW	93	110	3.6	24.7	3.2	11.3	2.7	8.6	48	2.6	14.7	1.8	4.7
13	Same area (500-1500 ft)	NNW	100	118	3.8	27.0	6.7	39.7	3.8	15.0	51	2.8	16.5	4.4	19.2
14	30 miles inland to 58°40'W (1000 ft to 1400 ft)	NNW	76	92	2.1	10.5	2.2	6.3	2.0	5.4	44	1.0	3.7	1.2	2.6
15	58°40'W to 60°05'W (≥ 1500 ft)	NNW	76	92	2.3	12.1	4.3	18.4	2.3	6.7	44	1.2	4.7	2.0	5.4
16	60°05'W to 60°30'W (< 1300 ft and protected from north)	W	65	80	1.4	5.8	1.6	3.9	1.8	4.7	40	0.5	1.5	1.0	2.0
17	60°30'W to Gull Lake Valley (> 1400 ft)	NW	80	97	[illegible]	10.5	4.7	21.4	2.0	5.4	44	1.0	3.7	2.4	7.2
23	Gull Lake to Churchill Falls (500-1600 ft)	NNW	80	97	1.4	5.0	3.2	10.2	1.2	2.2	44	0.5	1.2	1.3	4.0

TABLE VI-4: 75-YEAR RETURN PERIOD VALUES

Seg. No.		Maximum Winds			Maximum Ice Loads						Combined Wind and Ice Loads				
					Glaze		Rime		Wet Snow			Glaze		Rime	
		Wind Dir.	Wind Speed (mph)	Max. Gusts (mph)	Rad. in lb/ft		Rad. in lb/ft (0.9)		Rad. in lb/ft (0.5)		Wind Speed (mph)	Rad. in lb/ft (0.9)		Rad. in lb/ft (0.5)	
1	Holyrood to Whitbourne (< 500 ft)	W	97	115	3.9	28.2	6.3	35.6	1.3	2.9	50	2.9	17.4	3.7	14.4
2	Whitbourne to 10 miles west of Clarenville (< 500 ft)	W	102	120	4.5	35.8	6.8	40.7	1.3	2.9	53	3.4	22.5	4.3	18.4
3	10 miles west of Clarenville to Grand Falls (≤ 800 ft)	WSW	92	109	3.4	22.5	5.1	24.6	2.0	5.4	46	2.4	11.3	2.6	8.1
20	Grand Falls to north end of Humber Valley	NNE	102	120	3.7	25.8	5.5	28.1	2.4	7.2	53	2.7	15.5	2.9	9.7
8	North end of Humber Valley to top of ridge of Long Range Mountains on north side of Main River ~ 49°50'N (900 ft to 1200 ft)	NNW	30	97	3.2	20.4	2.4	7.2	2.2	6.3	46	2.1	10.5	1.4	3.2
9	Crossing Long Range Mountains (1200 ft to 1800 ft)	E	143	160	4.5	35.8	10.0	81.7	2.4	7.2	92	3.4	22.5	7.5	48.5
10	Along west Coast Plain (≤ 500 ft)	SW	83	100	3.7	25.8	3.5	13.1	1.7	4.3	46	2.7	15.5	2.0	5.4
10a	East side of High Lands of St. John (500-1700 ft)	SW	102	120	3.7	25.8	6.8	40.7	2.4	7.2	53	2.7	15.5	4.3	18.4
11	51°N to Strait of Belle Isle (≤ 500 ft)	NNE	97	115	3.9	28.2	6.3	35.6	2.9	9.7	50	2.9	17.4	3.7	14.4

TABLE VI-4: 75-YEAR RETURN PERIOD VALUES (Continued)

Seg. No.		Maximum Winds			Maximum Ice Loads						Combined Wind and Ice Loads				
					Glaze		Rime		Wet Snow			Glaze		Rime	
		Wind Dir.	Wind Speed (mph)	Max. Gusts (mph)	Rad. in	lb/ft	Rad. in	lb/ft (0.9)	Rad. in	lb/ft (0.5)	Wind Speed (mph)	Rad. in	lb/ft (0.9)	Rad. in	lb/ft (0.5)
12	Strait of Belle Isle to 30 miles inland from coast near corner of Quebec (< 500 ft)	NNW	97	115	3.7	25.8	3.5	13.1	2.9	9.7	50	2.7	15.5	2.0	5.4
13	Same area (500-1500 ft)	NNW	102	120	3.9	28.2	7.3	46.2	4.0	16.3	53	2.9	17.4	4.6	20.7
14	30 miles inland to 58°40'W (1000 ft to 1400 ft)	NNW	80	97	2.2	11.3	2.4	7.2	2.2	6.3	46	1.1	4.2	1.4	3.2
15	58°40'W to 60°05'W (≤ 1500 ft)	NNW	80	97	2.4	12.9	4.6	20.7	2.4	7.2	46	1.3	5.3	2.3	6.7
16	60°05'W to 60°30'W (≤ 1300 ft and protected from north)	W	68	83	1.5	6.4	1.8	4.7	2.0	5.4	42	0.5	1.5	1.3	2.9
17	60°30'W to Gull Lake Valley (≥ 1400 ft)	NW	83	100	2.2	11.3	5.1	24.6	2.2	6.3	46	1.1	4.2	2.6	5.1
23	Gull Lake to Churchill Falls (500-1600 ft)	NNW	83	100	1.5	5.5	3.5	11.9	1.3	2.5	46	0.5	1.2	2.0	4.8

VII. SIGNIFICANT RESULTS AND RECOMMENDATIONS

It is difficult to reach any absolute conclusions based on only seven months of on-site data. However, several observations can be made:

- The icing observed and/or measured during the winter of 1974-1975 was no more extreme than had been predicted in the earlier studies.

- Less ice occurred at Site 1 than had been expected; however, this was a relatively light icing year throughout the Province.

- Windspeeds recorded at Site 2 on the ridge of the Long Range Mountains were much higher than predicted in the 1973 study. Windspeeds recorded 30 feet above the surface of the ridge were much greater than at any levels below 5000 feet in the free air upstream of the ridge. It is quite apparent that windspeeds at Site 2 result from vertical convergence of the air stream as it is forced up and over the obstructing ridge. For the Site 2 location, the return period values developed for Segment 9 in the 1973 study are much too low. A new return period graph with a higher average annual extreme windspeed but with less slope was required. A mean annual extreme wind of 110 mph and a 50-year return period of 140 mph resulted.

- In a subjective sense, it appears that shifting the line route eastward at the crossing of the Long Range Mountains will result in some sheltering and reduce the wind loads on the line. The actual quantitative magnitude of this reduction is not readily apparent. The windspeeds in the more sheltered portions are likely to be as much as 20 percent lower than at Site 2; however, there are two locations along the new route where windspeeds comparable to Site 2 should be expected. Both locations appear to be vulnerable to the full force of the easterly winds. One location is at the top of a small east-west canyon and nearly directly east of Site 2. The other location is on the ridge just before the route dips down to Inner Pond.

- Comparison of winds measured at Site 4 with corresponding winds recorded at Battle Harbour resulted in small increases in the return period values predicted for the mainland segments of the route. Once again, the decreased slope of the graphs resulted in greater increases in the mean annual extremes in the 50-year return period values.

- The combined wind and ice load estimates were readjusted in accordance with the method described in the September 1974, study using winds which occurred in conjunction with icing conditions. Once again, Segment 9 in the Site 2 area has the highest transverse wind loads, combining 87 mph winds with 6.8 radial inches of rime for the 50-year return period value

- Major uncertainties exist in evaluating the sheltering which will be achieved by re-routing to the east of Site 2. The only way to realistically determine the magnitude of the sheltering is to instrument a site in that area in conjunction with instrumentation at Site 2. Experience during the winter of 1974-1975 dictates that power will be required to operate deicing equipment if the wind recorders are to be kept operational.

- Of prime importance during the winter of 1975-1976 is the erection of a 100-foot guyed tower to serve as a passive ice collector. This simple device will serve as a visual indicator of the change in ice accumulation with height. It was observed that during the 1974-1975 winter ice thickness on the 30-foot towers varied from 6 inches near the ground to 14 inches near the top. It will be important that, to evaluate the effect of successive storms, the ice be allowed to accumulate until it is melted or blown off. Pictures of this tower-collector will need to be taken at each site visit as well as a written description of what is observed.

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