THE UNIVERSITY OF MANITOBA

MARINE INSURANCE AND ITS EFFECTS ON THE MOVEMENT OF GRAIN THROUGH THE PORT OF CHURCHILL

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BY

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A practicum submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF NATURAL RESOURCE MANAGEMENT

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ABSTRACT

The estimated potential grain throughput of the port of Churchill is considerably greater than the actual grain throughput. Other studies and actual estimation in this practicum show this statement to be true. Marine insurance coverage is one of the factors contributing to this discrepancy. Insurance coverage is the variable which dictates the length of the shipping season and rates charged including the basic premium, the additional or route premium, and the surcharge on the additional premium. To obtain an extended shipping season and a lowering of rates, the period of insurance coverage would have to be extended and rates would have to be reassessed.

The primary objective of the practicum is to deal with the limitations imposed on merchant grain shipping by marine insurance coverage including marine insurance rates and the length of the shipping season. A second objective is to investigate whether new developments in technological and ice forecasting aids warrant change in marine insurance coverage. Marine insurance coverage, ice conditions, and technological and ice forecasting advances are examined to determine 1) if the duration of insurance coverage should be extended, and 2) if insurance rates should be lowered.

It was concluded that:

1. Marine insurance underwriters have limited the length of of the shipping season on the Hudson Bay route which in turn

may have limited the throughput of the port of Churchill.

2. There is a case for lower insurance rates on merchant grain vessels using the Hudson Bay route. Based on the analysis of new technological development and forecasting aids made on the Hudson Bay route since the mid-1950's, a change in marine insurance rates and the period of coverage is recommended.

3. The conclusions of the practicum are limited by the source of research data available, more particularily by a) the secretive nature of the marine insurance industry regarding rate formulas, data on rates for the basic insurance premium, and 'insurance paid out' data from both the insurance industry and the Ministry of Transport Canada, and b) the nature of recorded information regarding casualties sustained on the Hudson Bay route prior to 1972.

ACKNOWLEDGEMENTS

It is impossible to name all the people in the numerous government and private agencies who have given freely of their time to assist in this study. Therefore, I would like to express my appreciation to all those who assisted in any way. The following were most helpful and cooperative in providing constructive criticism : the Port Churchill Development Board, the National Harbours Board (Churchill), the Canadian Board of Marine Underwriters, the Canadian National Railways (Grains Industry, Winnipeg), the Canada Centre for Remote Sensing (Winnipeg), the Ministry of Transport Canada including the Canadian Coast Guard and the Atmospheric Environment Service,and the Natural Resource Institute (University of Manitoba).

The study was conducted during the period June 1975 through May 1976 with the support of a Center for Transportation Studies (University of Manitoba) grant. Computer time was provided by the University of Manitoba. The _Reports on Hudson Bay Marine Insurance Rates_ authored by the Commonwealth Shipping Committee, the Hedlin Menzies report _Port of Churchill - Potential for Development_, and discussion with the Canadian Board of Marine Underwriters were the basis for determining insurance information. Employees and publications of the Ministry of Transport Canada and the National Research Council of Canada aided the accumulation of data relevant to ice conditions, and technological and ice forecasting advances

made on the Hudson Bay route.

I would particularily like to thank the members of my practicm committee for their assistance:: Dr. Edward Tyrchniewicz, Chairman; Professor Sam Trachtenberg; and Mr. Edmund Guest.

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CHAPTER I

INTRODUCTION

A. Preamble

The port of Churchill (Figure 1) is located at approximately $58^{\circ}46'$ N latitude $94^{\circ}12'$ W longitude on the western shore of Hudson Bay in the estuary of the Churchill River. Hudson Strait, 400 miles to the north-east of Churchill, provides access to the Atlantic Ocean for those vessels that utilize this northern port. Passage to the Arctic Ocean is by way of Foxe Channel and Hecla Straits. The constraints of climatic conditions and ice formation on the Hudson Bay route and specifically in Churchill harbour, as defined by marine insurance underwriters, now restrict the navigation season to about 98 days on the average between 20 July and 25 October.[1]

The potential grain throughput of the port of Churchill is subject to debate. The amount of grain moving through the port has not been sufficient to test the handling facilities on this artery of transport to their potential capabilities. Reports dealing with this subject state that the estimated potential grain throughput of the port of Churchill is considerably greater than the actual throughput. The Hedlin Menzies

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[1] This season corresponds to the possible opening "shipping season" date of 20 July at Cape Chidley and the average harbour closing date of 25 October as derived in Chapter III. The navigation season is of greater length; however, it has been restricted by the length of the shipping season as defined by marine insurance.

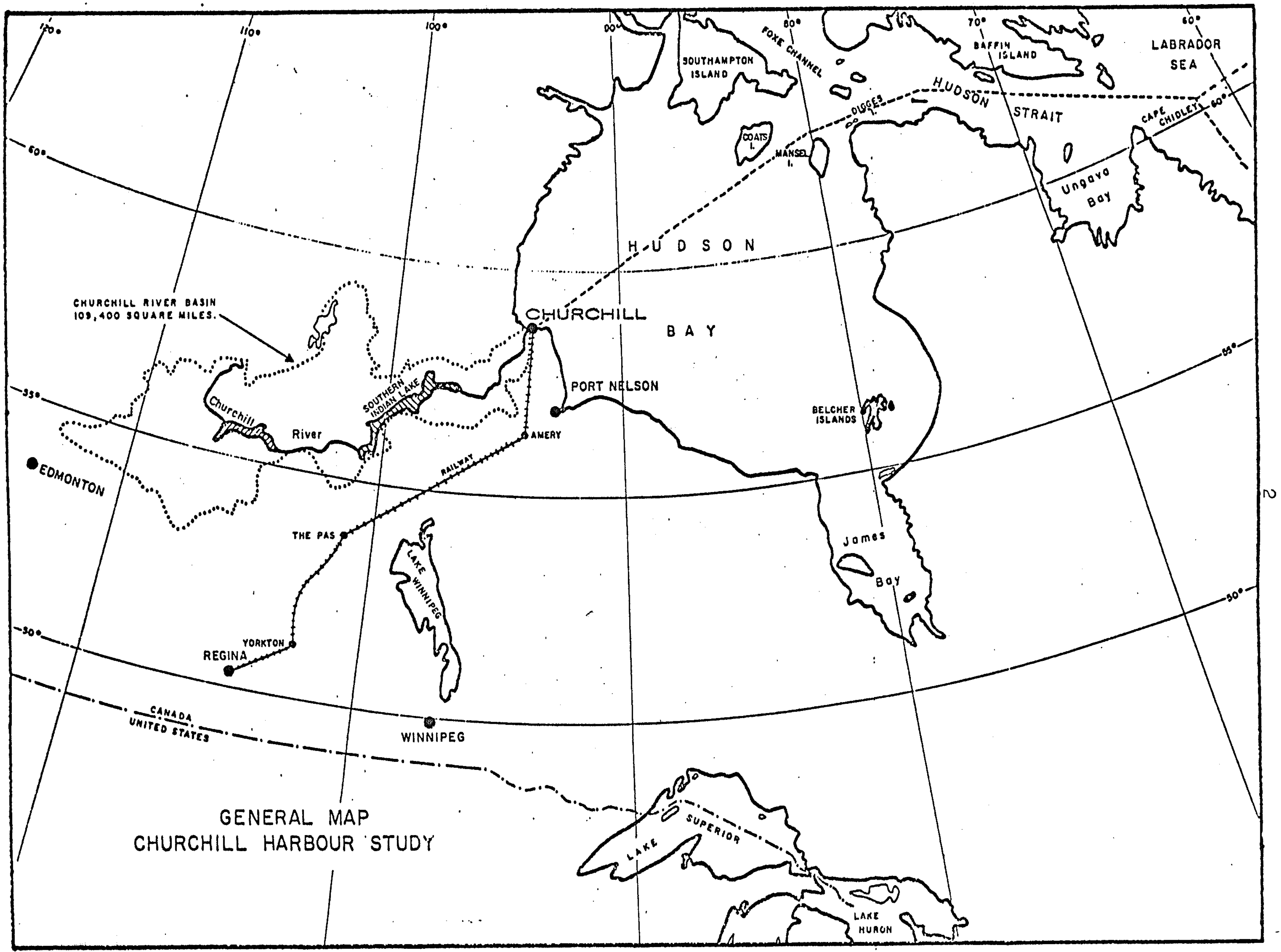

Figure 1 Access Routes to Churchill
Source: T.M. Dick, Churchill Harbour Study, National Research Council, (Unpub), 1966.

report[2] and the Bryden report[3] list the estimated potential throughput of the port, with existing facilities and operating season, at 30 million bushels of grain.

Another estimation involves a calculation which uses 1) the actual throughput of the port for a particular shipping season, 2) the number of loading days worked in that season, and 3) the length of the shipping season. For the shipping seasons 1971 to 1976 inclusive (Table 1) this method derives a range for the potential throughput from 28.85 to 37.29 million bushels of grain in 1973 and 1974 respectively. The actual throughput in the period 1971-1976 averaged 23.88 million bushels of grain.[4] This average figure is approximately one-third lower than the average estimated potential throughput of 33.94 million bushels derived in Table 1.

The potential movement of grain over each component of the Hudson Bay transportation artery is portrayed by the following flow-chart in millions of bushels per shipping season.[5]

Rail transportation
44.16
|
Port handling facilities
42.72 to 56.96
|
Ship transportation
42.72+

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[2] Hedlin Menzies and Associates, Port of Churchill - Potential for Development, (Transport Canada, 1969), 1-111.

[3] Bryden Ltd., and Tecktrol Ltd., Port of Churchill Investment Design, February 5, 1975, p. 11.

[4] Canadian Grains Industry, Statistical Handbook 74, (Canada Grains Council, 1975), p. 163.

[5] Potential throughput figures in Table 1 are estimates based on what has been shipped through Churchill each season. Figures in this flow-chart represent actual capacities based on the capabilities of each facility which are discussed in Appendix A, pages 90, 88, and 89 respectively.

Table 1 Estimated Potential Grain Throughput of the Port of Churchill

YEAR	TOTAL GRAIN SHIPPED (mi.bu.)	SHIPPING SPAN (days)	ACTUAL SHIPPING DAYS	LENGTH OF SHIPPING SEASON (days)[a]	POTENTIAL THROUGHPUT (mi.bu.)[b]
1971	25.24	85	75	94	31.55
1972	25.33	83	64	92	36.48
1973	18.85	75	58	89	28.85
1974	22.74	71	55	90	37.29
1975	22.70	60	59	89	34.28
1976	28.39	79	72	89	35.20
Mean	23.88				33.94

SOURCE: National Harbours Board records.

[a] Three days were not included at the beginning of the shipping season to allow ships to travel from Cape Chidley to Churchill. The least date used for the end of the shipping season was 22 October to allow ships three days to pass Cape Chidley by midnight 25 October resulting in a minimum shipping season of 89 days.

[b] Potential throughput = $\frac{\text{shipping season}}{\text{actual shipping days}}$ x total grain shipped

The actual throughput of the port of Churchill is lower than its estimated potential throughput. During preliminary investigations, it was found that four of the major factors related to increasing the throughput of the port of Churchill were: 1) Canadian Wheat Board involvement in promoting the use of the port of Churchill; 2) the limitations of marine insurance coverage; 3) the lack of adequate siding facilities on the rail line to Churchill; and 4) the role played by the other major participants including the grain buyer, his agent or dealer, the shipowner or charterer of a ship, and the insurance underwriter.[6]

The major purpose of the practicum is to deal with the limitations on shipping imposed by marine insurance coverage. Insurance coverage is the variable which dictates the length of the shipping season.[7] The mitigation of the vessel manoeuverability problem during the slush ice period in Churchill harbour, may warrant a renegotiation of the additional or route premium and the surcharge on vessels leaving Churchill between 20 October and 25 October. It may also warrant an extension of the shipping season as defined by marine insurance coverage.

B. Objectives of the Study

1. The practicum will identify and describe the effect that 1) the duration of marine insurance coverage, and 2) marine insurance rates, have on the use of the port of Churchill.
2. A second objective is to investigate whether new developments in technological and ice forecasting aids warrant change in marine insurance coverage.

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[6] These factors were determined in Appendix A.

[7] The navigation season may be defined as the period of time in which navigation is possible. The shipping season is that period of the navigation season for which ships are covered by Lloyd's or London marine insurance with the exception of self-insuranced vessels of East European countries.

C. Scope of the Study

1. An increase in port of Churchill throughput by consideration of port efficiency will not be included in the study.
2. The study will encompass only grain traffic.
3. An increase in port of Churchill throughput by consideration of rail capacity will not be included in the study.
4. Marine insurance coverage on merchant grain vessels using Churchill will be discussed in relation to ice conditions, and technological and ice forecasting advances made on the Hudson Bay route.
5. A benefit-cost analysis regarding an extension of the shipping season will not be included in the study.

D. Methodology

A modification of marine insurance rates and a lengthening of the shipping season may increase the seasonal handling capabilities of the port of Churchill. The following factors will be examined to determine whether marine insurance rates should be modified and the duration of insurance coverage should be extended:

1. An examination of a history of marine insurance affecting ships using the port of Churchill.
2. An examination of ice conditions during the breakup, freeze-up and interim periods which may justify a lengthening of the shipping season on the Hudson Bay route.

3. An examination of technological and ice forecasting advances made since the mid-1950's with the purpose of assessing their impact on marine insurance.

E. Organization of the Remainder of the Study

Each factor listed in the methodology will be discussed separately followed by a discussion chapter. The inter-relationship of each factor with current marine insurance coverage will be discussed to arrive at conclusions, recommendations, limitations of the study, and areas for further research.

CHAPTER II

MARINE INSURANCE

Marine insurance coverage is examined to determine a history of insurance rates and the duration of coverage on the Hudson Bay route, the difference between the rate structure on the Hudson Bay route and the St. Lawrence route, the factors for determining coverage, and the essence of Canadian Hull Advisory Committee Insurance. The findings in this chapter may contribute to further analysis related to the modification of marine insurance rates and an extension of the shipping season.

A. Insurance on Vessels Using the Port of Churchill

The cost of insurance on ocean-going vessels consists of the premium for basic insurance, the additional or route premium for routes representing additional hazards, and the surcharge on the additional premium.[8] The basic and the additional premium is for insurance known in the trade as 'with average' and 'free of particular average'. It applies to vessels not over 15 years of age that do not pass Cape Chidley before 23 July and pass 64° W latitude (Cape Chidley) on or before 20 October. For extensions up to the 25 October,

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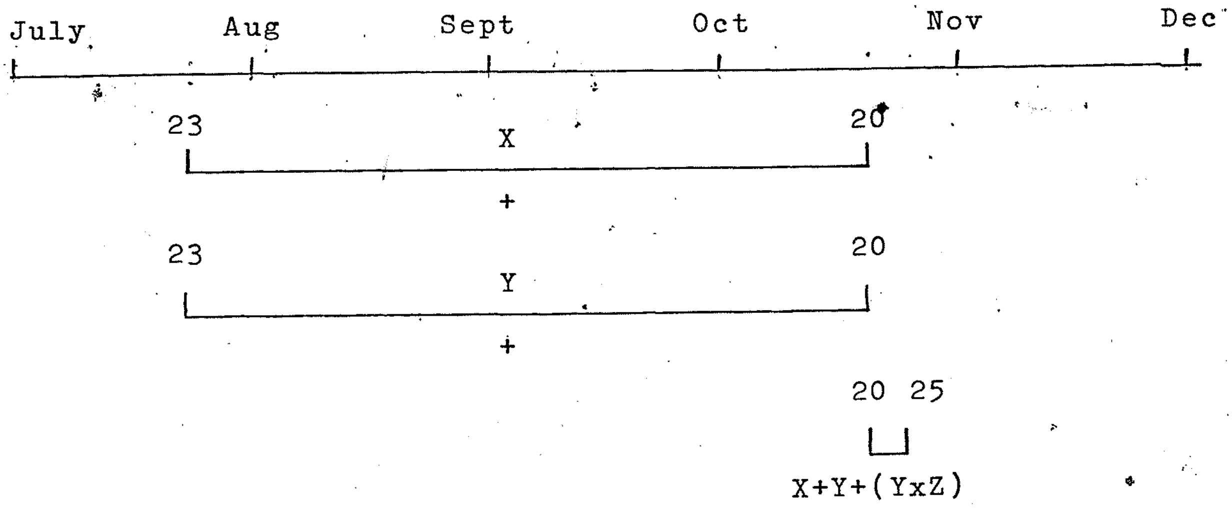
[8] For an explanation of the reason for the additional premium, see section 1a, Appendix D.

the additional premium is to be increased by a 25 per cent surcharge (Table A.2).[9] The application of each premium is summarized in Figure 2. The premiums which are employed for any date during the season apply on a vertical basis.[10]

Figure 2 The Use of Insurance Premiums During the Shipping Season[a]



[a] X = basic premium, Y = additional or route premium, Z = surcharge on additional premium

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[9] The duration of insurance coverage fixed in 1971 still applies. The season prior to this applied to vessels that did not pass Cape Chidley before 23 July and leave Churchill on or before 15 October or by midnight 20 October for an additional surcharge of 25 per cent. These dates were changed by the 1971 London schedule. The season alteration in 1971 amounts to the same coverage, but now worded differently.

[10] The season for insurance can be extended if a shipping company and/or charterer obtains insurance for the extended period. (D. Morris, Manager, Winnipeg Branch, Marine Office Appleton and Cox, 28 April 1976). A shipping company can use the route outside the insurance season by taking the risk without having insurance coverage.

Due to the requirement of the additional or route premium, the Hudson Bay route is at a disadvantage in relation to the St. Lawrence and Pacific Coast routes which require only the payment of the basic premium during the same period in which the Hudson Bay route is operational. A comparison of the basic premium on these routes is not possible as rates for the basic premium cannot be obtained.

A history of the minimum additional premium on the Hudson Bay route shows that as experience and knowledge of the route was gained since the opening of the port to ocean-going vessels, the premium for vessels fitted with a gyro compass has been gradually reduced (Table A.1). The minimum additional premium fixed on 4 July 1956 was changed in 1971 to calculation by use of a percentage of the vessel's gross annual rate.[11] The schedule for the minimum additional preium was suspended on 23 May 1972 as very little notice was being taken of them by underwriters.[12]

An example of the difference between the additional premium of the Hudson Bay and St. Lawrence routes is as

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[11] The additional premium fixed on 4 July 1956, as affected by an insurance change in 1955, applied up to the publication of the Hedlin Menzies report in 1969. Schedules applying to the Hudson Bay and St. Lawrence routes 1971 were obtained. However, a comparison of rate changes cannot be made as the method of insurance calculation had changed. Therefore further discussion of insurance rates will apply to the period 1955-1970 inclusive. The limitations of the use of the Gross Annual Rate for calculation of the additional premium is discussed in Chapter VI.

[12] J.L. Beamish, Former Chairman, Trade Development Committee, Canadian Board of Marine Underwriters, Toronto, Correspondence, 1 June 1976.

follows. The minimum additional premium for 1969 for the Hudson Bay route, in terms of Canadian currency, is

Per Ton on G.R.T. . . . . 14.3¢
Percentage on Insured Value . . . . 27.5¢ per $100.[13]

The cost per bushel of grain depends on the size of the vessel and the insured value. The Hedlin Menzies report estimates that for new vessels, the cost would be 2.0 cents per bushel for a vessels with a capacity of 50,000 tons dwt., and 1.5 cents per bushel for a capacity of 50,000 tons dwt.[14] This amounts to approximately 1.7 cents per bushel for a vessel with a capacity of 35,000 tons dwt. using Churchill.

During the winter months, vessels proceeding to Gulf of St. Lawrence ports pay a minimum additional premium. The highest of these premiums in Canadian currency for unstrengthened vessels proceeding west of Baie Comeau to either Quebec City, Three Rivers, or Montreal during the period 1 January to 31 March is

Per Ton on G.R.T. . . . . 53.6¢
Percentage on Insured Value . . . . 18.7¢ per $100.

The Hedlin Menzies report estimated that this would amount to about 2.3 cents per bushel for vessels of 15,000 tons dwt.,

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[13] The schedule for the minimum additional premium for the Hudson Bay route and the winter season of the Gulf of St. Lawrence is found on pp. 319-324 of Royal Commission Inquiry Into Northern Transportation, Province of Manitoba, Winnipeg, 1969. The shedules are dated 1967 but figures given above for rate per GRT and % on insured value include a 10 % addition to allow for devaluation of the pound sterling in November 1967.

[14] Hedlin Menzies, Op.Cit., 2-91.

and about 1.8 cents per bushel for vessels of 50,000 tons dwt.[15] For vessels of 35,000 tons dwt., the near maximum capacity of vessels using the Hudson Bay route, this would amount to approximately 2.0 cents per bushel.

This data shows that in 1969 the minimum additional premium for the Hudson Bay route was slightly lower than the minimum additional premium for full winter operation on the Upper St. Lawrence. However, during the summer shipping season for the Hudson Bay route, the insurance rate on the Hudson Bay route versus the Upper St. Lawrence was at least 1.7 cents per bushel more for vessels of 35,000 tons dwt. due to the omission of the additional premium on the Upper St. Lawrence route.[16]

B. The Factors for Determining Marine Insurance Coverage

The factors determining marine insurance rates are not rigidly tied to that aspect but can be applied to the factors for determining the length of the shipping season.[17] The opposite also applies.

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[15] *Ibid*., 2-92.

[16] Rates for the basic premium could not be obtained. The limitation of this aspect is discussed in Chapter VI.

[17] The 'Reports on Hudson Bay Marine Insurance Rates' authored by the Commonwealth (Imperial) Shipping Committee (CSC) was the basis for determining the factors for insurance coverage on vessels using the Hudson Bay route. The committee was made up of knowledgeable shipping people from Commonwealth countries, experienced persons in shipping and commerce, and representatives of the Joint Hull Committee who made recommendations to the underwriters concerning insurance coverage.

1. Marine Insurance Rates

a. Extra Risk on the Hudson Bay Route

At the time of the opening of Churchill to ocean-going (tramp) vessels in 1932, insurance rates included an additional or route premium because the Hudson Bay route involved an extra risk.[18]

b. Aids to Navigation Used on the Hudson Bay Route

The Joint Hull Committee lowered insurance rates and lengthened coverage when it learned about the addition of aids to navigation. For example, rates were lowered when bearings were obtained from shore stations or reports on ice conditions were obtained from the icebreaker stationed on the route.[19]

c. Aids to Navigation Used on Vessels

The Joint Hull Committee lowered insurance rates if vessels became properly fitted with direction finding apparatus which was inspected by the makers prior to vessel departure for Hudson Bay.[20]

d. Perils and Information Available on the Route

Insurance rates were set according to climatological and navigation hazards found on the route.[21] As information became available, rates were reduced and coverage extended.[22]

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[18] In insurance terms, risk is defined as something which may happen but not something which must happen. The reason for an additional premium is an increase in the risk involved. (Robert H. Brown, Marine Insurance - Cargo Practice, 1st ed., (Great Britain: Northumberland Press Ltd., Gatesherd, 1970), Vol. 2, pp. 51-52). By an increase in risk is presumably meant ice hazards and the type of vessel used. For exact remarks by the CSC, see Section 1a, Appendix D.

[19] See Appendix D, Section 1b.

[20] *Ibid*., Section 1c.

[21] *Ibid*., Section 1d.

[22] *Ibid*., Section 2c.

e. The characteristics of Vessels and Personnel Used

Underwriters have the right to set rates as the efficiency of the vessel and the crew warrant.[23]

f. The Small Number of Vessels Using the Route Each Season

Marine insurance rates prior to 1955 were set according to the number of vessels that used the route each year. Underwriters had to collect enough insurance each season to pay for minor damage and/or a total loss.[24] Therefore, it seems that an increased number of voyages to and from Churchill would have been necessary before a substantial reduction in the rate of premium could be secured. In the period 1955-1970 inclusive however, the only major change in rates, in 1955, was made to comply with tonnage rather than just the number of vessels using the route each season.[25]

g. Casualties

In the past, rates were reduced when a major casualty did not result in the previous season. This aspect is illustrated by the change in rates of the 1952 season in relation to casualties sustained in the 1951 season.[26]

d. Insurance Paid Out

The insurance paid out by the insurance industry is an important factor affecting the level of insurance coverage on

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[23] *Ibid.*, Section le.

[24] *Ibid.*, Section lf.

[25] *Ibid.*, Section lg.

[26] *Ibid.*, Section lh.

the Hudson Bay route relative to insurance coverage on the St. Lawrence route. The rates of the following year are adjusted to account for the severity of casualties in the previous year(s) and the insurance paid out to companies whose vessels reported casualties sustained on the Hudson Bay route. An historical account of insurance paid out could not be obtained for either the Hudson Bay or the St. Lawrence route.[27]

2. The Length of the Shipping Season

The length of the shipping season for foreign vessels has been assessed by the London Underwriters in relation to the information available regarding breakup and freeze-up dates on Hudson Bay and Strait, and the occurrence of slush ice in Churchill harbour in the autumn.[28] The length of the shipping season was extended as information regarding shipping on the route improved and experience increased. This aspect is depicted by Table A.2.

A limitation to the use of Churchill during ice periods may be the lack of heavy repair and salvage facilities on the route. The CSC stated in the past that this aspect adds additional risk to the operation of vessels on the Hudson Bay route.[29]

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[27] For additional information, see Section D, Chapter VI.

[28] For additional informatiom, see Appendix D, Section 2.

[29] For additional comments by the CSC, see Section 2d, Appendix D. Salvage and repair facilities on the Hudson Bay route are discussed in Chapter IV.

C. Canadian Hull Advisory Committee Insurance

Canadian Hull Advisory Committee insurance applies to Canadian flag vessels using the eastern Arctic between dates and in areas set out in the latest schedule of the Arctic Shipping Pollution Prevention Regulations (ASPPR) as modified by the Master of the CCGS Icebreaker nearby or the Ice or Pollution Control Officer for the area.[30]

Unlike the London Scale for Hudson Bay marine insurance coverage, the Canadian Scale uses only the basic premium. Insurance is computed only for the voyage for which application is made. The London Scale 1971 applied an additional premium to the basic premium.

For conventional unstrengthened vessels, the basic premium for the Canadian Scale 1972 per gross ton per day of logged time on the route was 18¢. The Canadian Scale is less expensive than the London Scale due mainly to the omission of the additional premium. In addition, the basic premium for the Canadian Scale may be considerably less expensive than the basic premium for the London Scale.[31] Mr. A. Copeland has suggested that in the future, the London Scale may be more comparable to the Canadian Scale because of the competitive nature of marine insurance both on a domestic and international basis.[32]

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[30] See Shipping Regulations, Chapter IV, for additional information.

[31] Rates for the basic premium London Scale could not be obtained. Therefore speculation is only possible. The limitations of this aspect are discussed in Section D, Chapter VI.

[32] A. Copeland, Former Chairman, Canadian Board of Marine Underwriters, Toronto, Correspondence, 23 April 1976.

D. Summary of Marine Insurance

1. With the exception of a change in 1971, the period of shipping and the rates for marine insurance have not changed since 1955 and 1956 respectively. Due to the lack of information resulting from the change in insurance calculation in 1971, further analysis of marine insurance rates will be restricted to the period 1955-1970 inclusive.

2. Marine insurance rates on grain shipped through St. Lawrence ports are considerably lower than rates on grain shipped from Churchill during the Hudson Bay shipping season; for 1969, the minimum additional premium on vessels using the Hudson Bay route was slightly lower than the minimum additional premium for full winter operation on the Upper St. Lawrence.

3. Two important factors affecting marine insurance assessment, 1) a history of marine insurance paid out and 2) a history of the rates for the basic premium, could not be obtained for vessels using both the Hudson Bay route and the Upper St. Lawrence route.

4. Canadian Hull Advisory Committee insurance is considerably less expensive than London insurance due to the omission of the additional or route premium.

CHAPTER III

ICE CONDITIONS ON HUDSON BAY AND STRAIT AND IN CHURCHILL HARBOUR IN RELATION TO THE LENGTH OF THE NAVIGATION SEASON

Ice conditions on the Hudson Bay route are examined to determine the relationship between the navigation season, aids to navigation, and marine insurance coverage.[33]

A. Ice Conditions on Hudson Bay and Strait

1. Breakup

Thawing and breakup on Hudson Bay and Strait begin about the middle of May in most years. Breakup is well advanced by the beginning of July and navigation becomes possible. At this time, small floe, first year winter ice is predominant. Navigation, with the use of conventional unstrengthened vessels, can begin by 20 July on the average and by 15 July in 'most favourable' years.[34] On 23 July, the date for the opening of the shipping season at Cape Chidley, Hudson Strait usually contains some small floe ice of concentrations one-to-three/tenths to four-to-six/tenths. Ice from Foxe Basin and the Gulf of Bothnia flow into Hudson Strait in mid or late July by which time it has rotted extensively.

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[33] Appendix B provides a detailed description of ice behaviour during the breakup, freeze-up and interim periods.

[34] The opening date of the shipping season corresponds to vessels passing Cape Chidley. Ice conditions on Hudson Bay and at Churchill three to five days after passing Cape Chidley would be less severe.

2. Freeze-up

The growth of ice usually begins in north Hudson Bay in early November after freeze-up in Foxe Basin. The ice forms more quickly along the west shore of Hudson Bay and affects Churchill usually about mid-November. The center of Hudson Bay remains open for some weeks longer. The only difference in ice formation on Hudson Strait is the occurrence of polar ice from Foxe Basin and Davis Strait, and the slower formation of ice in eastern Hudson Strait due to the moderating effects of the north Atlantic.

Ice observations indicate that the worst ice conditions on the Hudson Bay route during November will be found at the western approaches to Hudson Strait in the area bounded by Bell Peninsula, and Coates, Mansel and Nottingham Islands.

The occurrence of winter ice in Foxe Basin from the previous winter can be used to predict unfavourable navigation conditions in late October and November.[35]

Maximum winter ice thickness of four to six metres is found in both Hudson Bay and Strait. Ridging may increase ice thickness by two to three times the initial thickness. Ice is constantly moving. There are always leads and weaknesses in the ice which can be exploited by icebreakers and/or merchant vessels.

The present limit to the navigation season on Hudson Bay and Strait seems to be 10 November in average years and

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[35] This aspect is discussed in detail in Section I, Chapter IV.

approximately 31 October in 'most unfavourable' years. This corresponds to the occurrence of permanent ice outside Churchill harbour on 10 November in favourable and average years, and the occurrence of permanent ice in western Hudson Strait in average and unfavourable years. When ice occurred outside Churchill harbour and in the western approaches to Hudson Strait on 5 November with the exception of years such as 1965 and 1972, it was composed of first-year new and nilas ice.

3. Iceberg and Growler Hazard in Hudson Strait

Icebergs from Davis Strait never travel any further westward than Charles Island due to the pattern of surface currents in this area (Figure B.8). Eighty per cent of the hazard in the overall hazard area between 74°W and 59°W longitude is centered about 67°W longitude for approximately 450 miles.[36]

Second year or polar ice may enter Hudson Strait from Foxe Basin. Second year or polar ice which drifts into Hudson Strait via Foxe Channel has rotted extensively. By August this influx has stopped. Very rarely will polar ice from Foxe Basin drift into the northeast corner of Hudson Bay.[37] The extent of dissipation of Foxe Basin ice during the breakup and summer periods will reflect navigation conditions in late October and also in the following shipping

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[36] The location of icebergs and growlers in Hudson Strait is discussed in greater detail in Appendix B.

[37] Hedlin Menzies, Op.Cit., 1-124.

season.[38]

Icebergs, and to a lesser extent growlers, can be seen at a fair distance in clear weather by day or night. They are a hazard only in fog or driving snow in which the speed of the vessel should be reduced to suit the visibility. In relation to the navigation season, data show that fog has the greatest hazard in July, August, and September while blowing snow occurs mainly outside the present shipping season.[39]

B. Ice Conditions in Churchill Harbour

1. Breakup

Records on the opening of Churchill harbour have been kept by the National Harbours Board. Opening dates have been plotted on figure 2 and the average opening date of 12 June computed. The earliest opening date has been 27 May and the latest 21 June or 32 days prior to the opening date of shipping at Cape Chidley.

2. Freeze-up

Ice occurrence in Churchill harbour during the autumn consists of slush ice and permanent ice cover. The first occurrence of ice is the large quantities of slush ice carried past the wharf on the ebb tide from its formation points upstream on the Churchill River. The second occurrence is the formation of a permanent ice cover or freeze-up that will persist until breakup the following spring.

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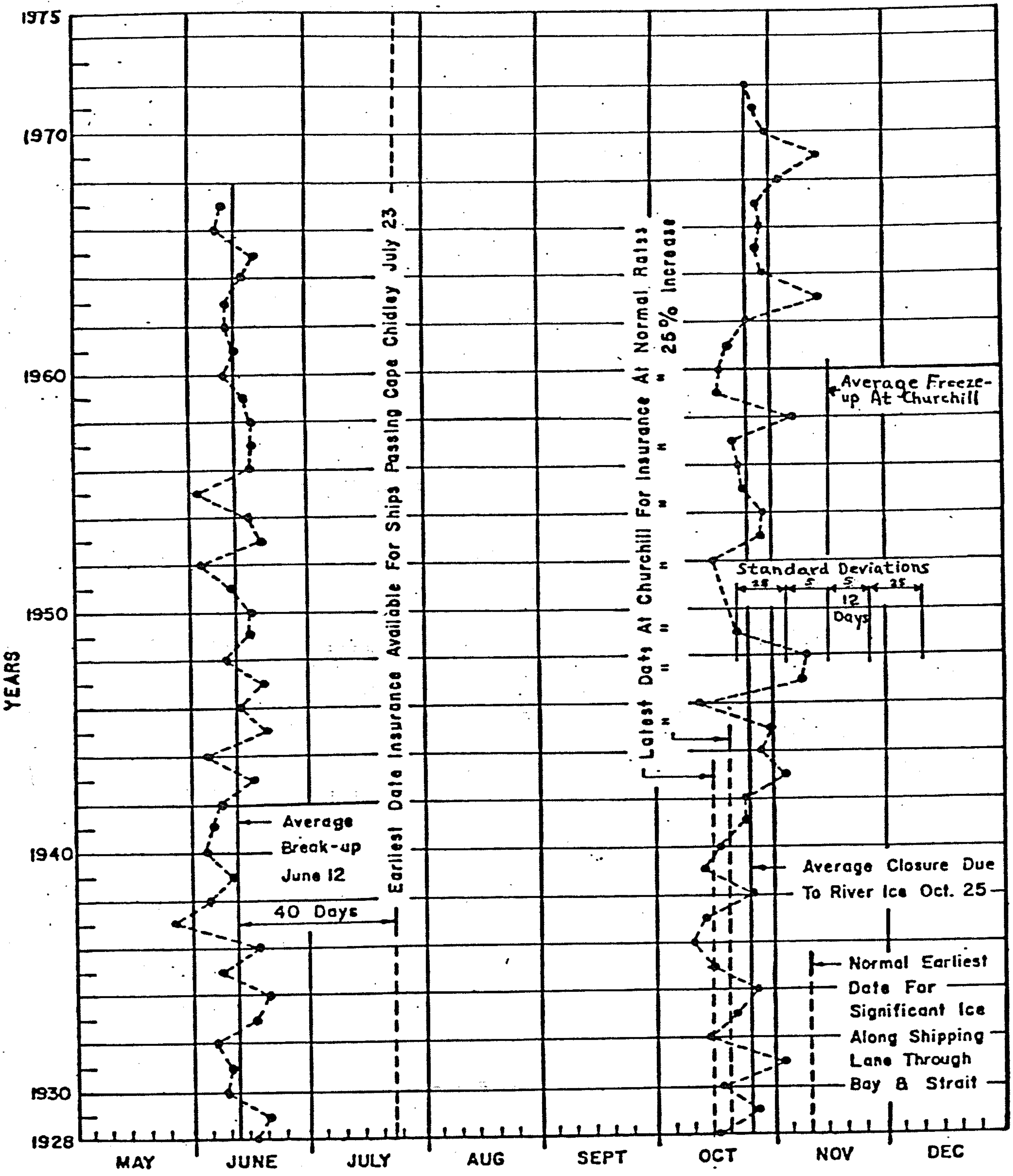
[38] This aspect is discussed in greater detail in section I, Chapter IV.

[39] See Table B.2 and B.3, Appendix B.

Figure 2 HARBOUR BREAKUP AND CLOSING DATES



a. Slush Ice

Reports have noted that the formation of slush ice is a result of the atmospheric temperature and more specifically mean October temperature.[40] This aspect corroborates evidence that the Churchill River diversion project will not affect the formation of slush ice in the lower Churchill River.[41]

Strong currents occur at the harbour entrance and along the face of the wharf. The configuration of the estuary upstream of the harbour is such that the ebbing tidal flow is projected towards the north bank above Cockles Point where it is deflected and then projected towards the south side where the wharf is located (Figure 3). The current is also attracted to the wharf by the dredged channel which accommodates a large flow along the wharf and beyond at a small hydraulic gradient.

Even when the volume of slush ice is not excessively large, the surface flow pattern in this area creates a concentration of ice along the dock face. This hampers berthing; ice which is moving past the dock jams between the dock face

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[40] For greater detail, see section I, Chapter IV.

[41] Mean October river discharge for the lower Churchill River does not have any correlation with the closing of Churchill harbour to navigation. The minimum and average compensation flow to be released from South Indian Lake in October will be in the order of 500cfs and 8500 cfs respectively (calculated from data extracted from Manitoba Hydro simulation program E1200). During the month of October, when ice is forming on the river, the natural flow below Missi Falls averages 12,200 cfs, giving a total average flow of 20,700 cfs. Flows of this amount have not resulted in the closing of the harbour to navigation at a much earlier than average date (Table B.4).

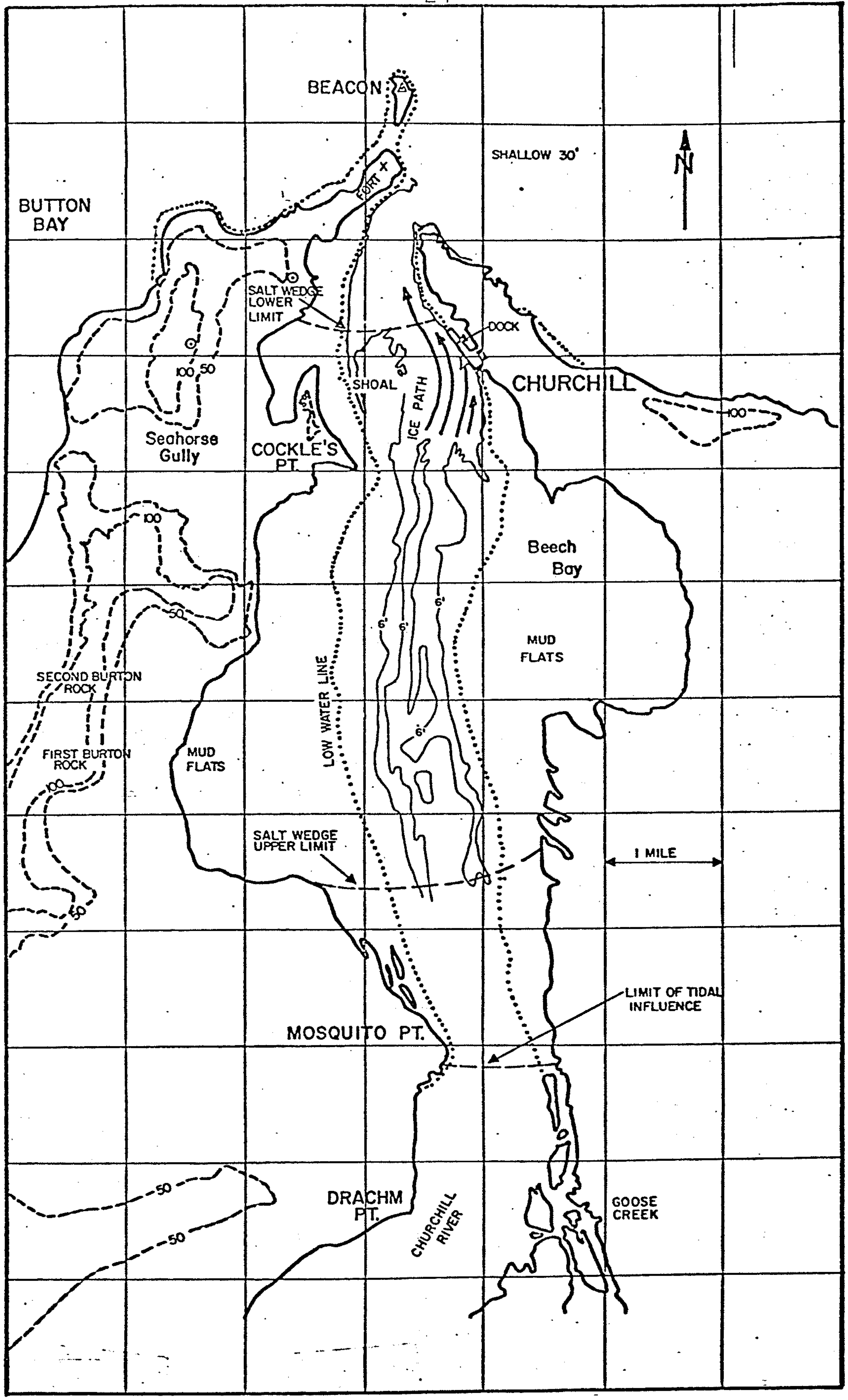

Figure 3 Churchill Harbour
Source: T.M. Dick, Feasibility of Extending Navigation Season at Churchill Harbour, (Ottawa: NRC, 1966).

and the ship's bow, ultimately exerting pressure on the mooring lines making it difficult to maintain ships at their berths.

The closing of Churchill harbour, due to the restrictions of marine insurance, is determined by the date large quantities of slush ice form in the river influencing the use of vessels at the port.[42] In the seasons 1928 to 1972, closing due to fresh water in the harbour occurred in the pattern shown in Table 2. An average closing date of 25 October has been computed.

Table 2 Date of Churchill Harbour Closure to Navigation[a]

Closing of the Navigation Season	Per Cent of Years %
October 9	0
October 15	14
October 22	39
October 29	82
November 13	100

a The above figures were established from an examination of historical data, namely the dates of Churchill harbour closure to navigation and the last date considered safe due to the occurrence of slush ice as listed in Table B.4.

Mr. Al Wokes, Sr. has maintained that slush ice is not an important factor in ending the shipping season.[43] During Wokes' time at Churchill, only one vessel had ever

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[42] See Section B.2, Chapter II.

[43] Al Wokes, Sr., Former Port Manager with a career of 34 years at Churchill, Interview, Selkirk, Manitoba, 7 May 1976.

been torn away from her moorings by slush ice, and in this case, the cause was in some doubt. Wokes maintained that vessels that were affected by the slush ice were the tug boats employed at the port and small tramp coastal freighters that come to the port at the end of the season to pick up screenings. Mr. Earl Scharf has stated that a Master experienced with navigation in slush ice would have no problem navigating.[44] An inexperienced Master might have a problem with slush ice blocking his vessel's engine intake, causing the engine to overheat. Both Wokes and Scharf stated that vessels have never been damaged in slush ice, but the use of an icebreaker during the slush ice period would provide for easier manoeuverability of merchant vessels.

b. Permanent Ice Formation

An analysis of freeze-up records shows that the mean date for final freeze-up is 15 November with a standard deviation of twelve days.[45] Sea water temperatures control the formation of permanent winter ice in the harbour. Estimates of probability for continuous, permanent ice cover in the harbour can be made by assuming a normal distribution (Table 3). On the average, the harbour has closed to navigation about 20 days in advance of the average final harbour freeze-up date of 15 November.

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[44] Earl H. Scharf, Manager, Port of Churchill, Correspondence, 21 June 1976.

[45] D.K. MacKay, J.R. MacKay, 'Historical Records of Freeze-up and Breakup on the Churchill and Hayes Rivers', Geographical Bulletin, (Ottawa: 1965), Vol. 7, No. 1, p. 16. Freeze-up records at Churchill from 1720 to 1965 (143 Observations) were analyzed. Freeze-up in their report refers to the formation of continuous ice cover that will persist until the following breakup. ~~Their~~ calculation is plotted in fig.2.

Table 3 Date of Churchill Harbour Freeze-up

Date	Probability of Freeze-up Later Than Given Date (%)
October 22	97.7
November 3	65.9
November 15	50.0
November 27	15.9
December 9	2.3

C. Summary of Ice Conditions on the Hudson Bay Route in Relation to the Navigation Season

1. Navigation during the breakup period depends on the ice conditions in Hudson Bay and Strait as Churchill harbour is open at least 32 days before ships can proceed past Cape Chidley.

2. The navigation season depends on ice conditions in relation to the air temperature. On the average and in 'most favourable years', navigation at Cape Chidley can begin by 20 July and 15 July respectively.

3. Slush ice formation in the Churchill River is responsible for the average closure date of 25 October for Churchill harbour due to the restrictions of marine insurance coverage. The harbour is closed to navigation about 20 days in advance of the average, permanent, harbour, freeze-up date of 15 November.

4. The limit to navigation on Hudson Bay and Strait, which corresponds to the occurrence of permanent ice cover outside Churchill harbour and in western Hudson Strait, seems to be

10 November on the average and 31 October in 'most unfavourable' years.

5. The navigation season extends on the average from 20 July to 10 November or 114 days, and in 'most favourable' years from 15 July or sooner to 15 November or 124 days, assuming that the problem of vessel manoeuverability in slush ice in Churchill harbour can be mitigated.

CHAPTER IV

TECHNOLOGICAL AND ICE FORECASTING ADVANCES

Physical and non-physical aids to navigation are discussed to assess the impact of their advances on marine insurance since the mid-1950's.[46] These aids are a necessity to safe navigation during, and also for an extension of, the shipping season. The CSC, if still in existence, would have been receptive to the type of information found in this chapter. In relation to the formation and movement of ice from Foxe Channel, the CSC stated "...if as a result of such observations during a series of years, it would become possible to give accurate and early advise of approaching ice, the underwriters would be prepared to consider the adoption of moveable opening and closing dates for the season."[47]

A. Shore Aids to Navigation on the Hudson Bay Route

Since the mid-1950's, the shore aids to navigation on the Hudson Bay route have improved considerably including the addition and alteration of numerous radiobeacons, radar ref-

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[46] Physical aids include shore and ship aids to navigation, ice reconnaissance and remote sensing techniques, the type of grain vessels used, a solution for the slush ice problem in Churchill harbour, and the use of ice strengthened vessels. Non-physical aids include written aids to navigation, ice forecasting techniques, and shipping regulations.

[47] Commonwealth Shipping Committee, Seventh Report on Hudson Bay Marine Insurance Rates, 1936, (Great Britain: Her Majesty's Stationery Office, 1936), p. 13.

lectors, lights, light buoys, and structural characteristics of light towers.[48]

1. Lights

All lights in Canadian waters are under the control of the Ministry of Transport Canada. They are maintained by the National Harbours Board whenever navigation in the vicinity is open. Lights used solely as harbour lights are not exhibited when the harbour is closed, although general navigation may remain open.

By the end of 1974, the Hudson Bay route contained 35 lights as compared to 15 lights in 1953. Included in this count is the beacon light at Churchill airport which is not listed as an aid to navigation.

Lights found on Hudson Bay and Strait, which are relevant to merchant shipping, are white in colour with the exception of the light buoys found at the entrance to the Churchill River and around the berth area.[49]

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[48] This information was derived from List of Lights, Buoys and Fog Signals, Atlantic Coast, 1975, Canada: Ministry of Transport, corrected to Notices to Mariners, weekly edition No.43 of 1974, January 1975), and Annual Reports, Seasons of Navigation 1953-1961, Navigation Conditions on the Hudson Bay Route From the Atlantic Seaboard to the Port of Churchill (Canada: Ministry of Transport, Nautical Division). Table C.1 gives a description and the year last altered. Table C.2 lists the new aids to navigation the Hudson Bay route 1953 - 1975 inclusive. Table C.3 lists the altering of established aids to navigation on the Hudson Bay route 1953 - 1975 inclusive.

[49] Buoys are governed by regulations as to colour as stipulated in the Pilot of Arctic Canada, Vol. 1, 1970, 2nd ed. (Ottawa: Canadian Hydrographic Service, Marine Sciences Branch, Ministry of Energy, Mines and Resources, 1970). Coloured lights are inferior in power to white lights. They are more quickly lost under unfavourable weather conditions.

2. Buoyage

Generally, buoys are maintained in position during the season of navigation. In localities where the lights are maintained in operation throughout the year, the buoys are always kept in position. In districts where navigation is closed in winter, the buoys are kept out in autumn until the last vessel has cleared, or as late as the ice will allow, with due regard for their safety. The buoys are replaced in the spring, in order of priority.

3. Fog Signals

There is only one fog signal on Hudson Bay and Strait. Ships Approaching Acadia Cove, Resolution Island, may request the firing of an explosive bomb signal. This signal is fired at ten minute intervals by the radio personnel and has an audible range of six miles. The frequency of fog in July and August in the Hudson Strait area may warrant the use of fog signals at other localities on the Strait.[50]

4. Radiobeacons

The Hudson Bay route contained thirteen radiobeacons in 1974 compared to five in the mid-1950's.[51] Seven of the eight additions to the radiobeacon system have been made in

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49 See fog and blowing snow statistics, Table B.2.

50 In the 1950's, radiobeacons were known as direction finding stations. Table C.4 gives additional information on radiobeacons regarding locations, frequency of operation, range of apparatus, characteristics and remarks. Additional radiobeacons at Koartac (Cape Hopes Advance), Resolution Island and Churchill are not listed in Table C.1, but in Table C.4.

the Hudson Strait area. Radiobeacon service is available to enable ships equipped with direction finding apparatus to take a bearing or to take several consecutive bearings which will provide a fix.

5. Radar Reflectors and Radar Transponder Beacons

The number of radar reflectors used on the Hudson Bay route has increased from two in the mid-1950's to seven in 1974. All reflectors, with the exception of the Churchill harbour reflector, are located in the Hudson Strait area. There are no radar transponder beacons (RACONS) found in the Hudson Bay and Strait area. The RACON is an active system which is triggered by the ship's radar. The response is indicated on the ship's radar screen. Radar reflectors are passive but normally provide a more effective reflective surface to the aid upon which they are fitted.

B. Written Aids to Navigation

1. Aids to Navigation

An updated account of aids to navigation is provided by the Ministry of Transport Canada to shippers and other users.[51]

2. Charts

The Canadian Hydrographic Service (CHS) publishes a series of 'Information Bulletins' which contain a comprehen-

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[51] See Lists of Lights, Buoys and Fog Signals--Atlantic Coast, 1975, (Canada: Ministry of Transport Canada, Ottawa, January 1, 1975), Radio Aids to Marine Navigation, Atlantic and Great Lakes, (Canada: Ministry of Transport, Telecommunications, Vol. 20, December 1, 1975), and the weekly edition of Canadian 'Notice to Mariners' for amendments to the above publications.

sive list of all charts and publications. Arctic charts of the pre-1970 period were largely based on aerial photography. Since 1970, a program has been underway to update these charts from controlled topographic and geodetic surveys.

The Canadian 'Notices to Mariners' also contains amendments to correct Canadian charts.

3. Navigation Instructions

Publications of the Ministry of Transport Canada provide information on navigation in ice infested waters and in ice itself.[52]

4. A History of Ice Conditions

Since 1964, the Aerial Ice Reconnaissance and Ice Advisory Services of the Atmospheric Environment Service (AES) have provided a published account and description of ice conditions on Hudson Bay and Strait. Besides including a detailed account of ice observations,[53] the AES provides a summary and analysis of detailed observations.[54]

C. Aids to Navigation Used on Merchant Vessels

Merchant vessels using the Hudson Bay route use the following aids to navigation: echo sounding device; gyro

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[52] These publications include the Ministry of Transport Canada pamphlet Ice Navigation in Canadian Waters, and Radio Aids to Marine Navigation, Atlantic and Great Lakes, which contains details of Aerial Ice Reconnaissance and Ice Advisory Services, Hudson Bay and Approaches, published by the Canadian Ice Advisory Service. The Pilot of Arctic Canada provides additional information regarding ice reconnaissance from aircraft, the operation of ships in ice, the use of aids to navigation, and the broadcasts of ice and weather information.

[53] Government of Canada, Ice Observations, Hudson Bay and Approaches, (Canada: Atmospheric Environment Service, Ottawa).

[54] Government of Canada, Ice Summary and Analysis, Hudson Bay and Approaches, (Canada: Atmospheric Environment Service, Ottawa, 1963-1971).

compass; direction finding device; position fixing device; and radio telephone.[55] The use and limitations of these aids will be discussed below.

1. Radar

All merchant grain vessels using the Hudson Bay route during the period 1970 through 1975 contained radar apparatus. Radar apparatus on vessels is supplemented by seven radar reflectors on the Hudson Bay route. The reflectors provide a reflective surface, and a strong echo, from which the vessel is provided with a bearing.

Radar is also used for the detection of icebergs, growlers, and for determining leads of open water in ice fields.[56] Radar reduces the possibility of severe damage to vessels. The use of radar for ice detection is particularily important during the hours of darkness and in conditions of poor visibility. A Ministry of Transport Canada study found that in 2000 yards of sea clutter, any ice of sufficient size to be dangerous will be detected beyond the clutter region.[57]

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[55] A survey was carried out on merchant grain vessels using the Hudson Bay route during the period 1970-1975 inclusive. A total of 173 grain vessels used the route during this period; only 148 vessels were listed in <u>Lloyod's Registry of Shipping, 1973-1974</u>. A comparison of this survey with a similar survey for the mid-1950's was not possible because a <u>Lloyd's Registry of Shipping</u> was not obtained for this period. The survey of the aids used in the 1970's is still useful as it gives an indication of the degree to which essential aids are used.

[56] Greater detail is given in section D Appendix B regarding the effect of climate on radar use, and the use of radar for ice detection.

[57] A.D.Hood, "An Analysis of Radar Ice Reports Submitted by Hudson Bay Shipping(1953-1957)", Thirty-Second Annual Report, <u>Navigation Conditions on the Hudson Bay Route from the Atlantic Seaboard to the Port of Churchill</u>, (Canada, Ministry of Transport, 1960), p. 44.

To ensure safety, continuous radar watch is a necessity since a growler entering the clutter region undetected is almost certain to remain undetected.

Due to their shape, growlers and bergy bits are the most difficult types of ice to detect. The same Transport Canada study noted that of the 54 growlers reported, only 22 were detected by radar, all in calm water outside the clutter region. Ice floes were much easier to detect as field ice has a tendency to dampen any sea clutter that may be present. Any large area of open water, such as a lead, can be easily distinguished.

2. Echo Sounding Device

All grain vessels using the Hudson Bay route during the period 1970-1975 inclusive contained an echo sounding device, an apparatus used mainly for depth readings.[58]

3. Gyro Compass

All grain vessels using the Hudson Bay route during the period 1970-1975 inclusive contained a gyro compass.[59] Due to the error or unresponsiveness of the conventional magnetic compass in the western approaches to Hudson Strait, the gyro-magnetic compass has been used in its place.[60] The gyro-magnetic compass has proved to be serviceable for

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[58] See footnote #55 for details on the vessel survey.

[59] Ibid.

[60] This aspect is illustrated in the report of the use of the magnetic compass by Captain Mouat in the western part of Hudson Strait as reported by the Imperial Shipping Committee, Third Report on Hudson Bay Marine Insurance Rates, 1932, (London: Her Majesty's Stationery Office, 1932), p. 4.

navigation up to 200 miles of the north magnetic pole and has the additional advantage of serving as a simple magnetic compass should the ship's power fail.[61]

Gyro compasses can be prone to variable errors when used for bearings. However, these errors may be detected by obtaining suitably spaced radar fixes.

4. Direction Finding Device (DF)

All grain vessels using the Hudson Bay route during the period 1970-1975 inclusive contained direction finding apparatus.[62] A vessel can determine its bearing and/or range from the radiobeacon transmitting shore stations by the use of its own DF apparatus and/or communications receiver, but without the necessity of establishing communication with the transmitting station except, in certain cases, for the transmission of a request for beacon service.[63]

5. Position Fixing Device (PFD)

A survey of 148 grain vessels using the Hudson Bay route during the period 1970-1975 inclusive shows that 60 vessels contained PFD.[64] In addition, all Canadian Coast Guard vessels, with the exception of the CCGS John A. MacDonald and the CCGS Labrador, contain PFD.

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[61] Government of Canada, <u>Pilot of Arctic Canada</u>, Vol. 1, 1970, 2nd., (Ottawa: Canadian Hydrographic Service, 1970), p. 111.

[62] See footnote #55 for greater detail.

[63] The radiobeacon stations and corresponding vessel apparatus used on the Hudson Bay route are medium frequency direction finding apparatus (MF/DF).

[64] See footnote #55 for greater detail.

Position fixing devices include the Decca and Loran navigation system. Decca is intended for coastal and landfall navigation while Loran is intended mainly for ocean navigation. Decca receivers are not found on the Hudson Bay route while the Loran system can be applied only in approaching Hudson Strait from the east.

D. Pilotage Service at the Port of Churchill

Pilotage service at Churchill is seasonal and operative for approximately three months in the year from the last week in July to the last week in October.[65] It is not a full-time occupation and is conducted by the Port Warden (pilot) and Deputy Port Warden under the unofficial direction of the port Manager, who acts as Harbour Master and is responsible for all movements of ships within the harbour limits.

The duties of the two pilots are confined to the pilotage of ships inward and outwards, including berthing, unberthing and movages inside the harbour with the assistance of the two tugs. The pilot's operation is aided by the long twilight of the short summer season.

Shipping statistics and records indicate that, with the exception of small craft, all ocean-going and coastal vessels employ the services of a pilot including occasional vessels that are exempt, depending on the Master's knowledge of the harbour and the prevailing weather conditions. The

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[65] Government of Canada, Report of the Royal Commission on PILOTAGE, Part II Study of Canadian Pilotage Pacific Coast and Churchill, (Ottawa: Queen's Printer, 1968), p. 410.

skilfulness and reliability of the pilots employed at Churchill is borne out by an unblemished record of no major casualty since the port opened.[66]

E. Icebreaker Use on the Hudson Bay Route

During breakup at least two icebreakers are employed in the Hudson Strait area. In early July, an icebreaker enters the Strait to activate and service the shore aids to navigation in the area. At the beginning of the shipping season an icebreaker is available in the Strait to provide reconnaissance and/or escort vessels through ice congested areas. This icebreaker is usually located in areas where heavy concentrations of ice may retard the progress of shipping.

At the end of the shipping season, a heavy icebreaker is based at either Frobisher Bay or in the vicinity of the Strait, awaiting the departure of the last vessel from the Strait. The N.B. M^{c}Lean is also stationed at Churchill awaiting the departure of the last vessel from Churchill, whereupon it deactivates all aids to navigation. After leaving Churchill, the N.B. M^{c}Lean remains in Hudson Strait until all other vessels have cleared the area.

F. Repair and Salvage Facilities on the Hudson Bay Route

The nearest heavy repair facilities are 2000 miles from Churchill at St. John's, Newfoundland. The repair fac-

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[66] Op.Cit., p. 412.

ilities at Churchill have not changed since the 1930's. The same type of repairs are still being carried out, but now with modern equipment. The plate shop at the Churchill elevator is equipped for handling no more than 1/4 inch plate intended for elevator repairs. Repairs to damaged vessels must be done above the water level with assistance from cranes at the berth.

The N.B.M^{c}Lean, a CCGS icebreaker, is stationed on the Hudson Bay route throughout the navigation season. It is equipped for towing vessels and providing rescue operations. Other CCGS icebreakers stationed on the route during the shipping season include the d'iberville, the Wolfe, and the John A.MacDonald. Derricks found on these vessels are much more powerful than those of the N.B. M^{c}Lean.

G. The Type of Grain Vessel Used on the Hudson Bay Route

The type of merchant grain vessel used on the Hudson Bay route has changed in the last two decades from bulk carriers with a draft of less than 30 feet to use of larger bulk carriers with a draft of greater than 30 feet. Records on the size of vessels used at the port of Churchill show that the number of grain vessels approaching maximum size capabilities has been steadily increasing. Historically, the number of grain vessels using Churchill has decreased from a high of 58 in 1959 to an average of around 30 in the 1970's.[67]

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[67] Government of Canada, Churchill: Canada's National Harbour of the North, (Ottawa: National Harbours Board, 1973), Table IVA.

Seasonal grain throughput increased by approximately 11.5 million bushels or an increase of 88 per cent between 1955 and 1971, the dates for the last significant changes in insurance coverage.[68] At the same time, the average cargo size increased from .34 million bushels in 1955 to .70 million bushels in 1970 and a high of .78 million bushels in 1969. The average cargo size has recently changed to 1.15 million bushels in 1975 (Table 4). In addition, the net registered tonnage (NRT) of ocean vessels using Churchill has steadily increased from 4260 NRT in 1959 to 8750 NRT in 1972, an increase of 106 per cent.[69] Comparable figures after 1972 were not obtained.

Table 4 The Average Size of Grain Cargoes Loaded at the Port of Churchill (millions of bushels)

Year	1950	1955	1958	1959	1960	1961	1962	1963	1964
Shipments	20	38	55	58	48	48	49	48	41
Size	.34	.34	.36	.38	.41	.40	.44	.48	.53
Year	1965	1966	1967	1968	1969	1970	1971	1972	1975
Shipments	45	40	33	34	28	35	36	30	20
Size	.55	.55	.63	.66	.78	.70	.70	.84	1.15

Source: National Harbours Board

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[68] *Op.Cit.*, Table IIF

[69] *Op.Cit.*, Table IVA.

H. Ice Reconnaissance

1. Ice Reconnaissance Aircraft

Ice observing in the Hudson Bay region commenced in 1948 on an experimental basis. Since 1957, on a regular basis for at least the length of the shipping, ice reconnaissance flights covering Hudson Bay, Hudson Strait, Foxe Channel, James Bay, Frobisher Bay, and the northern Labrador coast have been conducted by Ministry of Transport Canada aircraft based in either Frobisher Bay or Churchill.

Ice reconnaissance flights now commence in early spring with periodic coverage provided in the area in each of March, May, and June. The frequency of flights during the period July through November has varied from year to year depending upon ice conditions and the extent of shipping. During this period, flights, which are normally scheduled two times per week, provide information to account for ice movements and a shipping lane for the next three to four days or until the next reconnaissance flight.[70] Ice monitoring during breakup is given more emphasis than monitoring during freeze-up.[71] During the ice free period, reconnaissance flights are cancelled with the exception of a high Arctic reconnaissance flight passing over Hudson Strait in route. Reconnaissance data is upgraded during any part of the year by ice observers working from flights of the Canadian Armed Forces.

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[70] Ice information for the shipping route must be obtained by the Master of a vessel before entering Hudson Strait prior to 10 August.

[71] Mr. Einarson, Atmospheric Environment Service, Correspondence, Winnipeg, Manitoba, 16 September 1976.

A field unit consists of a reconnaissance field manager assisted by as many ice observers as necessary. The two Lockheed, Electra L-188C aircraft, which are avaiable to provide reconnaissance, contain accurate navigation equipment employing dual Omega and Inertial Navigational Systems, including a ground mapping radar to assist in navigational accuracy and to determine positions of significant ice edges and other features. Remote sensing equipment includes a tri-metrigon aerial camera, an infra-red line scanner which provides information on areas of thin ice, and a lasser profilometer which provides information on ridge heights and frequencies.

The most severe limitation of the current aircraft observations is the inability to obtain reconnaissance during heavy cloud and adverse weather conditions. An all-weather, day-night sensor is available but the price is high. AES is proposing to introduce this system in 1978.[72]

Ice reconnaissance aircraft are also equipped with airborne facsimile transmitters to broadcast ice observations directly to ships. The aircraft surveys the area within approximately 100 miles of the ship, maps the ice on a real time basis, and broadcasts data in chart form directly to the ship. This data will provide routing of the ship for the next 12 to 15 hours.

The data relay to Ice Forecasting Central in Ottawa

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[72] W.E. Markham, Chief, Ice Climatology, Ministry of the Environment, Ottawa, Correspondence, 31 May 1976.

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is considered the weakest link in the system.[73] The ice charts are sent by landline to Edmonton. The raw data is passed on to Ice Forecasting Central using broad-band or regular telephone lines. From Ice Forecasting Central, the data is sent to Halifax using a broad-band channel. A facsimile broadcast in five H.F. radio frequencies is conducted twice daily up to forty minutes at a time from the Canadian Forces Base transmitter at Halifax. A scheduled facsimile transmission is made on days when an ice reconnaissance flight is made. In addition, ice briefing and advisory services are provided during the navigation season by Ice Forecasting Central, and by weather offices in the north including Churchill, Frobisher Bay and Resolute Bay, all on a 24 hour basis.[74]

The Hudson Bay route also has immediate access to eleven radio stations plus four coast guard radio stations.[75] In comparison, the route contained only four radio stations in the mid-1950's.

2. Satellite Systems

The effectiveness of meteorological satellites has progressed since the early 1960's with the use of TIROS to use

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[73] W.E. Markham, Modern Demands on the Canadian Ice Advisory Service (Inter-disciplinary Symposium on Advanced Techniques in the Study of Snow and Ice Resources, Monterey, California, December, 1973).

[74] Additional information on the broadcast of daily tactical forecasts, special tactical forecasts on request, thirty-day ice forecasts, and radiofacsimile broadcasts is found in the Atmospheric Environment Service publication Aerial Ice Reconnaissance and Ice Advisory Services, Hudson Bay And Approaches.

[75] See figure C.1. This count does not include the radio stations at Eskimo Point, Rankin Inlet, and Chesterfield Inlet.

of the more recent NOAA and LANDSAT satellites. AES receives facsimile weather pictures, taken by NOAA satellites, from their receiver stations in Vancouver, Halifax and Toronto, and transmits this data by teletype to Ice Forecasting Central and to other places across Canada. LANDSAT 'quick look' imagery also has been obtained from Donald Fisher Associates at Prince Albert, Saskatchewan.[76]

The twice daily coverage of NOAA permits examination of changing distribution of ice in cloud free areas. The VHRR imagery allows good ice-mapping capabilities with details of floe, lead and fracture patterns. Experiments with NOAA imagery have shown that information on ice type and ice thickness can be obtained with the infra-red imagery.[77] Obstruction of the earth's surface by cloud is a significant problem in the interpretation of ice extent in satellite photographs. A technique known as minimum brightness compositing (CMB) has been developed with the use of NOAA imagery. The use of adjusted CMB average has resulted in the ability to distinguish ice pack and conditions. A major disadvantage is the five day processing period for a CMB chart.[78]

LANDSAT, in use since 1972, has provided much higher

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[76] A LANDSAT read out station is also being built near St. John's, Newfoundland.

[77] L.A. LesChach, Potential Use of Satellite I-R Data and Numerical Analysis for Near Real Time Ice Thickness Forecasting in the Beaufort Sea, (San Francisco: Beaufort Sea Symposium 1974).

[78] E. Paul McClain, Remote Sensing of Sea Ice from Earth Satellites, (United States Government Sponsors, International Workshop on Earth Resources Survey Systems, May 3-14, 1971), 2-582.

resolution data than previously available. The satellite repeats its same ground track every 18 days.[79] In the high Arctic the coverage may be as many as 10 consecutive days out of 18 because of overlap of orbital tracks. There is no night time capability nor cloud penetration. During the Arctic summer nights it may be possible, when there is sufficient light, to obtain coverage during the ascending satellite orbits and thereby double the coverage.

The high resolution means considerable detail can be obtained on ice movement including the development of fractures leading to the formation of distinct ice floes, the growth and deterioration of leads, shearing movements of ice masses, the formation of new grey ice within leads, the distinction between young and older forms of ice and the deterioration of ice surfaces evidenced by the formation of puddles, thaw holes and drainage patterns.[80] The high resolution permits observation of larger icebergs and their patterns. The accumulation of high detail data from LANDSAT over a long period of time is invaluable in building up a history of ice movements, type and condition.

Delivery of data to Ottawa using broad-band or regular telephone lines can be accomplished in an hour or two

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[79] A.K. Quillan, Donald J.Clough, <u>Benefits of Remote Sensing of Sea Ice</u>,(Ottawa: Canada Centre for Remote Sensing, Ministry of Energy, Mines and Resources, December, 1973), p. 3.

[80] J.C. Barnes, and C.J. Bowley, <u>Use of ERTS Data for Mapping Arctic Sea Ice</u>, (Symposium on Significant Results from ERTS-1: Proc., New Carrollton, PU, March, 1973), 1.B.-1377.

after satellite pass. The relay of raw data to ships is usually done on a schedule basis with significant delays possible.[81] Reduction of this interval is currently being studied by the Ministry of the Environment Canada. A high quality communications link for the transmission of data to Ottawa and relay to ships and shore stations in the Arctic is possible as illustrated by the project to demonstrate near real time facsimile transmission of sea-ice satellite imagery.[82] All agencies found that cloud free data was useful to their operation. A conclusion of this project was that more frequent coverage from LANDSAT and the use of satellite borne microwave radar, which would eliminate loss of data in cloud covered areas, would significantly improve the usefulness of this service.

Radar satellites are being planned for the early 1980's. There are many problems to resolve, not the least of which is data relay and communication channels. An operational system in this regard is probably at least ten years away. However, because of its expense, such a program is more appropriate on an international rather than on a national scale.[83]

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[81] The routine followed is: 1) prepare a microfiche daily for distributionby mail, 2) a picture fax relay is used on a real time basis during the summer. The data is <u>not</u> relayed to other locations or to ships except by special arrangements.

[82] E. Shaw, 'Near Real-Time Transmission of Sea-Ice Satellite Imagery', <u>Third Canadian Symposium on Remote Sensing, 1975</u>, (Ottawa: Canada Centre for Rmote Sensing, Ministry of Energy, Mines and Resources, 1975), p. 3.

[83] W.E. Markham, Chief, Ice Climatology, Ministry of the Environment, Ottawa, Correspondence, 31 May 1976.

I. Ice Forecasting

1. Slush Ice in Churchill Harbour

The formation of slush ice seems to be a result of the atmospheric temperature. Ice production commences in the river in advance of the sea because the fresh water of the Churchill River responds to atmospheric cooling more quickly than sea water.[84] The high correlation between dates of Churchill harbour closure to navigation and mean October temperature indicates a strong relationship between the two variables.[85] Earlier research results note that the time of harbour closure at Churchill can be estimated with fair accuracy (with a standard deviation of 2.6 days) on the basis of temperature alone.[86] Historical records show that in most instances when Churchill harbour remained open to navigation in November, mean October temperature was above the freezing point.[87] Slush ice will not be produced unless the temperature is below the freezing point.

2. Hudson Bay and Strait

The AES prepares a 'seasonal outlook' for Hudson Bay in early June. Thirty day ice forecasts issued twice monthly

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[84] T.Milne Dick, <u>Feasibility of Extending Navigation Season at Churchill Harbour</u>, (National Research Council of Canada, Ottawa, December, 1966), p. 24.

[85] Thomas Henley, <u>The Impact of Manitoba's Hydro's Churchill River Diversion on the Length of the Navigation Season at the Port of Churchill</u>, (Natural Resource Institute, University of Manitoba, Winnipeg, 1974), p. 16. 'Harbour closure' refers to the occurrence of slush ice.

[86] MacKay, MacKay, <u>Op.Cit</u>., p. 16.

[87] See Table B.4.

begin in mid-June and continue until early October.[88] The accuracy of ice forecasts is in the 70 per cent range. The trends in ice movement behaviour are usually accurately indicated. "Bust" situations can be avoided as movement analysis is much more conservative than weather analysis.

The ice forecasting analysis found that the ice conditions of, say, November are not related to the localized weather situation of that month but are related to the three month period prior to November.[89] This finding may provide for a more accurate thirty day forecast. A more thorough analysis by the AES may enhance the following results for breakup and freeze-up at the western approaches to Hudson Strait.

a. Breakup

Late breakup seems to be characterized by a mean daily temperature and a total monthly precipitation of less than or approximately average for the three month period prior to July. The same characteristic was found to hold true for the three month period prior to April.

Two climatic relationships seem to exist for the three month period prior to early breakup in July. Either

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[88] W.E. Markham, Chief, Ice Climatology, Ministry of the Environment, Ottawa, Correspondence, 16 June 1976. Atmospheric and oceanographic factors, specifically wind, temperature, solar input, and currents, are the major factors used in ice forecasting. One, three, five, or thirty day forecasts of mean wind and temperature departure from normal can be used as well as analogue comparisons with previous years.

[89] A detailed account of the ice forecasting analysis is found in Appendix B. See the Glossary for a definition.

mean daily temperature and total monthly precipitation was average or mean daily temperature was below or at average while precipitation was well above average.

b. Freeze-up

In 'most unfavourable' years the three month period prior to November had a mean daily temperature of less than average. In addition the mean daily temperature for June and July was below average. In favourable years, the three month period prior to November had a mean daily temperature greater than or approximately average.

For 'most unfavourable' years, first permanent ice resulted in late September or early October. First permanent ice occurred in favourable years after or at approximately the average date of 19 October. The extent of dissipation of first-year ice in Foxe Basin during the summer period is also an indication of early or late freeze-up conditions.

J. A Solution to the Slush Ice Problem in Churchill Harbour

The various schemes for the mitigation of the slush ice problem, with the exception of icebreaker use, have been discussed in various reports.[90] The alternative solutions are as follows:

1. Compressed air systems and submersible pumps.

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[90] Bruce Pratte, Progress Report on Churchill Harbour Model, (Ottawa: National Research Council of Canada, 14 March, 1975).
Hedlin Menzies, Op.Cit., Appendix D.
T.M. Dick, Op.Cit.

2. New channel to alter current distribution.
3. Ice boom.
4. Deflecting groin.
5. Complete protection of the wharf and turning basin.
6. Diversion of the Churchill River above the harbour.
7. Breakwater (dyke) at the south end of the dock.
8. The effect of the diversion of the Churchill River into the Nelson River by Manitoba Hydro.

The construction of a simple tidal barrier seems to be the best alternative. A tidal barrier would eliminate the strong tidal current along the face of the wharf so that any remaining slush ice would not be a problem. A tidal barrier would have the further advantage of reducing currents in the harbour entrance to negligible proportions. In the event of the need for an extension of the shipping season beyond the slush ice phase, the elimination of strong currents would also simplify dealing with sheet ice in the harbour by means of an icebreaker, compressed air systems or submersible pumps.

K. Shipping Regulations

The only shipping regulation which may have an effect on marine insurance coverage is the Arctic Shipping Pollution Prevention Regulations (ASPPR) which became law in October 1972.[90] Included in these regulations are the amendments of 21 January 1974,[91] and the Shipping Safety Control

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[90] Other regulations are listed in the Pilot of Arctic Canada, Sailing Directions Labrador and Hudson Bay, or the Canadian 'Notice to Mariners'.

[91] Government of Canada, 'Arctic Shipping Pollution Prevention Regulations', Canada Gazette, Part II, Vol. 106, No. 20, 10 October 1972, Amendments C.G. PartIII, Vol. 108, No. 3, 21 January 1974. The amendments of 21 January 1974 provides a 'Table' showing the type of vessel and corresponding ice class for each of seven existing shipping registers.

Zones Order.[92]

ASPPR is the Canadian law which governs the time period for which vessels are allowed to navigate on the Hudson Bay route and on other Arctic waters under Canadian jurisdiction. It is also a guideline for Canadian Hull Advisory Committee insurance which restricts the use of Canadian owned, conventional, unstrengthened vessels to between 20 July and 31 October.

L. An extension of the Shipping Season and the Use of Ice Strengthened Vessels

1. Unstrengthened Vessels, Unassisted

In comparison to the Lloyd's shipping season between 23 July and 15 October, Canadian owned, conventional unstrengthened vessels can use the Hudson Bay route between 20 July and 31 October.[93] On the other hand, an analysis of ice conditions on the Hudson Bay route shows that the average navigation season is between 20 July and 10 November.[94] A shipping season between 20 July and 7 November (Figure 4) is possible

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[92] Government of Canada, 'Shipping Safety Control Zones Order', Canada Gazette, Part II, Vol. 106, No. 16, 2 August 1972. The Shipping Safety Control Zones Order sets out the Arctic water zones as defined for each class of vessel. Included in this order is Schedule H of ASPPR and the corresponding mapped zones. These schedules indicate the order of maximum ice thickness for which a vessel must be structured for the various Arctic zones for the various dates.

[93] A definition of strengthened and unstrengthened vessel is found in the Glossary. In the 1970's, unstrengthened vessels using the Hudson Bay route have increased in size and seem to have the power to navigate in young ice.

[94] All data in this section assumes that the problem of vessel manouverability in slush ice in Churchill harbour can be mitigated.

allowing three days to pass the western approaches to Hudson Strait.

The Hedlin Menzies report states that at the beginning of winter when ice is forming, unstrengthened vessels of average size and power could make good progress through continuous young ice of up to 10 cm. (4 in.) thick.[95] A ship caught in ice of up to 10 cm. will have two to three days to clear Hudson Strait before thin winter ice forms. An examination of ice conditions on 5 November show that, with the exception of unfavourable years for ice conditions, ice had developed to the new and nilas stage when it occurred on the shipping route.[96]

Therefore, 7 November would seem to be a reasonable date for unstrengthened unescorted vessels to leave Churchill on the assumption that icebreaker assistance could be received in an exceptional year as 1965. A possible late season route in the Bigges Island area may lengthen the navigation season beyond 10 November for unstrengthened vessels and more likely for bow strengthened vessels.[97]

2. Unstrengthened Vessels, Icebreaker Assistance

Icebreaker escort will improve the capabilities of

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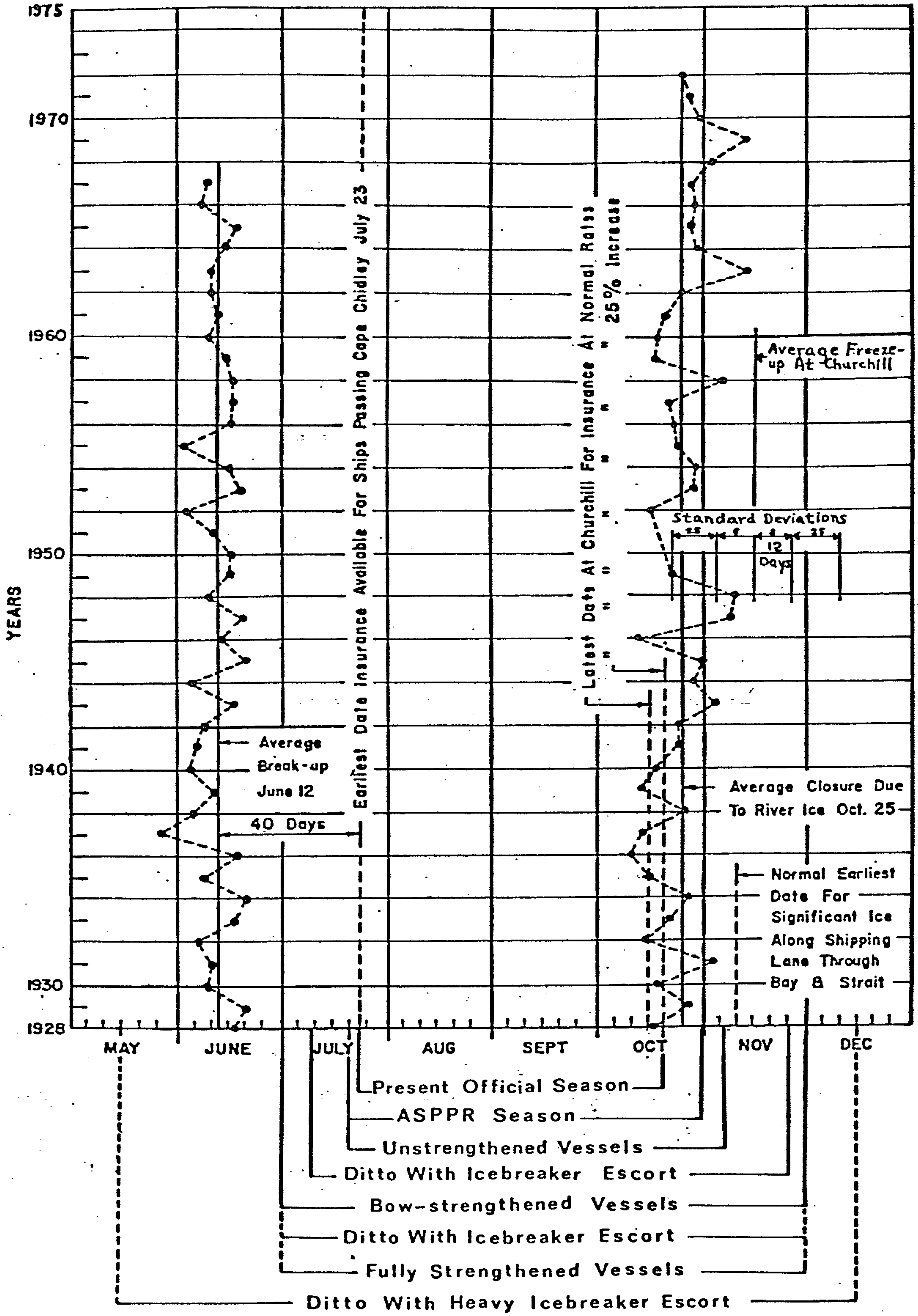
[95] Hedlin Menzies, Op.Cit., 2-27.

[96] For the period 1964 through 1971, new and nilas ice occurred in four years either outside Churchill harbour or at the western approaches to Hudson Strait, or at both on 5 November.

[97] For additional information see Commonwealth Shipping Committee, Seventh Report on Hudson Bay Marine Insurance Rates, 1936, (Great Britain: Her Majesty's Stationery Office), 1936, and Willis A. Richford, President, Hudson Bay Route Association, A Presentation to the Marine Underwriters Visiting Churchill, (Churchill Manitoba, August 25, 1972), p. 4.

Figure 4 POSSIBLE EXTENDED SHIPPING SEASON



unstrengthened vessels only to a limited degree in thick winter ice which is not attained until well into winter. In any kind of ice, the vessel must not follow too close in case the icebreaker is suddenly slowed down by the ice. Consequently, there is often time for floes to drift into the lead formed by the icebreaker and to damage the escorted vessel unless slow speed is being maintained.[98]

Icebreaker assistance may be of greater value at the end of the shipping season for escort through young or early winter ice. Icebreaker assistance seems to be feasible at least until 19 November and probably for a week beyond this date to 26 November.[99]

With icebreaker assistance it would be reasonable to advance the opening of the shipping season for unstrengthened vessels by at least one week to 16 July and probably by two weeks to 9 July in average years. Ice concentration is greater in the period 9 July to 16 July warranting icebreaker assistance. Icebreaker assistance may not be necessary after 16 July if reconnaissance assistance is available from aircraft, shore stations and icebreaker.

3. Vessels with Strengthened Bows, Unassisted

An adequately strengthened bow will enable a vessel with full power to make good progress through winter ice having a concentration of six tenths.[100] The danger of damage

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[98] Hedlin Menzies, Op.Cit., 2-29.

[99] This analysis is restricted by the lack of ice data after 19 November.

[100] Hedlin Menzies, Op.Cit.

to the rest of the hull, if beset in heavy wind-driven ice, remains.

ASPPR sets the shipping season for bow strengthened vessels (Arctic Class I) between 1 July and 30 November. An analysis of this shipping season is limited by a lack of ice data after 19 November. Regardless, the ice regime on this date allows for the use of vessels with strengthened bows beyond 19 November.[101]

4. Vessels with Strengthened Bows, Icebreaker Assistance

Estimation of a shipping season for convoys of this type is difficult because ice observations are not available beyond 19 November. Heavy ice concentrations up to the first week in July may not permit vessels other than fully strengthened vessels through substantial areas of nine-tenths pack ice even with icebreaker assistance. Better knowledge of ice thickness at this time may enhance this analysis.

Regardless, icebreaker assistance would allow vessels with strengthened bows to proceed more quickly through higher concentrations of winter ice. Assistance would also reduce the danger of the vessel becoming beset in very close pack ice.

5. Vessels with Full Ice Strengthening, Unassisted

The shipping season for the least fully strengthened vessel, Lloyd's Arctic Class 1A, is 1 July to 30 November.

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[101] In four years during the period 1964 - 1971, the route contained young ice in the area outside Churchill or in the western approaches to Hudson Strait on 19 November. In the other four years, with the exception of 1965, the extent of ice was much greater in the same area.

Vessels which are fully strengthened to a greater degree can use the route beyond these dates.[102] The use of ice reconnaissance techniques would speed up progress through pack ice.

6. Vessels with Full Ice Strengthening, Icebreaker Assistance

With a sufficiently powerful icebreaker, it would be technically possible to keep the Hudson Bay route open all year round. At the beginning of the shipping season, with a modern icebreaker of adequate power, the escort of strengthened ships through Hudson Bay and Strait would be possible and not unreasonable from the time that thawing begins, and the concentration of ice begins to lessen, in mid-May. Similarily, at the end of the shipping season, icebreaker escort is feasible beyond mid-December. The ability of an icebreaker on the Hudson Bay route at this time of the year has been demonstrated by the visit of the CCGS Louis S. St. Laurent to Churchill from 2 to 4 December 1970, the latest date any ship has arrived at Churchill.[103]

M. Summary of Technological and Ice Forecasting Advances

1. Shore aids to navigation have improved in location and increased in number since 1955, the year of the last signif-

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[102] Lloyd's Arctic Class Vessels 6 through 10 have the capability to use the Hudson Bay route all year round. Figure 4 shows only the season for Lloyd's Arctic Class 1A.

[103] Wes D. Graham, 'The Impact of New Technology on Northern Transportation', Proceedings of the Seminar on Transportation, 1970-1971, Edited by A.H. Soliman, (Winnipeg: Center for Transportation Studies, June 1971), Vol. 4, p. 64.

icant change in marine insurance coverage on the Hudson Bay route prior to 1971.

2. Written aids to navigation including aids to navigation, charts, navigational instructions, and especially the historical data processing of ice conditions have also been updated since the mid-1950's.

3. All merchant grain vessels using the Hudson Bay route are equipped with all the essential navigation devices, including radar, echo sounding device, gyro-compass, and direction finding devices, to complement the shore aids to navigation. Radar is important for navigation on ice routes such as the Hudson Bay route, The limitations of radar should, however, be realized.

4. Ice forecasting and reconnaissance techniques used on the route have improved considerably since the late 1950's. Future improvement of these techniques will have a greater impact on shipping at and beyond the extremes of the shipping seaason.

5. In comparison to the 1950's and 1960's, there has been a trend in the 1970's to using larger grain vessels on the Hudson Bay route.

6. The Arctic Shipping Pollution Prevention Regulations now restrict the use of conventional unstrengthened vessels to 104 days between 20 July and 31 October as modified by Masters of the CCGS Icebreakers and Ice or Pollution control officials. The use of ice forecasting and reconnaissance techniques provides for a navigation season up to 10 November in most years.

CHAPTER V

DISCUSSION

The preceeding chapters examined the reasons for the study and the factors affecting marine insurance coverage. This chapter will integrate the information regarding the factors affecting marine insurance coverage to arrive at an adjustment for the length of the shipping season and marine insurance rates.

A. The Relationship Between the Slush Ice Problem and the Length of the Shipping Season

As defined by marine insurance coverage, vessel use and harbour closure at the port of Churchill in the autumn seem to correspond to the average slush ice formation date of 25 October. The continued use of experienced pilots and the future use of icebreakers during the slush ice period may mitigate some of the problems associated with navigation in slush ice. Past experience show that vessels will not be damaged in slush ice. Thus the shipping season at Churchill harbour should correspond to the shipping season on the remainder of the Hudson Bay route. The problem with slush ice is centered around keeping the vessel moored at the dock while loading takes place and turning the vessel for departure. A physical solution besides the use of icebreakers is currently being discussed by the National Harbours Board.

B. The Relationship Between Ice Conditions on the Hudson Bay Route and the Length of the Shipping Season

The history of ice conditions on the shipping route to Churchill via Hudson Bay and Strait warrants the use of conventional unstrengthened vessels beyond the limits of the present shipping season. The duration of marine insurance coverage has limited the throughput of the port of Churchill which may be realized by a longer shipping season.

During freeze-up, vessels should clear 77° W latitude by at least 31 October in unfavourable years, 10 November in average years, and 15 November in favourable years. In average years, new, nilas, and grey ice may be encountered on the route during the first half of November and/or late October. Ice of this type will not hinder the use of unstrengthened vessels. Watch should still be kept for polar ice which is very infrequent during the freeze-up period.

During breakup, vessels can pass Cape Chidley by 20 July in average years as ice conditions are not much different from ice conditions on 23 July. In favourable years with the use of regular aids to navigation, navigation is possible by approximately 15 July or as estimated by officials of the Atmospheric Environment Service and/or the Arctic Shipping Pollution Prevention Regulations. However for earlier navigtion, the beginning of ice surveillance and servicing of the route by icebreaker and aircraft should commence at an earlier date. The commencement of navigation in unfavourable years should correspond to estimates made by the officials of ASPPR and AES.

Small floe ice in low concentrations is present on the shipping route at the beginning of the shipping season. This characteristic warrants the use of conventional unstrengthened vessels in the type of ice which may be encountered on the route in the first half of November and/or late October.

Therefore the London Underwriters should lengthen the shipping season on the Hudson Bay route to correspond to the standard dates of shipping between 20 July and 10 November to be modified by the Master of the CCGS Icebreaker in the area and/or the Ice or Pollution Control officer for the area.

C. The Relationship Between the Arctic Shipping Pollution Prevention Regulations and the Length of the Shipping Season

Shipping with the use of conventional unstrengthened vessels is restricted by the ASPPR shipping season of 20 July to 31 October as modified by the Master of the CCGS Icebreaker in the area or by the Ice or Pollution Control Officer for the area. As a result, shipping on the route can take place prior to 20 July and after 31 October as modified by the officials named above.[104] Regardless, the shipping season, as defined by ASPPR which directly affects Canadian Hull Advisory Committee

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[104] This shipping season, set by Canadian Hull Advisory Committee insurance which is directly affected by ASPPR, applies to only Canadian Flag vessels. Foreign vessels usually use the route during the London Shipping season.

insurance, should correspond to the average opening and freeze-up dates of 20 July and 10 November respectively on the Hudson Bay route to be modified by the official named above.

Failure of ASPPR official to expand the ASPPR shipping season may limit the future shipping season as defined by London insurance. If the shipping season for London insurance is lengthened, it may not be made as flexible as the ASPPR shipping season. Historically, the London shipping season has not been flexible with the exception of possible bidding for insurance for shipping beyond the limits of the standard shipping season. Thus if the present ASPPR shipping season for unstrengthened vessels is not extended, the London shipping season may correspond to the ASPPR season if the London season is extended.

Another problem which may arise is the scheduling of vessels well in advance for a modified shipping season beyond or prior to the limits of the standard shipping season. Sales of grain through Churchill would also have to correspond to the modified segments of the shipping season. Ice forecasting and reconnaissance would have to be correlated closely with the scheduling of grain vessels by the Canadian Wheat Board and other charterers. As more experience is gained, the standard shipping season should correspond to shipping between 15 July and 15 November to be modified season by season by the appropriate officials. The extension of the standard shipping season must be adopted by ASPPR officials to be valid.

D. Icebreaker Use and An Extension of the Shipping Season

For an extension of the shipping season during the breakup period, icebreaker use should continue as in previous years, however with commencement of duties at an earlier date. During the period of extension, say between 15 and 20 July in favourable years, and also beyond 20 July until the first week in August, the icebreaker should continue to provide reconnaissance support if it is not convoying merchant vessels through ice. Navigation prior to 20 July in average years warrants the employment of more extensive coverage.[105]

At the end of the shipping season, the N.B. McLean is stationed at Churchill waiting for the departure of the last merchant vessel. For an extension beyond the limits of the present shipping season, an icebreaker should continue to be based at Churchill prior to commencement of the slush ice period but now with the duties of assisting vessels when required. Depending on ice forecasting and reconnaissance information, the icebreaker stationed in Hudson Strait until the end of the shipping season should be employed in the western approaches to Hudson Strait to assist vessels if required.

Icebreaker use in Hudson Strait at the end of the shipping season terminates when the last vessel clears Hudson Strait and shore aids to navigation are deactivated. Procedural changes pretaining to icebreaker use for an extension of

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[105] "More extensive coverage" does not necessarily mean the use of an additional icebreaker, but may include the additional assistance of real time air reconnaissance.

of the shipping season would not be a problem because the present philosophy of icebreaker support would continue.[106]

E. The Basic Insurance Premium on Vessels Using the Hudson Bay Route

The basic insurance premium on vessels using the Hudson Bay route is determined through competition. The volume of grain or total tonnage shipped via the St. Lawrence route is much greater than that for the Hudson Bay route. As a result, the basic premium paid on the Hudson Bay route is probably much higher than the basic premium paid on the St. Lawrence route.[107] However, rather than basing insurance on the tonnage statistics, insurance rates for each route should be determined by a ratio involving both insurance paid out and insurance paid in. A ratio of this type may provide for more equitable rates on the Hudson Bay route in relation to the St. Lawrence route. With the exception of salvage and repair facilities, the CSC has spoken of the Hudson Bay route as being safer than the St. Lawrence route. Therefore, seemingly higher than normal rates for the basic premium on grain vessels using the Hudson Bay route may have limited the throughput of the port of Churchill during a shipping season of present length.

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[106] Jacques Dion, Public Relation Liason, Transport Canada, Correspondence, 30 September 1976.

[107] As discussed in Section D, Chapter VI, the analysis is limited due to the availability of basic insurance rates paid on the Hudson Bay and St. Lawrence routes.

F. The Minimum Additional Premium on the Hudson Bay Route

The additional or route premium on vessels using the Hudson Bay route may have limited the potential grain throughput of the port of Churchill during a shipping season of present length. The additional premium has been required on the Hudson Bay route since 1931 due to the extra risk, presumably ice conditions and vessel type, found on the route at that time. This extra risk clause in 1931 applied to tramp vessels normally employed on routes of this type. However, since 1931 and even more so since the mid-1950's, the vessel type and aids to navigation affecting their use have changed considerably. Between 10 August and 16 October inclusive, ice conditions on the Hudson Bay route are well defined.[108] Records indicate that vessel loss and casualties sustained during this period are infrequent.[109]

Therefore the additional premium should apply to vessels using the route between 20 July and 9 August due to the frequency of ice during this period, and after 17 October due to the occurrence of slush ice in Churchill harbour. However, after additional information has been obtained on vessel operation in small floe ice prior to and also after 20 July and in slush ice at the end of the shipping season, the dates

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[108] The 17th of October is the earliest date for the closure of the port of Churchill due to slush ice within the period 1956-1975 which is related to the restriction of marine insurance. Prior to 10 August, Masters of vessels proceeding into Hudson Strait must report in to the Master of the CCGS icebreaker concerning ice conditions on the route.

[109] The three vessel losses during this period resulted from unnatural causes and cannot be blamed on the natural hazards of the route. For additional information see Appendix E.

for the additional premium should be changed to correspond to the adequacy of aids to navigation, and ice reconnaissance and forecasting advances.[110]

The rates for the additional premium should be modified to comply with an improved knowledge of ice conditions on the route since the mid-1950's. Commencing on the forecasted date for permanent ice formation at the end of the shipping season, a 25 per cent surcharge is feasible due to the additional risk from new ice.[111] Prior to 20 July, a 25 per cent surcharge is feasible due to the lack of navigation experience at this time. A summary of the dates and the specific insurance premiums for each part of the proposed shipping season is shown in Figure 6.

G. The Type of Grain Vessel Used Versus Marine Insurance

The trend to using larger grain vessels on the Hudson Bay route has continued from the 1950's until the present. Records show that the average cargo size increased slowly in the late 1950's and early 1960's. This increase accelerated more steadily during the mid-1960's until the early 1970's when the increase became more pronounced (Table 4).

Prior to the 1955 shipping season, the methodology for calculating insurance rates was changed. Rates were now based on tonnage rather than the number of vessels employed each season.[112] During the period 1955-1970 inclusive, rates

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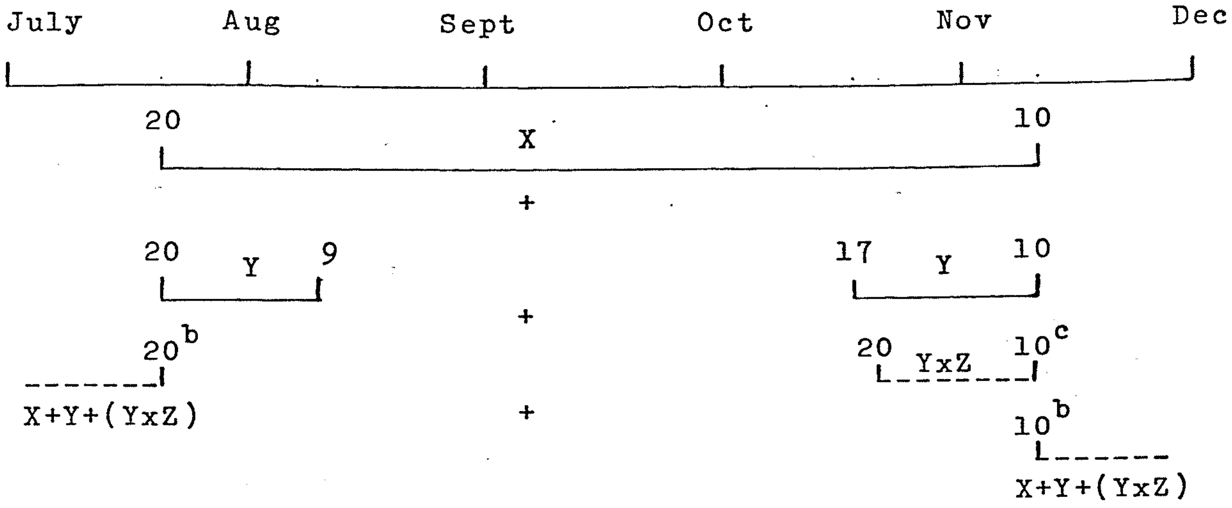
[110] Navigation in slush ice is not a serious problem. Since aids to navigation provide for easier manoeuvrability of grain vessels, the additional premium should be used.

[111] An historical, rather than an actuarial, basis was the reason for using a 25 per cent surcharge.

[112] See Section 1g, Appendix D.

Figure 6 The Use of Insurance Premiums For the Proposed Shipping Season[a]



[a] X = basic premium, Y = additional or route premium, Z = surcharge on additional premium

[b] The rate for this part of the shipping season depends on an adjustment of the standard shipping season.

[c] A surcharge will be charged depending on the forecasted date for permanent ice formation on the route after 20 October.

for the minimum additional premium changed only once. This change occurred prior to the 1956 shipping season. Other than this change, rates for the minimum additional premium did not change even though throughput increased by approximately 12.1 million bushels or by 98 per cent.[113] In addition, the average cargo doubled in size.[114] A corresponding drop in insurance rates as tonnage increased may have resulted in a greater throughput for the port of Churchill.

The number of grain vessels using Churchill decreased

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[113] Research did not uncover any insurance changes between 1955 and 1970 inclusive. The limitations of this aspect are discussed in Section D, Chapter VI.

[114] For additional information, see Section G, Chapter IV.

from a high of 58 in 1959 to 20 in 1974 and 1975, and 27 in 1976. The probability of loss with the use of a smaller number of larger vessels is less than with the use of a greater number of smaller vessels. The loss of a larger vessel would result in a greater amount of insurance paid out in comparison to that for the loss of a smaller vessel. However, due to the infrequent number of losses on the Hudson Bay route, the insurance industry would have no difficulty recouping the market after a loss. After the loss of the 'Bright Fan' in 1932, the CSC stated that if the same number of vessels visit Churchill in the coming as in the past season and there is no further loss, the market will have more than recouped itself by the end of the 1933 season (or 12 vessels later).[115] This suggests that relative to the size of vessel, a loss today would result in a much easier time rebuilding the market due to a greater number of vessels now using the route in comparison to the 1930's.

H. Perils and Information

Information is continually being accumulated regarding navigation conditions on the Hudson Bay route. In relation to this factor, the CSC often stated that the Hudson Bay route is much safer than the St. Lawrence route with the constraint that a smaller number of vessels use the Hudson Bay route each season.[116] In addition, the highest minimum additional premium

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[115] Imperial Shipping Committee, Fourth Report on Hudson Bay Marine Insurance Rates, 1933, (Great Britain: Her Majesty's Stationery Office, 1933), p.4.

[116] See Section 1f, Appendix D, for additional information.

paid on vessels using the Upper St. Lawrence route in the winter season is approximately equivalent to the minimum additional premium on vessels using the Hudson Bay route during the summer season.[117]

On the basis of being a safer route, the insurance rates on merchant vessels using the Hudson Bay route should be lowered in relation to the other major routes in Canada. In addition, information accumulated on navigation conditions on the route, including aids to navigation and ice conditions, warrants an extension of the shipping season. A shipping season of less than possible length may have detracted from the potential throughput possible at the port of Churchill.

I. Ice Reconnaissance and Forecasting

Ice reconaaissance and forecasting is geared towards the assistance of shipping on the Hudson Bay route. The procedures used reduces the risk to shipping during the breakup period. On this basis, the rates for insurance coverage should be reduced. This reduction is not necessary during the freeze-up period as reconnaissance usually recommences after the shipping season for merchant grain vessels ends.

Ice reconnaissance and forecasting procedures warrant a lengthening of the shipping season on the Hudson Bay route. In the latter half of October and in November, reconnaissance

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[117] This comparison, which was made in 1969, was the latest comparison possible due to the limitations of the practicum as outlined in Chapter VI.

procedures should continue as in the past, but with more emphasis on monitoring ice conditions in relation to shipping. During this period, reconnaissance activity should continue to be concentrated in ice areas which will most likely affect the route, namely the Foxe Basin area.

During the part of the shipping season most affected by ice conditions, reconnaissance flights should not be scheduled in a set pattern but in relation to the scheduling of vessel passage. This procedure may result in the use of updated data by the Master of a vessel. This procedure is especially important regarding the safe navigation of vessels using the route early in the shipping season and after the forecasted date for permanent ice formation in the autumn. Coordination of forecasting and reconnaissance with the scheduling of grain vessels should take place between the Canadian Wheat Board, private charterers, and the Atmospheric Environment Service to be of utmost assistance to shipping. Coordination of aircraft reconnaissance and the analysis of ice conditions with real time satellite data may add considerably to aircraft reconnaissance, especially regarding the dates initiated and the funds allocated to the program. Information relay to vessels may also become more reliable.

A modified or moveable shipping season around the standard shipping season of from 20 July to 10 November is feasible due to the accuracy of ice forecasting supplemented by air reconnaissance. During breakup, a favourable year warrants shipping prior to 20 July while unfavourable years warrants a reduction in the length of the shipping season. In the autumn, the shipping season can continue beyond 10 November in favourable years and end prior to 10 November in unfavourable years.

The use of ice forecasting and the frequency of reconnaissance should be examined by the Atmospheric Environment Service to determine precisely the navigation season provided by these procedures. This analysis should concentrate on the breakup period including the period up to 10 August. Ice conditions in relation to casualties during the latter part of this period may warrant increased reconnaissance assistance.[118] In average years, more frequent reconnaissance assistance may warrant the extension of the standard shipping season prior to 20 July.

J. Salvage and Repair Facilities

The CSC stated in the past that the non-availability of adequate salvage facilities on the Hudson Bay route is a major disadvantage of the Hudson Bay route.[119] Regardless of the state of the salvage and repair facilities on the route, historical evidence shows that the only temporary repair is administered to damaged vessels. Damaged vessels receive

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[118] Historically, it seems that the majority of minor casualties take place in the first few weeks of the shipping season. The level of reconnaissance assistance provided in the past 15 years may have decreased the percentage of casualties. The lack of casualty data during this period is discussed in Section D, Chapter VI.

[119] See Section 2d, Appendix D, for additional information.

extensive repair when they are put in dry dock after reaching home base.

Most minor damage sustained on the route is a result of ice damage at the beginning of the shipping season. If reconnaissance assistance has not reduced the number of minor casualties on the route since the late 1950's, the present state of the repair and salvage facilities on the route should be examined.[120] Regardless, with an extension of the shipping season, between say 15 July and 15 November in favourable years, the present employment of aids to navigation may decrease the severity of damage. However, an increase in the number of casualties may result proportionate to the number of voyages.

The type of salvage and repair facilities on the Hudson Bay route has not advanced since the 1930's. However, the present state and use of these facilities should not detract from a lowering of marine insurance rates and a lengthening of the shipping season on the Hudson Bay route.

K. The Necessity of Efficient Pilotage Service at the Port of Churchill

The difficulty of providing for an efficient pilotage service at Churchill to keep intact the past pilotage record of qualifications, skilfulness, and reliability is outlined in the Report of the Royal Commission on PILOTAGE. The efficiency of vessel use at the port of Churchill is jeopardized by financial problems at the port, employment of pilots in

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[120] Data limitations concerning a record of casualties are discussed in Section D, Chapter VI.

some additional official capacity, and employing or retaining experienced pilots.

The importance of maintaining efficient pilotage service is illustrated by the recommendations of the Royal Commission on Pilotage:

> "An efficient reliable pilotage service must be provided at Churcill for a number of reasons; it is an ocean port with special navigational problems; the consequences of a marine casualty are seriously aggravated by its remoteness from repair facilities; maximum use must be made of its facilities because of its short season of navigation; since it is the only seaport in Hudson Bay that will accommodate ocean-going vessels, it is of particular regional and national importance."[121]

> "The national importance of Churchill and its short season make it of public interest that maximum use be made of its facilities when it is open to ocean-going vessels. Hence, all reasonable steps should be taken to enhance its seasonal activities by facilitating ships' movements as much as possible consonant with safety. This aim can only be achieved through an efficient, reliable pilotage service. The Port Warden's Annual Reports...shows that even with the pilots assistance it is not always possible to bring ships into harbour and berth them under very adverse weather conditions. This situation would be seriously affected if a fully efficient pilotage service were not provided...Therefore, it is considered that the pilotage service at Churchill should be classified as an essential public service with the consequences such classification entails, such as compulsory pilotage..."[122]

L. An Extension of the Shipping Season on the Hudson Bay Route and the Opportunity Cost to the Remainder of the Grain Handling and Transportation System

The additional costs incurred to the grain handling and transportation system due to an extension of the shipping

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[121] Government of Canada, Report of the Royal Commission on PILOTAGE Part II Study of Canadian Pilotage Pacific and Churchill, (Ottawa: Queen's Printer, 1968), p. 427.

[122] Op.Cit., p. 428.

season on the Hudson Bay route include the costs required to provide for essential services. For an extension of the shipping season at the port of Churchill, additional costs of grain handling will be commensurate with the present level of services. This cost will result only if additional throughput results during the period of extension.[123] If additional throughput results, all operating costs may be recovered by greater throughput. In the short run, possible construction costs to mitigate the slush ice problem will not be incurred.

For an extension of the shipping season on Hudson Bay and Strait, operation costs may increase as the services of icebreaker and aircraft surveillance increase. Additional service will depend on ice conditions and the extent of shipping, and will be commensurate with the present level of services on the Hudson Bay route. An opportunity cost in this case may result as a benefit to this service.

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[123] The port usually closes when scheduled merchant vessels have cleared the port.

CHAPTER VI

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

A. Summary

The main objective of the practicum was to determine the effect of marine insurance coverage on the movement of grain through the port of Churchill. A second objective was to investigate whether new developments in aids to navigation since the last significant change in marine insurance in the mid-1950's warrant change in marine insurance coverage.[121]

The objectives were achieved by examining many factors including:

1. An examination of ice conditions on the Hudson Bay route, to determine the length of the shipping season, showed that a longer season for merchant shipping is warranted by the type of ice conditions encountered on the route at the ends of the shipping season as determined by a history of ice and navigation conditions.

2. An examination of technological and ice forecasting advances made on the Hudson Bay route since the mid-1950's with the pur-

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[121] There was an important change in the method of calculation of marine insurance coverage for the Hudson Bay route in 1971. This change could not be incorporated into the analysis as illustrated by Section D of this chapter. Regardless, an historical examination of the factors affecting insurance is important.

pose of assessing the impact on marine insurance coverage showed that a) shore aids to navigation have increased in number and strategic placement, b) the essential aids to navigation are being used on merchant grain vessels using the Hudson Bay route, c) ice forecasting and reconnaissance techniques have improved considerably since the mid-1950's in establishing themselves as a new innovation and an advantageous aid to navigation, and d) an efficient pilotage service at the port of Churchill pilotage area, and a record of infrequent total losses of merchant grain vessels have made up for the less than adequate, salvage and repair facilities on the route.

3. An examination of marine insurance coverage on grain vessels using the port of Churchill determined that: a) the factors determining insurance coverage include (1) extra risk pertaining to the additional premium, (2) aids to navigation including shore, ship, and now air, (3) information available on the route regarding aids to navigation, ice conditions, hazards, and the actual experience of navigation, (4) the record of the vessel, (5) tonnage, (6) casualties, and (7) insurance paid out; b) the rates for insurance coverage on the Hudson Bay route are not equitable in comparison to rates charged on the St. Lawrence route; and c) Canadian Hull Advisory Committee Insurance is less expensive and provides for a longer shipping season than London insurance.

4. The integration of the above factors shows that the effect of navigation conditions, and technological and ice forecast-

ing advances on the factors determining insurance coverage warrants a lowering of marine insurance rates and a lengthening of the shipping season.

To obtain an extended shipping season, the period of insurance coverage would have to be extended. Changes in the length of the shipping season made by ASPPR officials and the London Underwriters would have to be similar to establish a shipping season which corresponds to the navigation season. Charterers using the London shipping season, which is shorter than the ASPPR shipping season, may not be able to take advantage of the true shipping season unless an adjustment clause was included in the London Scale.

If an extension of the shipping season was to take place in the future, all aids to navigation, including shore aids to navigation, ice reconnaissance and forecasting aids, pilotage service, and icebreaker surveillance, would remain operational for the period of extension. However, the coordination of scheduling vessel passage in relation to ice conditions at each end of the shipping season may require integrated planning among the Canadian Wheat Board, the Atmospheric Environment Service, and other agencies.

The implementation of recommendations may increase the seasonal handling capabilities of the port of Churchill. From the analysis in the practicum, certain conclusions can be made and that bear upon the direction of more applicable marine insurance coverage including an extended shipping season which is of equal, if not less, risk to the producer, ship charterer, the insurance underwriters, and the environment.

B. Conclusions

1. Marine insurance underwriters have limited the length of the shipping season on the Hudson Bay route which in turn may have limited the throughput of the port of Churchill. A longer shipping season for conventional unstrengthened vessels is warranted between the standard dates of 20 July and 10 November which may be adjusted each season by officials of the Canadian Coast Guard Service, the Atmospheric Environment Service, and the Arctic Shipping Pollution Prevention Regulations. This season is warranted because 1) ice reconnaissance and forecasting techniques, and the advances of other aids to navigation used on the route reduces the risk to shipping, 2) ice conditions usually encountered on the route during the period of extension does not represent any additional hazard than that now experienced on the route, and 3) the experience of vessel use in slush ice in the Churchill harbour estuary warrant the operation of merchant vessels during the slush ice period.

2. There is a case for lower insurance rates for the basic and additional premiums. Lower insurance rates are warranted because 1) ice reconnaissance and forecasting techniques, and the advances of other aids to navigation used on the route reduces the risk to shipping, 2) total losses on the route have been very infrequent while minor casualties seem to be typical of the casualties related to icebound routes, 3) throughput has increased by approximately 100 per cent since

the change to calculating marine insurance rates by tonnage prior to the 1955 shipping season, and 4) the use of the additional or route premium is not warranted between 10 August and 16 October inclusive.

3. New developments in technological and ice forecasting aids adopted since the mid-1950's warrants a lowering of marine insurance rates and a lengthening of the shipping season.

4. The conclusions of the practicum are limited by the source of research data available, more particularily by a) the secretive nature of the marine insurance industry regarding rate formulas, data on rates for the basic insurance premium, and 'insurance paid out' data from both the insurance industry and the Ministry of Transport Canada, and b) the nature of recorded information regarding casualties sustained on the Hudson Bay route prior to 1972.

C. Recommendations

1. The navigation of merchant grain vessels should be allowed during the slush ice period.

2. Before a physical solution such as a tidal barrier is implemented, the mitigation of the vessel manoeuvrability problem in slush ice in Churchill harbour is possible through icebreaker assistance. The icebreaker, which is now stationed at the port to deactivate the aids to navigation after departure of the last merchant vessel, should be stationed at the port during the period of slush ice occurrence to assist vessels if necessary.

3. The standard shipping season for conventional unstrengthened

vessels should correspond to the average opening date of 20 July at Cape Chidley and the average freeze-up date of 10 November in the Nottingham Island area. A moveable shipping season to be adjusted each season by officials of the Atmospheric Environment Service and the Arctic Shipping Pollution Prevention Regulations is warranted around the dates of the standard shipping season.

4. The closing date of the shipping season should apply to vessels passing 77° W longitude rather than Cape Chidley or 64° W longitude.

5. Officials of the Arctic Shipping Pollution Prevention Regulations should extend the ASPPR shipping season for unstrengthened vessels to between 20 July and 10 November to be adjusted by the above officials each season.

6. Marine insurance rates, both the basic and additional premium on merchant vessels using the Hudson Bay route should be lowered and should cover the periods as set out in Figure 6. During the standard shipping season, the additional premium should apply from 20 July to 9 August and after 17 October inclusive. At the end of the shipping season, an additional surcharge of 25 per cent is feasible commencing on the forecasted date for permanent ice. The occurrence of slush ice in Churchill harbour does not warrant the use of the surcharge premium. For shipping prior to 20 July in average years, an additional surcharge of 25 per cent is feasible, pending change after information is gathered on reconnaissance effectiveness.

7. Coordination of ice forecasting, ice reconnaissance, and icebreaker support with the scheduling of grain vessels should take place among officials of the Canadian Wheat Board and/or private charterers, the Atmospheric Environment Service, and the Arctic Shipping Pollution Prevention Regulations to be of utmost assistance to shipping.

8. The Atmospheric Environment Service should incorporate the ice forecasting findings of the practicum into AES forecasting procedure.

9. The relationship between the repair facilities on the Hudson Bay route and at the port of Churchill, and the pilotage service in the Churchill district seems to be quite significant. Therefore, to reiterate the recommendations of the Royal Commission on Pilotage, the quality of pilotage should be maintained to ensure safety in the harbour area.

10. The Ministry of Transport Canada and/or the marine insurance underwriters should re-initiate the publication of a similar report to the "Reports on Hudson Bay Marine Insurance Rates", which were published by the Commonwealth Shipping Committee, or make the present avenue of insurance change known to the interested parties in Canada so that they may share in the favourable and/or unfavourable aspects concerning the Hudson Bay route.

11. The Ministry of Transport Canada should advise the Joint Hull Committee and the underwriters of changes made on the Hudson Bay route so that marine insurance coverage may be reassessed.

D. Limitations of the Study

1. Research Material Used in the Practicum

The practicum is limited by the source of research data. Information concerning ice conditions on the Hudson Bay route was obtained from various publications. The author did not have the resources to view personally the historical ice conditions on the route during the navigation season. Besides the guidelines provided by the Arctic Shipping Pollution Prevention Regulations, the estimation of a shipping season for all classes of ice strengthened vessels was not possible due to a lack of ice data after 19 November and due to a lack of ice thickness data prior to 1 July.

More pertinent sources of information regarding marine insurance coverage, besides the Commonwealth Shipping Committee's "Reports on Hudson Bay Marine Insurance Rates", the Hedlin Menzies report on the port of Churchill, and correspondence with the Canadian Board of Marine Underwriters, were not avaible. The author did not have the resources to speak directly to the London Underwriters who are the insurance leaders for Hudson Bay route marine insurance coverage. Regardless, some correspondence with marine insurance underwriters revealed that the marine insurance industry would not divulge the rates for basic insurance, data for "insurance paid out" resulting from casualties, and the factors affecting insurance assessment or coverage which were deduced from the reports published by the Commonwealth Shipping Committee. To add to this deficiency of data, the reports published by the Commonwealth Shipping

Committee were discontinued in 1962 resulting in a lack of published information on insurance affecting the Hudson Bay route after this date.

2. The Basic Insurance Premium

The basic insurance premium is the most important part of the rate structure. Rates for this premium are determined by competition with variation in rates resulting from the characteristic differences of each route and each vessel. The importance of the basic premium on the Hudson Bay route was further augmented by the change in 1971 by the London Underwriters to calculation of the additional premium by a percentage of the vessel's gross annual rate. The practicum is limited because the rates for the basic premium could not be obtained. The rate and changes in the rate for the additional premium on the Hudson Bay route are impossible to determine without the basic premium rates. In addition, further analysis of this aspect may show that the rate(s) for the basic premium for the St. Lawrence route is lower than the rate(s) for the basic premium for the Hudson Bay route. This difference may have resulted in a further widening of the competitiveness between the two routes.

3. The Use of the Gross Annual Rate to Calculate the Minimum Additional Premium

Prior to the calculation change in 1971, a rate "Per Ton on GRT" and Percentage on Insured Value" was published numerically. This method is still being used for the North America (Atlantic) schedule. A comparison of the rates for the additional premium between the Hudson Bay route and other routes has become impossible. In addition, the change, if any, in the rate for the Hudson Bay minimum additional premium is not distinguishable. This has resulted from a lack of knowledge of the rates for the basic premium.

4. Insurance Paid Out

An historical account of 'insurance paid out' resulting from casualties could not be obtained for either the Hudson Bay or St. Lawrence routes. An analysis of these figures in relation to the number of vessels using each route may be an indicator of what the insurance on the Hudson Bay route should be in relation to the insurance of the St. Lawrence route.

5. Casualties Sustained

Prior to 1972, all casualties sustained on the Hudson Bay route did not have to be reported to the Canadian authorities. A complete record of casualties sustained at the beginning of the shipping season is therefore not available. However, evidence reported by the Commonwealth Shipping Committee indicates that the majority of minor casualties occurred in the first few weeks of the shipping season. In addition the reports of the Commonwealth Shipping Committee were discontinued in the early 1960's, a few years after the Ice Advisory Service was originated. An analysis of ice reconnaissance frequency and casualties sustained after and prior to the beginning of the ice reconnaissance program may show that the present reconnaissance program has resulted in a lowering of the number and the severity of casualties. Data on insurance paid out may also reflect the same.

E. Areas of Further Study

1. Prior to incorporating the ice forecasting findings of the practicum into the forecasting procedure, the Atmospheric Environment Service should recheck and possibly improve on the findings as AES expertise may prove to be more significant.
2. Aids to navigation used on vessels, which were used on the Hudson Bay route, should be examined for a five year period in 1950's so that a comparison can be made with the observations made in Chapter IV.
3. The Atmospheric Environment Service should further investigate the use of real time satellite reconnaissance to be used in conjunction with present aircraft reconnaissance and ice condition analysis.
4. The Ministry of Transport Canada should investigate ice forecasting and aircraft reconnaissance in relation to the navigation season which may result from these procedures. The efficiency of reconnaissance should also be examined to evaluate the percentage and kind of casualties now sustained on the Hudson Bay route.
5. If reconnaissance assistance has not decreased the percentage and severity of casualties, the Ministry of Transport Canada should investigate the need for better repair and salvage facilities on the Hudson Bay route.
6. For an extension of the shipping season, the Ministry of Transport Canada should investigate the need for additional

fog signals on Hudson Strait to guard against the possibility of blowing snow in November and fog in July and August.

7. A study should be undertaken to investigate more thoroughly an extension of the shipping season in an ice covered season prior to 15 July and after 15 November.

8. Officials of the Ministry of Transport Canada and/or the Arctic Shipping Pollution Prevention Regulations should investigate the possibility of extending the shipping season for ice strengthened vessels (Lloyd's Registry).

9. This practicum has shown that an extension of the shipping season may increase the throughput of the port of Churchill. A study should be undertaken to discuss the factors involved in increasing the throughput of the port of Churchill once the shipping season is extended by marine insurance underwriters.

10. A benefit cost analysis regarding an extension of the shipping season on the Hudson Bay route should be carried out by the Ministry of Transport Canada.

APPENDIX A

The Components Of The Grain Handling and Transportation System On The Hudson Bay Route

1. Grain Handling Facilities at the Port of Churchill

a. Unloading Facilities

Grain is received by rail in the Track Shed which has four car dumpers. The design capacity of the dumpers is 60,000 bushels per hour. The actual average working capacity is 45,000 bushels per hour.[1] Boxcars which have a maximum capacity of 2,400 bushels are still being used to transport grain to Churchill in order to meet prerequisites of weight stress on the Hudson Bay rail-line and unloading facilities at the port. Grain is unloaded by inserting a metal plate through the bottom of the grain door. The boxcar is then tilted to both ends to drain out the grain.

b. Storage Facilities

The grain elevator consists of a work house with two storage annexes of 100 bins each.[2] Total storage capacity is 5,000,000 bushels of grain. The only time of the year in which the storage facilities are usually full is in the period just prior to the opening of the shipping season. During the shipping season, grain stored in the elevator usually does not exceed four million bushels.[3] Storage area for one million bushels is left vacant to allow for working space due to delays in ship arrivals and departures, and delays in port facilities coincid-

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[1] National Harbours Board, <u>Churchill: Canada's National Harbour of the North</u>, (Ottawa, Canada, 1973), p. 3.

[2] Province of Manitoba, <u>Royal Commission Inquiry Into Northern Transportation</u>, (Winnipeg, 1969), p. 308.

[3] Dr. E. Tyrchniewicz, Department of Agricultural Economics, University of Manitoba, Interview, 1975.

ing with rail shipments to the port. Due to the "running nature of the port, approximately one-half of the storage area is used. The majority of the grain is unloaded from the train, is cleaned, and is then loaded into waiting ships.[4]

In addition to elevator storage, storage area for 107 rail boxcars is available adjacent to the elevator. The Canadian National Railways also has storage space for another 400 cars.[5]

c. Cleaning

The cleaning facilities consist of 28 Hart cleaners and five Monitor cleaners. The average working capacity of the cleaning equipment is 27,000 bushels per hour compared to a design capacity of 64,000 bushels per hour.[6] Working capacity in this regard is the average throughput during the few years prior to 1973. The cleaning capacity would have improved during the past few years because No. 2 Feed Barley has completely replaced No. 2 Northern Wheat as the main commodity shipped through Churchill.[7] Generally, barley requires less cleaning than wheat. No. 2 Northern Wheat must be passed through the cleaners two or three times before meeting the required dockage while barley has required only one cleaning. Regardless, the cleaning problem has been mitigated by working longer cleaning shifts. The working capacity of the cleaning equipment reflects the need for multiple cleaning of some classes of grain until the allowable maximum dockage is obtained. This maximum rate is approximately 1/3 lower than that of the other port grain handling equipment.

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[4] Mr. E. Guest, Executive Director, Port Churchill Development Board, Interview, April 1975.

[5] Province of Manitoba, <u>Inquiry</u>, Op.Cit., p. 308.

[6] <u>Churchill</u>, Op.Cit.

[7] No. 2 Feed Barley is cleaned at a rate of 27,000 to 28,000 bushels per hour. No. 2 Northern Wheat is cleaned at a rate of 20,000 to 25,000 bushels per hour.

d. Conveyors to Ships

After cleaning, weighing and necessary storage is completed, the grain is fed to one of the four conveyor belts which deliver grain to the spouts on the gallery. Only four spouts can be in use at one time - that is, one spout from each conveyor belt.[8] The average working and design capacity of the shipping conveyors is 40,000 and 60,000 bushels per hour respectively.[9] With the 40,000 bushel per hour average working capacity of the conveyors and the present one 14 hour working shift, the port facilities have a capacity of 480,000 bushels per day or 42.72 million bushels per 89 day shipping season allowing three days at each end of the shipping season.[10] With two shifts per day (24 hours), the capacity of the port facilities is 640,000 bushels per day or 56.96 million bushels per shipping season.[11]

e. Berthing Facilities

The main wharf is 3073 feet long, providing five deep sea berths and one berth for coastal vessels. The depth of dredging is 31.5 feet for four berths and 35 feet for the remaining deep sea berth with a dredged depth of 32 feet for a width of 100 feet from the wharf face. The turning basin has a total width of 800 feet from the wharf face with a dredged depth of about 30 feet.[12]

Specific delays in shipping consist of two basic problems. These include 1) the uneven arrival of ships combined with strong winds and currents which may delay berthing or departure, 2) the scheduling of departures in relation to a co-ordination

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[8] Churchill, Op.cit., p.3.

[9] Ibid.

[10] Three days were eliminated to remain within insurance constraints at the beginning and end of the shipping season.

[11] Using one 14 hour shift or 2 shifts per day, the number of hours of production is 12 and 16 hours respectively.

[12] Province of Manitoba, Inquiry, Op.Cit., P. 312.

of loading rate[13] and the constraints imposed by the availability of depth which compels larger vessels to leave the harbour during the two hours prior and subsequent to high tide.[14] Vessels having this problem are in the vicinity of at least 35,000 ton deadweight.

Considering shipping as a separate entity, the shipping capacity is calculated as follows. With two high tides per day, six ships can dock at Churchill each day. During an 89 day shipping season allowing three days at each end of the shipping season, 534 ships can dock at Churchill. At the average ship cargo size of 1.2 million bushels in 1974, the ship transportation capacity is far in excess of the other grain movement components and especially the one shift port capacity of 42.72 million bushels.

2. The Rail Facilities of the Hudson Bay Route

The Canadian National Railways (CNR) provides the only land link to Churchill. This rail-line runs south from Churchill to the Nelson River , from where it runs southwest through the town of The Pas to the junction of the main east-west trunk line of the CNR at Hudson Bay, Saskatchewan.

The southern two-thirds of this rail-line consists of 100 to 110 pound rail and can support gross weights up to 110 tons on four axle cars. An extensive track rehabilitiation program, which has a cost of $14 million,[15] is underway to upgrade the remainder of the line from its present 85 pound rail and 90 ton capacity to the standards now shown on the southern two-thirds of the Hudson Bay line. The track rehabilitation program should be completed by the end of 1978.[16] When completed, grain hopper

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[13] Ibid.

[14] K. Rosin, F. Saccomano, S. Trachtenberg, Lake Winnipeg-Churchill River Diversion Transportation and Navigation Study, (Winnipeg, April 1973).

[15] Tom Shillington, "Northern Transportation carriers must cooperate", Winnipeg Tribune, (Winnipeg, September 9, 1975), p. 16.

[16] Ibid.

cars can be used to maximum capacity throughout the entirety of this line.

This rail-line does not have any siding facilities capable of allowing grain unit-trains to pass each other. The longest siding track, which has approximately 75 car-lengths, is found between Wabowden and The Pas. The longest siding facility beyond Gillam has approximately 55 car-lengths.

Maximum capacity on the Hudson Bay rail-line is one 200 car train per day.[17] The amount of grain per boxcar in the 1970's has averaged approximately 2200 bushels. Including the additional weight of the boxcar, the total weight of each boxcar meets the prerequisite of 220,000 pound stress on the 85 pound rail beyond Gillam to Churchill. Therefore, 440,000 bushels of grain can be transported per day or 39.16 million bushels per 89 day shipping season. The addition of 5 million bushels stored in the grain elevator prior to the season brings the capacity of the rail facilities to 44.16 million bushels of grain.

3. The Hinterland of the Port of Churchill

a. The Drawing Area

The drawing area for grain shipments through the port of Churchill includes the area between the borders of Alberta and Manitoba and the area to the north of Regina extending to the most northerly grain growing areas of Saskatchewan. Also included in the drawing area is the Swan River region of Manitoba. Both the Canadian National and Canadian Pacific Railway (CPR) companies are involved in the transportation of grain from this area. Canadian National is, however, the only rail company which operates to Churchill. The grain growing areas serviced by

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[17] Mr. A. Stephens, CNR Grains Industry, Winnipeg, Manitoba, Interview, March 1976.

Canadian Pacific reduce the maximum capacity of the drawing area for the port of Churchill.

In a submission by the Port Churchill Devleopment Board to the Grain Handling and Transportation Commission, an examination of grain receipts for the 1973-74 crop year showed that CNR shipping blocks in the Churchill preferential area generated 141.4 million bushels of grain. In addition, the CPR shipping blocks within the same area had grain receipts of 85.8 million bushels. The total grain receipts within the area was 227.2 million bushels.[18]

b. The Marketing System

Marketing is the performance of all business activities involved in the flow of goods and services from the point of initial agricultural production until they are in the hands of the ultimate consumer.[19] The efficiency and operation of this system determines the quantity of grain that is marketed and the price received by the producer.[20] Pricing, in this regard for the export market, is the direct responsibility of the Wheat Board Commissioners.[21] Producers in general desire a marketing system that can provide them with the best return for the grains produced.

The Canadian Wheat Board (CWB) is responsible for marketing wheat and feed grains into the export market, and has been designated the sole marketing agency for wheat, barley, and oats in the Prairie Provinces Wheat Board Region.[22] These commodities,

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[18] Submission by the Port Churchill Development Board to the Grain Handling and Transportation Commission, November 1975, p. 4.

[19] Richard Kohls, Marketing of Agricultural Products, (New York, 1965), p. 6.

[20] Ibid., p. 1.

[21] Agricultural Science Proceedings, Grain Marketing: The Marketing System and Price Determination, Published by the Extension Division, University of Saskatchewan, Saskatoon, 1975, p. 33.

[22] Ibid., p. 31.

with the exception of oats, have been the main commodities shipped through the port of Churchill. The CWB also has the additional responsibilities of co-ordinating grain movement from the farm through terminal positions by administrating the Quota Delivery and Block Shipping System.[23]

The assigned acreage quota system was introduced in 1970-71 to primarily enable the CWB to bring into country elevators at the right time, the kinds, qualities and quantities of all grain required to compete effectively for market demand.

The block shipping system, introduced in 1969, divides the CWB region into shipping areas called blocks. In transporting grain from the farm to the terminal elevators, planning is co-ordinated between the country elevator, the terminal elevator and the railway companies through the use of the block shipping system, along with the Terminal Planning and Country Planning Division of the Grain Transportation Department.

The CWB, therefore, plays a major role in what the producer will grow, what the selling price of the grain will be, and ultimately it determines through which port grain is sold and shipped. The control of grain exports by the CWB is evident in the switch from wheat to barley shipments through the port of Churchill. This suggests that the Wheat Board can significantly influence grain shipments through Churchill.[24]

5. Marine Insurance

The final link in this artery of transport is ocean shipping. The length of the shipping season is governed by the period for which insurance is available, directly or indirectly, from Lloyd's of London.[25] Vessels from the U.S.S.R. and other East European countries which are self-insured have not been in the

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[23] Ibid., p. 49.

[24] "Support for Churchill", Winnipeg Tribune, (Winnipeg, September 19, 1975).

[25] Hedlin Menzies and Associates, Port of Churchill - Potential for Development, (Department of Transport Canada, 1969), 1-115.

habit of using Churchill outside the shipping season.[26] People studying this problem have suggested that insured or self-insured ships do not usually operate outside the shipping season because they have been contracted by the CWB to carry grain only during the shipping season and not beyond the present limits of the season.[27]

The cost of insuring both hull and cargo is included in the total forwarding costs. The cargo insurance rates assessed on the port of Churchill are considerably higher than rates assessed on other Canadian ports. In 1969-70, the rate per $100 of cargo to the United Kingdom from Montreal was between 9¢ and 10¢, the rate from Vancouver 17¢ to 19¢, and the rate from Churchill approximately 55¢ per $100 of cargo. The additional hull and cargo insurance costs on grain shipped through Churchill represent four to five per cent of the total cost of forwarding grain from the Prairies to the United Kingdom. A history of the minimum additional Premium for the Hudson Bay route is shown in Table A.1.

Insurance coverage is set according to the restrictions of climate and the navigation season.[28] A history of the shipping season as defined by marine insurance is shown in Table A.2. Ice conditions at the harbour and on both Hudson Bay and Strait control the shipping season. Breakup of river ice at Churchill begins by June and the harbour is ice-free by 21 June.[29] The restrictions to shipping in spring are found in Hudson Bay and Strait which normally are not sufficiently clear of ice for safe

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[26] Records of the National Harbours Board show that since 1958 there have been five years of departures beyond 20 October, all of which were made long before the closing of Churchill Harbour to navigation. The majority of late departures were made by Dalgleish Shipping lines which is insured by Lloyd's.

[27] Ed Guest, Executive Director, Port Churchill Development Board, Interview, 1976.

[28] See Section B, Chapter II.

[29] See Figure 2.

TABLE A.1. A History of Minimum Additional Premiums on The Hudson Bay Route[a]

Date	Per Ton G.R.T.				Cost Per 100 of Cargo			
	With Gyro		Without Gyro		With Gyro Cost		Without Gyro Cost	
	s.	d.[b]	s.	d.	s.	d.	s.	d.
12th March, 1931	2	0	2	0	50	0	50	0
12th May, 1932	2	0	2	0	40	0	50	0
13th March, 1935	1	6	1	6	22	6	39	0
30th April, 1936	1	6	1	6	17	6	39	0
10th May, 1937	1	6	1	6	15	0	30	0
1st August, 1940	All additional premiums subject to a 25 per cent increase on the 1937 rates.							
15th January, 1941	All additional premiums subject to a 37½ per cent increase on the 1937 rates.							
16th March, 1942	2	3	2	3	22	6	45	0
1st July, 1947	2	0	2	0	20	3	40	6
15th March, 1949	1	6	2	0	15	0	40	0
1st May, 1950	1	0	2	0	10	0	40	0
9th June, 1952		9	2	0	7	6	40	0
4th May, 1953		9	2	9	6	8	40	0
4th July, 1956	1	0	2	0	5	6	40	0

SOURCE: Commonwealth Shipping Committee, <u>Twenty-first Report on Hudson Bay Marine Insurance Rates - 1962</u>, (Great Britain: Her Majesty's Stationery Office, 1962).

[a] The method of minimum additional premium calculation was changed in 1971. Changes in rates were not included in this table for reasons discussed in Section D, Chapter VI.

[b] "s. d." is the British currency notation for shilling and pence.

TABLE A.2 A History of the Shipping Season on the Hudson Bay Route

	Period of Navigation		Extension allowable on payment of percentage surcharge on the additional premiums	
Year	From	To	From	To
1931	10 Aug.	30 Sept.	1 Oct.	7 Oct. (10%)
			8 Oct.	15 Oct. (25%)
1933	10 Aug.	7 Oct.	8 Oct.	15 Oct. (25%)
1936	5 Aug.(a)	10 Oct.	11 Oct.	15 Oct. (25%)
1950	26 July	10 Oct.	11 Oct.	15 Oct. (25%)
1952	23 July	10 Oct.	11 Oct.	15 Oct. (25%)
1955	23 July	15 Oct.	16 Oct.	20 Oct. (25%)
1971	23 July	20 Oct.(b)	20 Oct.	25 Oct. (25%)

Source: Commonwealth Shipping Committee, Report(s) on Hudson Bay Marine Insurance Rates, (Great Britain: Her Majesty's Stationery Office).

(a) Underwriters stipulated that Masters must consult the CCGS Icebreaker about ice conditions before passing into Hudson Strait at Cape Chidley.

(b) The last change in the dates for the end of the shipping season applied to vessels clearing 64° W longitude or Cape Chidley and not Churchill as previously.

passage of unstrengthened vessels until mid-July. Historical data show that the earliest and latest date for a vessel to pass Cape Chidley was 2 July (1955) and 10 August (1945) respectively. Icebreakers usually navigate Hudson Strait early in July while merchant vessels wait until after 23 July.

Churchill harbour is closed at approximately the same time that large quantities of slush ice form in the Churchill River. The growth of ice in both Hudson Bay and Strait does not affect shipping until it begins in early November. The shipping lane usually remains open until the second week in November. In the seasons 1928 to 1972 the earliest and latest dates for closing the harbour were 10 October and 13 November respectively or by 25 October on the average.[30] Hudson Strait was not completely iced over until 13 November at the earliest and 4 December at the latest. The earliest and latest dates when Hudson Bay at Churchill was packed with ice to the horizon were 31 October and 30 November respectively.

6. Conclusions

1. The rail and port facilities on the Hudson Bay route pose only a physical problem which can be solved by upgrading these facilities. The rail and port facilities can handle the present throughput with reasonable scheduling.

2. Movement of export grain is not a problem of actual movement through the use of the block shipping and quota delivery system but seems to be a problem of price determination and actual port utilization and/or promotion by the Canadian Wheat Board.

3. Insurance coverage is the variable which dictates the length of the shipping season. The cost of insuring both hull and cargo is included in the total forwarding costs and is generally considered to be a deterrent to utilizing the Hudson Bay route. To obtain an extended shipping season, the period of insurance coverage would have to be extended.

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[30] See Table B.4.

APPENDIX B

Ice Conditions On Hudson Bay and Strait And In Churchill Harbour

1. The Formation and Behaviour of Sea Ice

Very cold weather, particularily with strong winds, rapidly cools the surface layer until ice crystals or 'spicules' form.[1] These increase in number until the sea is covered with "slush" which tends to break up into separate masses and frequently to form "pancakes" with raised edges as a result of collision between the masses.

The initial growth of sea ice can be very rapid, perhaps 7.5 to 10 cm. (3 or 4 inches) in the first 24 hours and 5 to 7.5 cm. (2 or 3 inches) more in the second 24 hours. The insulation then provided reduces the further rate of growth so that first-year or winter ice seldom exceeds 4 to 6 metres.

The ice crytals are non-saline and the salt which has been rejected forms a locally more-concentrated brine. If the formation of sea ice is fairly rapid, the brine becomes trapped between the crystals so that first-year ice normally has an overall salinity of from 4 to 15 percent.

Because of its method of formation and entrapped brine, first-year sea ice is weaker then fresh water ice. It also becomes "rotten" and melts more quickly during breakup.

Brine ducts will occupy a large portion of the volume, reducing the net volume of "coherent" ice. The actual ice surrounding the brine ducts will have considerable strength right until it melts. As time increases and melting takes place, the total volume of the ice decreases and water or air occupies the interstices created by the melting.[2]

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[1] Section 1 has been extracted from Hedlin, Menzies and Associates, Port of Churchill - Potential for Development, (Canada: Department of Transport, 1969), Vol. II, Appendix A.

[2] Bruno Renard, Ice Incidence on Hudson Bay Drilling Campaign (Calgary: Acquitaine Company of Canada Ltd., 1974), Appendix B, p. 25.

Observations of ice decay indicate that the ice does not melt simply by decreasing in thickness only, but by a change in all dimensions, including drainage through the brine channels and around the crystal boundaries. Mechanical and thermal effects are both effective. Such an interpretation partially explains the apparent anomaly that fairly thick, large blocks of ice exist until very shortly before a zone becomes ice free.

If first-year ice does not melt completely in one year, it lives on to become polar ice. Polar ice is stronger and harder than first-year ice because much of the brine has been leached out and replaced by frozen water filtered down during the summer.

An essential feature of sea ice is that it is always moving under the effect of winds, waves and currents. Over large areas, wind forces can be great and resulting pressures force the ice over one another to produce rafting. By the end of winter, first-year ice is usually extensively rafted; rafted ice is typically 10 to 20 metres thick but may be occasionally 50 or more metres thick.

Initial and early forms of ice, such as frazil crystals, slush, pancake ice and ice rind, are known as new ice. Ice which has become a level sheet and obtained a thickness of 10 to 30 cm. is young ice. Ice from 70 to 120 cm. is called medium winter ice. Ice greater then 120 cm. thick is called thick winter ice.

Once winter ice has formed, it will usually remain in floes with concentrations of nine-tenths or more during the winter period of continuing freezing. Due to movement, ice will always have some cracks or leads and numerous lines of weakness where cracks have occurred and refrozen.

When thawing takes place, the big floes gradually break up and the proportions of small floes, ice cake, and brash increase. The surface melting of the floes create numerous puddles, some of which become thaw holes. The entrapped brine hastens the internal melting of the ice which eventually becomes rotten and disintegrates.

As the thawing process reduces the size of the floes, there is an interplay between the concentrations of ice pack and the amount of open water. The effect of winds and currents may maintain or re-create high concentration of ice in certain areas and drive the ice pack back onto areas which had previously become open water.

2. Ice Conditions on Hudson Bay and Strait

a. Breakup

Thawing and breakup on Hudson Bay and Strait begins most years about the middle of May. Ice concentration of less than nine-tenths usually appear towards the end of May, and significant areas of open water appear about the same time. It is not until June that the main ice pack of Hudson Bay becomes completely broken up into small and medium floes and concentration is greatly reduced. Larger floes are not normally observed after the beginning of July. At this time, breakup is well advanced and navigation becomes possible.

The type of ice encountered is predominantly first-year winter ice. First-year winter ice is weaker than fresh water ice because of its method of formation and entrapped brine; thus it becomes "rotten" and melts more quickly during breakup.

A summary of ice distribution data over the 24-year period 1929 to 1953 show that in 'most favourable' and average years, navigation can begin by 15 July (Figure B.2) and 20 July (Figure B.3) respectively.[3] In 'most unfavourable' years, ice may prove unpenetrable at this time and is more abundant everywhere. The ice situation on 25 July, even in 'most favourable' years, has not changed considerably (Figure B.4). Regardless

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[3] Charles N. Forward, "Sea Conditions Along the Hudson Bay Route", Geographical Bulletin, No. 8, (Ottawa: Geographical Branch, Department of Mines and Technical Surveys, 1956), pp. 22-50.

navigation is now much safer especially with greater use of ice reconnaissance techniques.[4] The prevailing winds are generally from a northerly direction so that the earliest large area of open water appears on the north side of the Bay. Once a location becomes open water, pack ice does not come back onto it.[5] By the third week of July, there is usually an open water route between East Hudson Strait and Churchill along a northerly arc.

An analysis of ice distribution data 1964-71 in the breakup period supports the above findings.[6] Some of the conclusions of this analysis are as follows: first-year ice was predominant; ice floes become less concentrated especially during the period 9 July to 23 July; and, in six of the eight years, Hudson Strait had a concentration of from one-to-three tenths to four-to-six tenths small floe ice on 23 July.

Most Foxe Basin ice is found locally, and can generally be distinguished by its discolored appearance. Small concentrations of first-year winter ice are usually present in Foxe Channel and Basin throughout August. Weather systems usually confine this ice to the Foxe Channel area. If first-year ice drifts into Hudson Strait, it should not pose a hazard to shipping due to its rotted state. Ice floes from the Gulf of Boothnia, which are harder and less discoloured, do not usually commence to drift into the west end of Hudson Strait until mid or late July by which time they have rotted extensively.[7] By August, this influx has stopped and Hudson Strait is clear of such ice.

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[4] The opening date of the shipping season corresponds to vessels passing Cape Chidley. Ice conditions on Hudson Bay and at Churchill three to five days after passing Cape Chidley would be less severe.

[5] Examine successive breakup dates for a particular year, footnote #6 below.

[6] This analysis was comprised of examining ice conditions during the period 1964-71 inclusive for the dates 25 June, and 9, 16, and 23 July, Ice Summary and Analysis, Hudson Bay and Approaches, (Toronto: Atmospheric Environment Service, Department of Environment, annual publications since 1964).

[7] Government of Canada, Pilot of Arctic Canada, (Ottawa: Canadian Hydrographic Service, 1968), 2-2.

b. Freeze-up

Succeeding the growth of ice on Foxe Basin, the growth of ice on Hudson Bay begins in the north of Hudson Bay usually early in November and spreads southwards. The ice forms more quickly along the west shore of the Bay and affects Churchill usually about mid-November. The centre and southeast areas of the Bay reamin open for some weeks longer. An analysis of ice conditions show that ice formation in Hudson Bay during freeze-up consists almost entirely of first-year ice. Only in 'most unfavourable' years has ice developed past the 'new and nilas ice' stage by mid-November on the Hudson Bay route.

Ice formation on Hudson Strait takes place quite similarly as ice formation on Hudson Bay. The only difference is the occurrence of polar ice from Foxe Basin and Davis Strait, and the slower formation of ice in Eastern Hudson Strait due to the moderating effects of the North Atlantic.

Based on measurements at shore stations, maximum winter thickness, where not ridged or rafted, would vary from four to six metres in both Hudson Bay and Strait depending on the location and the severity of the winter (Figure B.1). The extent of ridging is usually about two-to-four tenths and two-to-five tenths of the area in the Bay and Strait respectively. Ridged ice is typically 10 to 20 metres thick but may be occasionally 50 or more metres thick.

In November, although the main bodies of Hudson Bay and Strait are fairly open, ice from Foxe Channel and local shore ice begins to present a serious obstacle to navigation. Ice distribution data over the 24-year period 1929 to 1953 shows that only in 'most unfavourable' years (Figure B.5) are both Hudson Bay outside Churchill harbour and the western approaches to Hudson Strait blocked by ice on 30 October.[8] Contrary to this, as depicted by freeze-up 1965 and 1972, ice occurrence is

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[8] Forward, Op.cit.

possible in western Hudson Strait a few days earlier.[9] On 10 November (Figure B.6) in 'most favourable' years and in average years, there is an occurrence of continuous ice only outside Churchill harbour. However, only in 'most unfavourable' years is ice prevalent both in the western part of Hudson Strait and outside Churchill harbour on 10 November.

An analysis of ice conditions for the years 1964-1973 inclusive show that when ice occurred outside Churchill harbour and in the western approaches to Hudson Strait on 5 November, it was usually composed of first-year new and nilas ice, with the greatest concentrations of ice (7-9/10) on the shipping route occurring at the western approaches to Hudson Strait. Only in 'most unfavourable' years, and in this period 1965 and 1972, was the shipping route on Hudson Bay and Strait blocked by continuous ice on 5 November.

On 20 November (Figure B.7), the shipping lane was blocked by continuous ice at Churchill, both inside and outside the harbour, in 'most favourable' and average years. In 'most unfavourable' years, ice in the western part of Hudson Strait blocked the shipping route; the size of the ice area outside Churchill harbour was also more extensive than on earlier dates.

In view of all these factors, the limit to the navigation season on Hudson Bay and Strait seems to be 10 November, with approximately 31 October the limit for 'most unfavourable' years. At present, commercial shipping in Hudson Strait itself ends on 31 October.[10] With better use of ice forecasting methods, shipping may be extended beyond 10 November.

Ice cover grows rapidly during late November and early December; there is an effective coverage of winter ice over the whole of Hudson Bay and Strait by the end of December. The maximum ice thickness of about five to six metres is reached in

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[9] Ice forecasting techniques, discussed in Seftion I, Chapter IV, make it possible to predict similar occurrences.

[10] T.M. Dick, <u>Feasibility of Extending the Navigation Season at Churchill Harbour</u>, (Ottawa: National Research Council of Canada, 1966), p. 5.

May (Figure B.1). Ice is seldom in the form of a continuous sheet over large areas because it is constantly being broken into floes of various sizes by the action of winds, waves and currents. Except for the fact that ice is fixed to the shore, the ice is constantly moving and there are always leads and weaknesses in the ice which can be exploited by icebreakers. The effect of strong winds cause tremendous pressure in the ice fields which results in extensive ridging and rafting.

3. Iceberg and Growler Hazard

Other forms of ice encountered at sea include icebergs, bergy bits, and growlers. Thousands of bergs are calved annually by glaciers of Western Greenland and make their way southward through Davis Strait. Most of them continue on towards Newfoundland but some pass into Hudson Strait. Due to the pattern of surface currents in this area, icebergs from the Davis Strait area never travel any further westward than Charles Island (Figure B.8).

Observations made by the Department of Environment Canada during the period 1963 to 1967 inclusive show that there are two to three times fewer icebergs in fall or winter than in spring or summer (Table B.1). The flux of icebergs through the eastern Hudson Strait are:

40% of those crossing 62°N in August through November
Nil from February until mid-June
20% the rest of the time

TABLE B.1 Flux of Icebergs Through Eastern Hudson Strait

	Jan	Feb	Mar	Apr	May	Jun
Flux through 62 N	107	95	139	135	145	134
Flux through H.S.	21	0	0	0	0	14
	Jul	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Flux through 62 N	124	84	61	53	37	93
Flux through H.S.	49	33	24	21	23	19

Data, submitted by Masters of vessels using the Hudson Bay route into Churchill during the shipping season of 1953 to 1957 inclusive, may be used to define the general area of dangerous navigation on Hudson Strait.[11] The location of all ice formation reported during the survey period is shown in Figure B.9. Of particular note is the almost complete absence of ice west of longitude 75° and east of longitude 60°.

The greatest concentration of ice is located between the eastern approaches to Hudson Strait and Cape Hopes Advance. Figure B.10 is a graph of ice density versus longitude for the shipping seasons 1953 to 1957, inclusive. Hazardous ice conditions ~~seem to~~ be confined to the area between longitude 74° west and longitude 59° west, a distance of 900 miles. Eighty percent of the hazard, in this overall area, is centered about longitude 67° west for approximately 450 miles. This area of high ice concentration appeared in the same general location for the five years of the survey and may be considered the most dangerous section of the route to Churchill.

A comparison of reports from ships navigating Hudson Strait before and after 1 September, and particularily reports from all ships that made two voyages during the season, indicates that 50 to 60 percent less ice will be encountered in the latter half of the shipping season.[12]

Icebergs, and to a lesser extent growlers, are a hazard to shipping only in fog or driving snow in which the speed of the vessel should be reduced to suit the visibility. Records show that icebergs and growlers in eastern Hudson Strait do not represent a serious hazard to shipping during the shipping season especially if a proper lookout is kept by all vessels passing through this area.[13] Table B.2 give the frequency of fog at Nottingham Island and Resolution Island as defined

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[11] A.D. Hood, "An Analysis of Radar Ice Reports Submitted by Hudson Bay Shipping (1953-1957)", Thirty-second Annual Report, Navigation Conditions on the Hudson Bay Route from the Atlantic Seaboard to the Port of Churchill, (Canada: Dept. of Transport, 1960), p. 44.

[12] Ibid.

[13] Hedlin, Menzies, Op.cit., 1-117.

by the number of days visibility is less than 5/8 mile.[14]

TABLE B.2 Frequency of Fog at Nottingham and Resolution Islands

	Jan	Feb	Mar	Apr	May	Jun
Nottingham Is.	2	1	1	1	5	8
Resolution Is.	2	1	1	2	7	13
	Jul	Aug	Sept	Oct	Nov	Dec
Nottingham Is.	9	10	6	4	-	1
Resolution Is.	16	10	12	4	1	-

In contrast to fog, blowing snow occurs mainly outside the present shipping season. Table B.3 give the frequency of blowing snow for Hudson Strait as defined by the number of days visibility is less than 6 miles.[15]

TABLE B.3 Frequency of Blowing Snow at Nottingham and Resolution Islands

	Jan	Feb	Mar	Apr	May	Jun
Nottingham Is.	9	12	5	6	3	1
Resolution Is.	9	9	8	6	2	0
	Jul	Aug	Sept	Oct	Nov	Dec
Nottingham Is.	0	0	1	4	8	10
Resolution Is.	0	0	0	4	12	15

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[14] H.A. Thompson, "The Climate of the Canadian Arctic", The Canada Year Book, 1967.

[15] Ibid.

Second-year or polar ice which enters Hudson Bay and Strait from Foxe Basin via Foxe Channel has rotted extensively. By August, this influx has stopped. Very rarely will polar ice from Foxe Basin drift into the northeast corner of Hudson Bay.[16] Old ice will not be encountered in Hudson Bay and Strait in the shipping season of the following year if ice in Foxe Basin dissipates completely. Bruno Renard observed that because Foxe Basin was completely cleared of ice in the summer of 1973, no old ice was met by Acquitaine's drilling rig in the Summer of 1974.[17]

4. Radar Use in Ice Detection

a. The Effect of Climate on Radar Use

Weather conditions can produce an adverse effect on radar detection of ice, particularly in fog and rain, under which conditions the return from ice may be reduced or even obscured just when most needed. Regardless, one advantage of radar results from the fact that most radio waves are not blocked by fog or heavy rain, as light is, so that a radar can "see" objects even when they are completely hidden in dense fog. In moderately rough weather, there may be a temporary lapse of a clear return on the screen, which in most instances rectifies itself by a few sweeps of the antenna.

Atmospheric conditions, in which there is a decrease of the moisture content, may produce a ducting effect on the radar beam which in turn can result in the loss of the target. This condition is also often associated with a temperature inversion Ducting may also bring about an opposite reaction in that radar rays are bent in a direction corresponding to the earth's curvature and thus permitting much greater range reception.

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[16] Hedlin, Menzies, Op.cit., 1-124.

[17] Renard, Op.Cit., Section 3.1.

The most difficult problem of ice detection is created by the merging of sea returns with those of ice in the form of growlers or bergy bits, when there is a moderate sea state. Keen observation is essential on the part of the operator, to differentiate between these two confused returns. It may be noted, however, that growlers appear and disappear, but in approximately the same position on the Plan Position Indicator with each rotation of the antenna.[18] Sea returns on the other hand, is changing constantly, and does not appear in the same relative position.

When proceeding through pack ice in low visibility, a ship should exercise caution as icebergs can be obscured by returns from the pack ice at distances up to two miles. Beyond this range, however, large icebergs can be detected from the adjacent pack ice. The shadows cast by large bergs can be misinterpreted for leads or open water. Some assistance in determining the presence of large bergs in pack ice at short range may result by the use of anti-jamming controls, but this is by no means infallible.

b. Radar Use for Detecting Icebergs, Growlers, and Leads

In a survey carried out by the Department of Transport Canada, radar was found to be an invaluable aid in navigating Hudson Bay Shipping lanes; its use may be dangerous if not wisely employed and its limitations appreciated.[19] The detection of numerous ice formations, namely growlers and bergy bits, in sea clutter is difficult and in many cases impossible.

The detection range versus radar cross-sectional area, of each of the 265 formations of the total 725 ice reports for the Department of Transport analysis, is plotted in Figure B.11. There is considerable scatter but this is to be expected

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[18] A Plan Position Indicator (PPI) is a device which reads or registers radar receptions.

[19] Hood, Op.Cit., pp. 41-58.

when the cross-sectional area of the target (value of A) must be estimated in many cases and the receiver sensitivity (K) is considered equal for all radars.[20]

A low antenna height seems to be no problem in navigation. In the Department of Transport survey, the average antenna height was found to be 56 feet for a loaded ship and 71 feet for a ship under ballast. The lowest antenna height recorded for a merchant ship navigating Hudson Strait was 42 feet. This height is equivalent to a radar horizon of 18,000 yards and is considered more than ample for navigating ice-infested waters.[21] Larger bergs, detected at greater ranges, would not be fully illuminated by the radar beam but this has no bearing on safe navigation.

Sea clutter was found to be a predominant factor in detection of the smaller types of ice at close range.[22] Sea clutter, in excess of 4,000 yards, is not usually encountered in a passage of Hudson Strait. In 2,000 yards of clutter, any ice of sufficient size to be dangerous will be detected beyond the clutter region. Even if lost on closing to a lesser range, the location of the ice relative to the ship will be known.

To be certain of detection in sea clutter, a growler must have an echo amplitude greater than that of the clutter. The echo from a growler, at a given range, is a direct function of its radar cross-section, whereas the echo from the sea clutter, at the same range, consists of the returns from all of the wave fronts in the area illuminated by the radar beam. A growler that is undetected at sea-clutter range normally has a cross-sectional area smaller than the combined area of the wave fronts, and is obscurred at the shorter ranges by the increased

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[20] The fundamental radar equation $R^4 = K \times A$ was used where R is the detection range.

[21] Hood, Op.cit., p. 48.

[22] Ibid., p. 44.

amplitude of the clutter. It is at this time that anti-clutter devices are extremely valuable because of their ability to arrive at maximum sensitivity at maximum clutter range where the growler echo is greater than the sea-clutter echo.

The maximum radar cross-section for the Department of Transport study was 150 square feet. From Figure B.11, maximum detection range for a growler of this size is approximately 6,000 yards. Under normal conditions, with sea clutter less than 2,000 yards, any growler large enough to cause damage to a ship will be detected beyond the clutter region. However, to ensure safety in 2,000 yards of sea clutter, continuous radar watch is a necessity, since a growler entering the clutter region undetected is almost certain to remain undetected.

For an average breadth of 15 feet, the volume of ice would be 5,000 to 6,000 cubic feet and the weight in excess of 100 tons. Growlers of this type are usually smoothly rounded by the action of the waves and consequently have very poor echoing properties. The detection range of this growler, in a calm sea, would be between 2,000 and 3,000 yards. For a ship proceeding at ten knots, this represents a warning time of six to nine minutes. A growler of 100 tons is quite capable of inflicting severe damage to a ship. The Department of Transport study noted that of the 54 growlers reported, only 22 were detected by radar, all in calm water outside the clutter region.

The same survey reported thirteen ice floes, all detected at ranges greater than 4,000 yards. Even in strong sea-clutter, the edge of a floe presents a sharp line of demarcation between ice and sea-clutter, and consequently a packed ice floe is not considered a dangerous ice formation. Field ice has a tendency to dampen any sea clutter that may be present. If sufficiently loose, the ice fields can be navigated and frequently lanes will be found that are reasonably clear of ice. When a ship is traversing an ice field, the radar picture is similar to that for sea-clutter but any large area of open water, such as a lane, can be easily distinguished.

5. Ice Forecasting

Ice thickness analysis was carried out to determine a methodology for forecasting ice conditions during breakup and freeze-up.[23] The analysis was prompted by earlier observations by C. N. Forward.[24] Forward found that 1) in years when breakup or clearing ice from the area occurred at a relatively early date, temperatures were higher than average or approximately average during several winter and spring months, 2) temperatures were lower than average for several previous months when final clearing of ice occurred relatively late, and 3) freeze-up was delayed by above average October and November temperatures. Forward also stated that brief periods of higher or lower than average temperature do not have nearly as significant an effect as longer periods of a month or more in duration. For this reason, the analysis attempted to pinpoint a significant period before breakup and freeze-up which could be used for ice forecasting.

A. Results

The statistical analysis found that the ice thickness at Coral Harbour was related to the three month period prior to the month of final breakup and permanent freeze-up. The R^2 values for 'ice thickness for the previous three months', precipitation, snow cover on the ice, and temperature are 91.44, 91.18, 89.19 and 87.85 percent respectively. These figures

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[23] A stepwise multiple regression analysis using SPSS was carried out on climatic data ranging from October 1958 to December 1972 at Coral Harbour, N.W.T. The dependent variable was mean monthly ice thickness while the independent variables were mean monthly snow thickness (on top of the ice), mean daily temperature, total monthly precipitation, and each mean ice thickness of the previous seven months. In Chapter III, the critical area for breakup and freeze-up was found to be the western approaches to Hudson Strait. Climatic data for Coral Harbour was used for this analysis due to the lack of data for Nottingham Island. This decision should not detract from the analysis as Coral Harbour is located approximately 150 miles west northwest of Nottingham Island which is located in the center of the western Hudson Strait area.

[24] Forward, Op.cit.

explain the percentage variation of the regression of ice thickness on the above variables. The analysis also indicates that temperature and precipitation are inversely related to ice thickness.

The above findings were used for further analysis. The mean daily temperature and the total monthly precipitation was examined to determine the relationship between these variables and 'most favourable' and 'most unfavourable' ice conditions during the three month period prior to breakup and freeze-up.[25]

b. Freeze-up

Air temperature data was the only variable used for the freeze-up analysis because precipitation data of the three month period prior to freeze-up is overlapped by the summer period and thus should not have any effect on ice thickness during this period of ice dissipation.

The years 1965 and 1972 were found to be 'most unfavourable'. In both years, the three month period prior to November had mean daily temperatures less than average. In addition, the mean daily temperature for June and July was below average.

The years 1966, 1968, and 1970 were found to be favourable. In all three years, the three month period prior to November had mean daily temperatures greater than average with the exception being August of 1968 which had a mean daily temperature approximately average.

First permanent ice can also be used as an indicator for short term ice conditions.[26] For most unfavourable years, 1965 and 1972 had first permanent ice on 8 October and 27 September respectively. These dates were well below the average date of 19 October for first permanent ice. With the exception of 1970, all favourable years had first permanent ice after the average date.

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[25] The favourable and unfavourable breakups and freeze-ups were determined in the analysis of ice conditions in Chapter III.

[26] First permanent ice is the date for the formation of new ice which does not dissipate until breakup.

In addition, the annual mean temperature was below average for 'most unfavourable' years and above average for favourable years.

The dissipation of winter ice in Foxe Basin can be used as an indicator in forecasting possible ice conditions which will result in late October and/or early November. In 'most unfavourable' and unfavourable years, winter ice from the previous winter does not dissipate before new ice begins to form in late October. This factor reflects the below average temperatures of the summer and autumn periods. In addition, Bruno Renard observed that old ice will not be encountered in Hudson Bay and Strait in the shipping season of the following year if ice in Foxe Basin dissipates completely.[27]

c. Breakup

Late breakup was most apparent in 1964 and 1972. The three month period prior to July had mean daily temperatures less than average or approximately average. Total monthly precipitation for the same period was less than average or approximately average. In addition the three month period prior to April had mean daily temperatures of less than average or approximately average. Precipitation during this period was mainly less than average.

The years 1947, 1965, 1966, and 1968 had a favourable breakup. Two types of relationships seem to exist. For the three month period prior to July, 1) mean daily temperature and total monthly precipitation were average, or 2) mean daily temperature was below or at average while precipitation was well above average.

In addition, late breakup was characterized by annual mean temperatures of less than average, and early breakup was characterized by annual mean temperatures of greater than average with 1965 being the exception due to below average temperatures in summer and autumn.

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[27] Renard, Op.Cit.

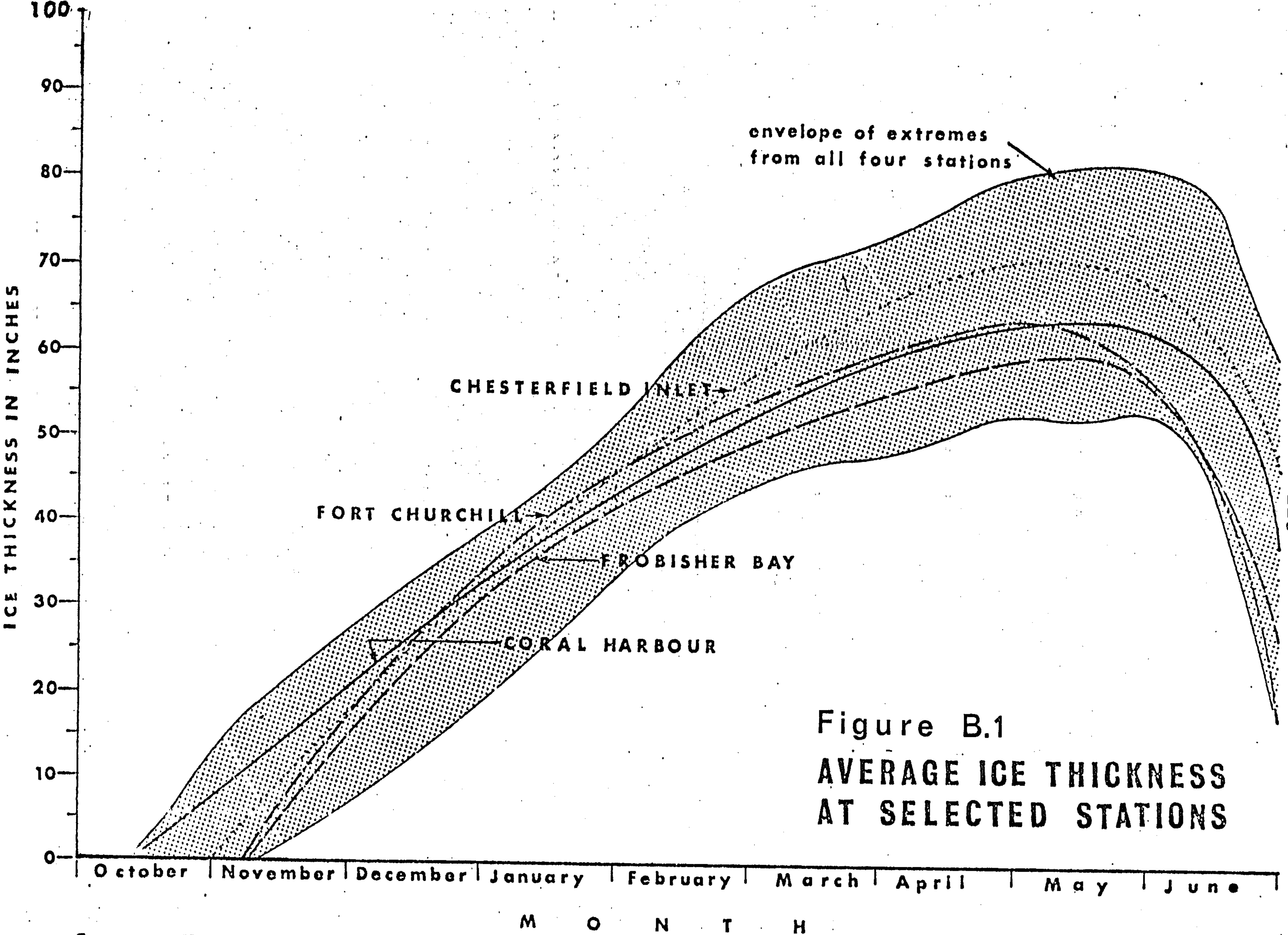


Figure B.1

AVERAGE ICE THICKNESS AT SELECTED STATIONS

Source: Hedlin,Menzies and Ass., Port of Churchill - Potential For Development, prepared for the Department of Transport Canada, 1969.

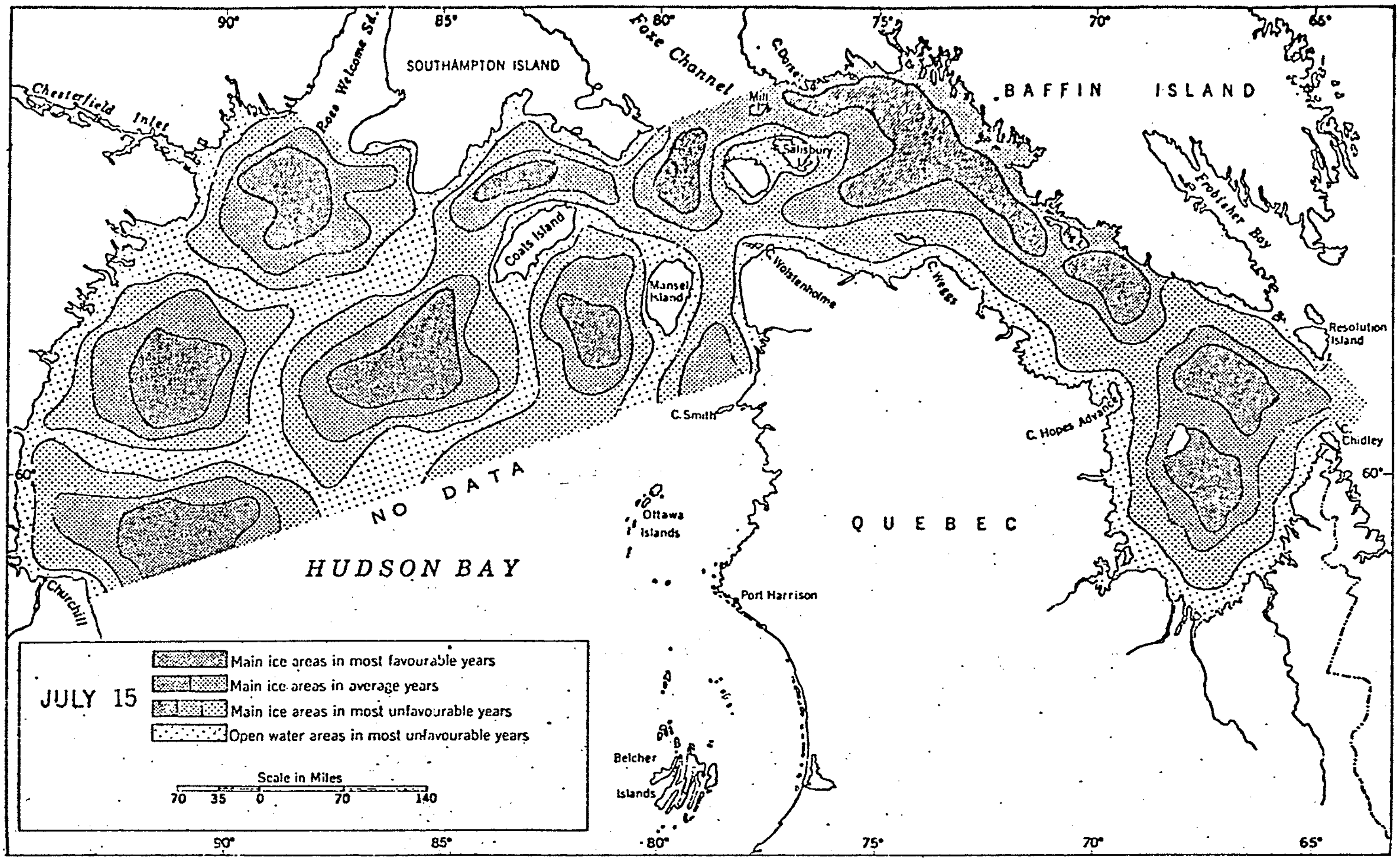


Figure B.2 Limits of main ice areas along the Hudson Bay route on July 15. *

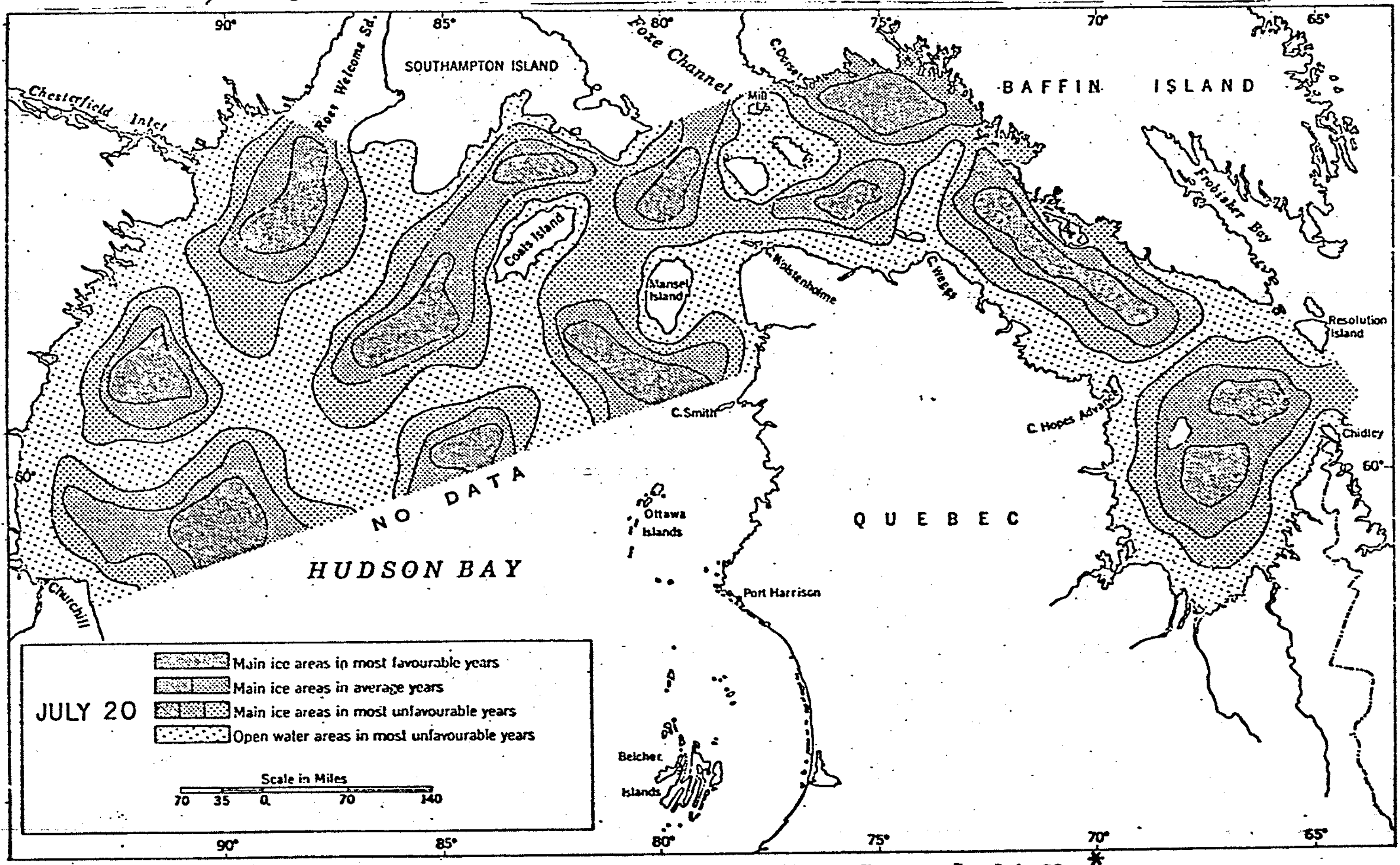


Figure B.3 Limits of main ice areas along the Hudson Bay route on July 20. *

*Source: C.N. Forward, "Sea Ice Conditions Along the Hudson Bay Route", <u>Geographical Bulletin</u> No. 8, (Ottawa: Dept. of Mines, 1956).

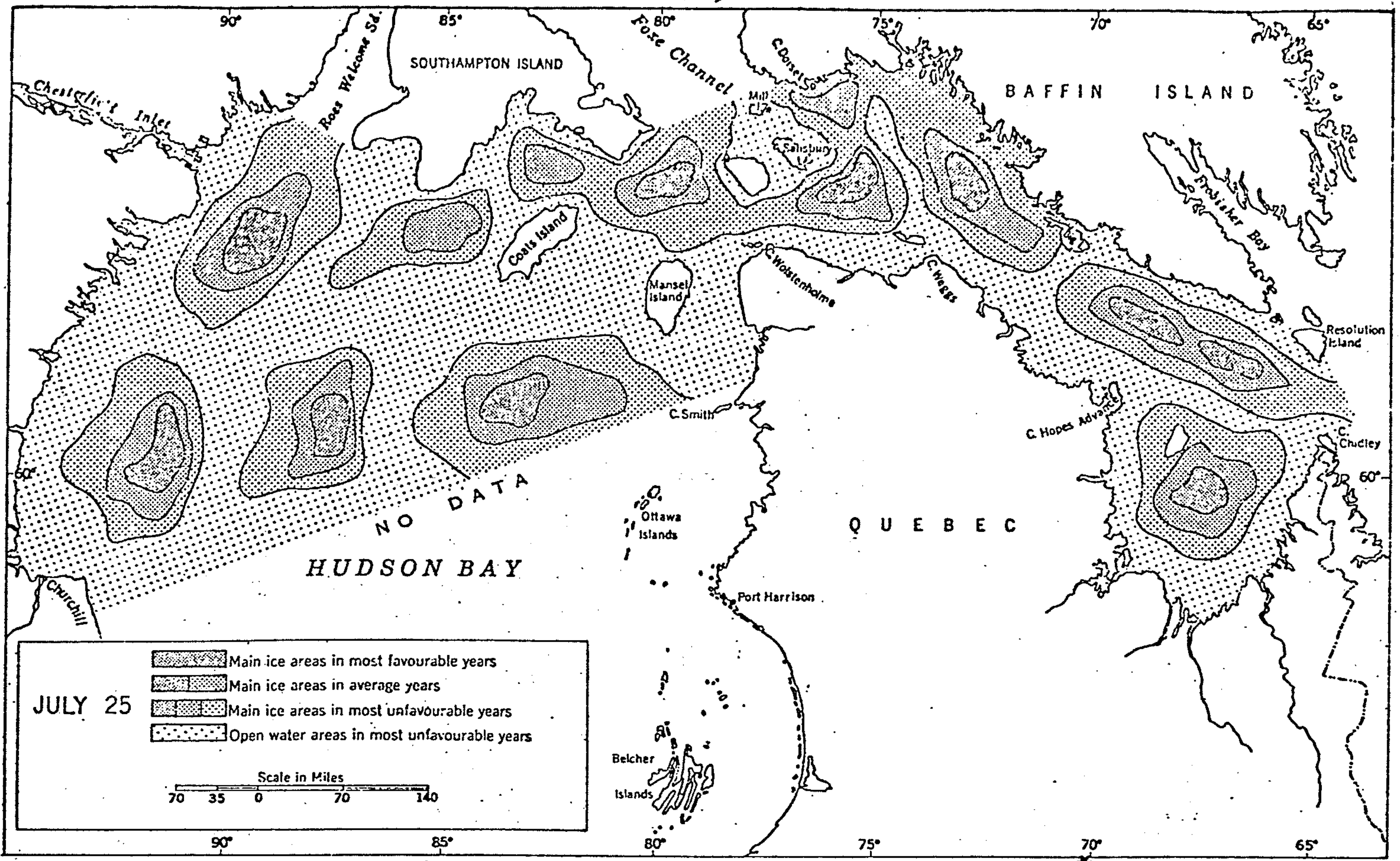


Figure B.4 Limits of main ice areas along the Hudson Bay route on July 25. *

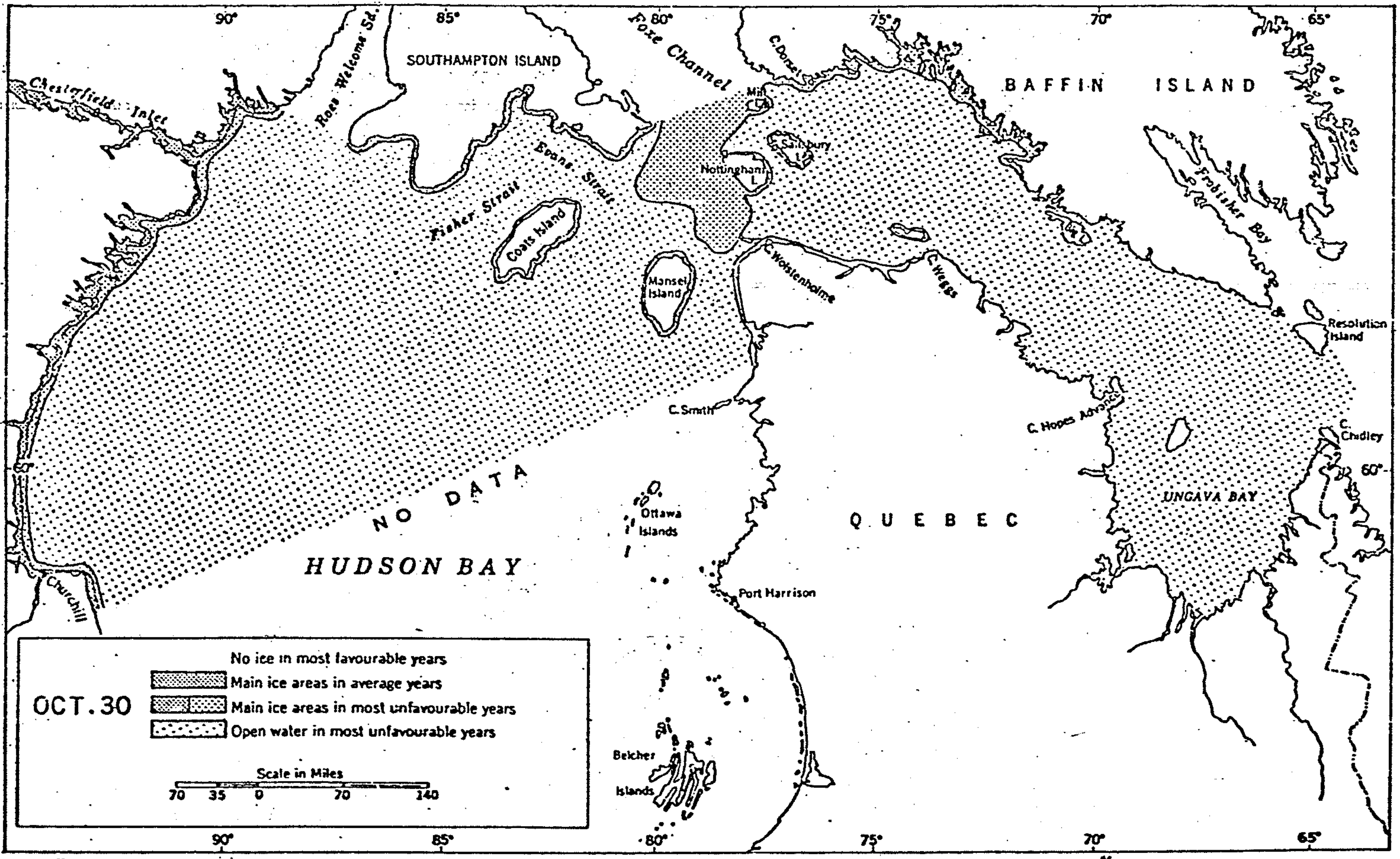


Figure B.5 Limits of main ice areas along the Hudson Bay route on October 30. *

*Source: C.N. Forward, "Sea Ice Conditions Along the Hudson Bay Route", Geographical Bulletin No. 8, (Ottawa: Dept. of Mines, 1956).

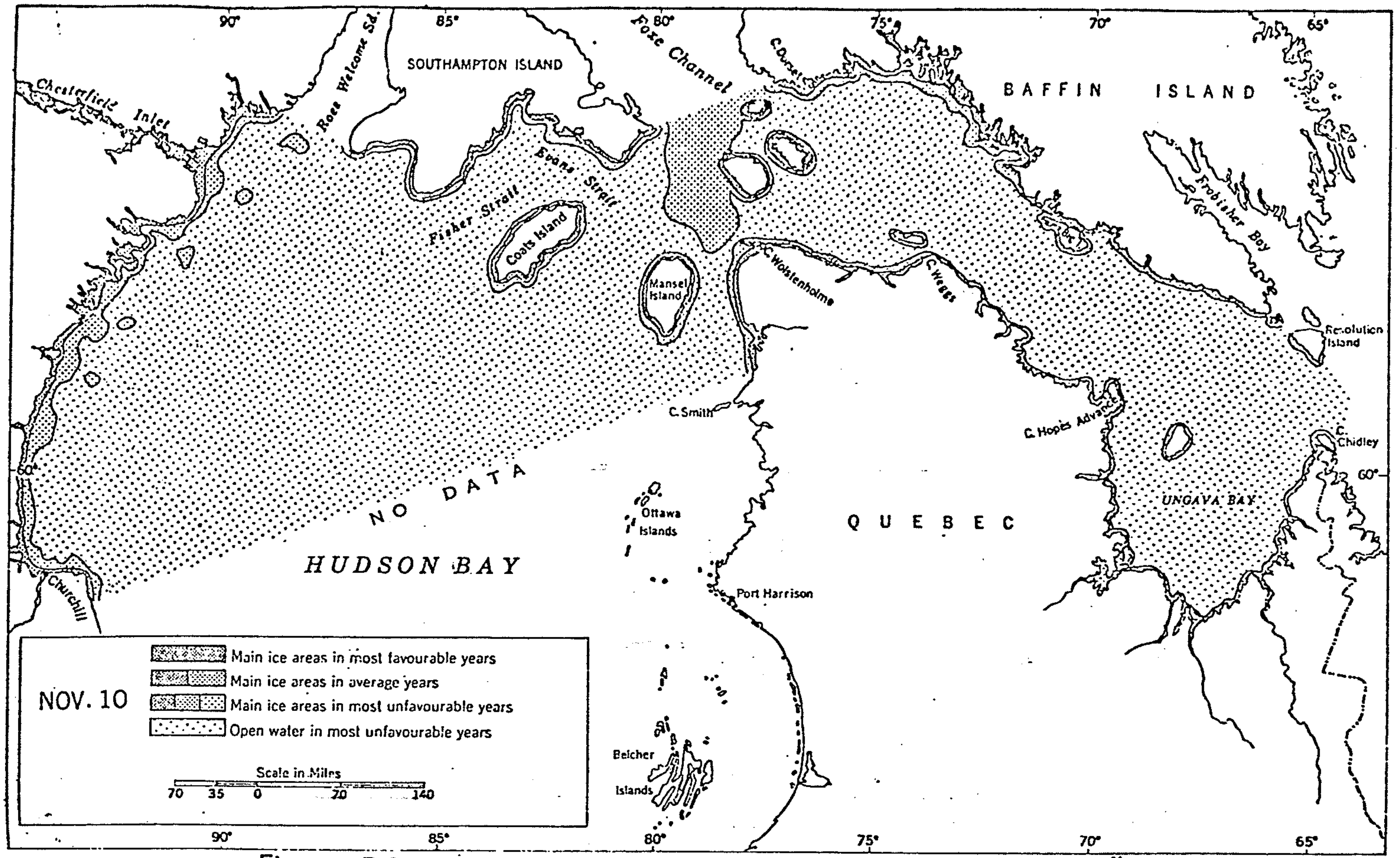


Figure B.6 Limits of main ice areas along the Hudson Bay route on November 10. *

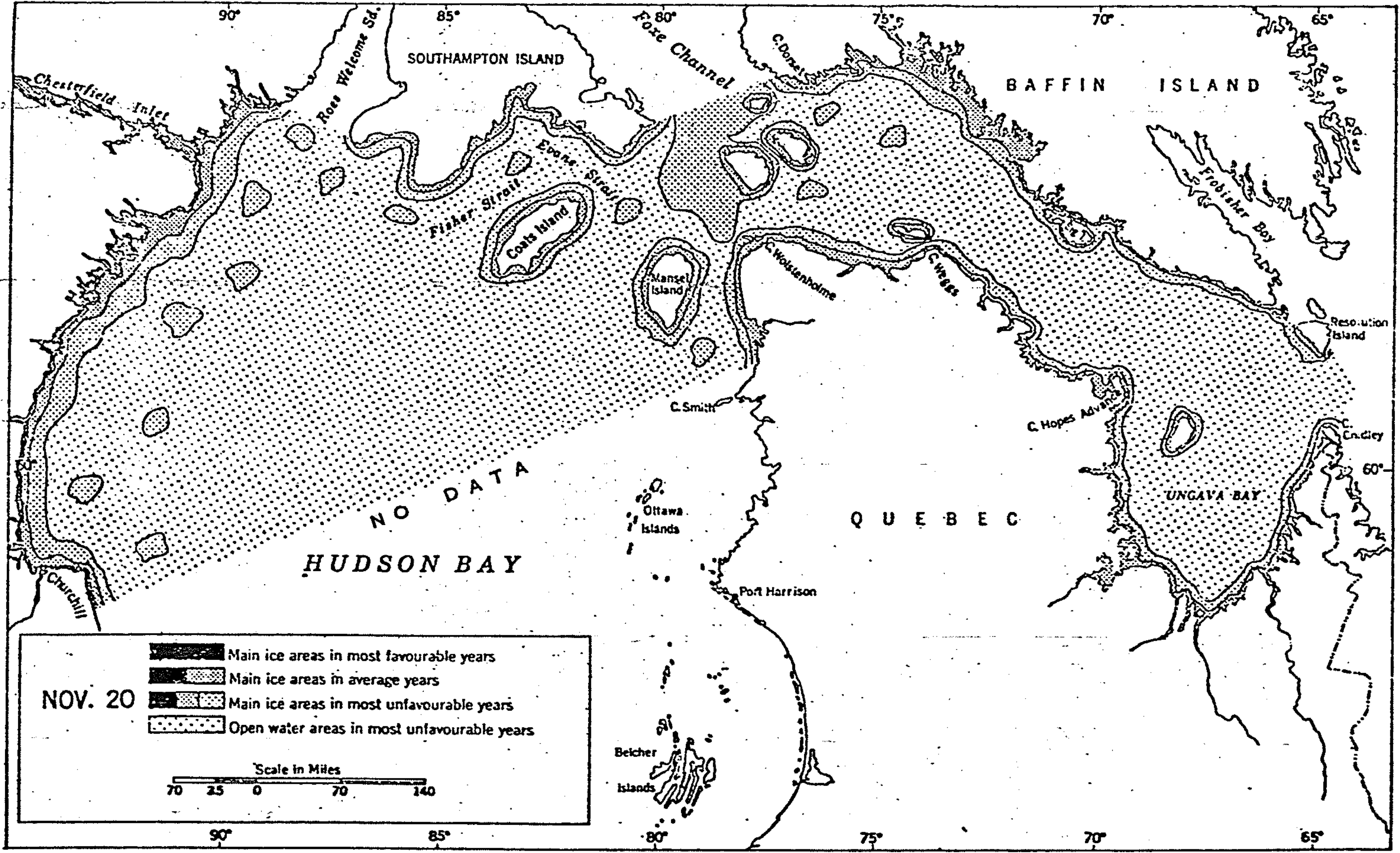
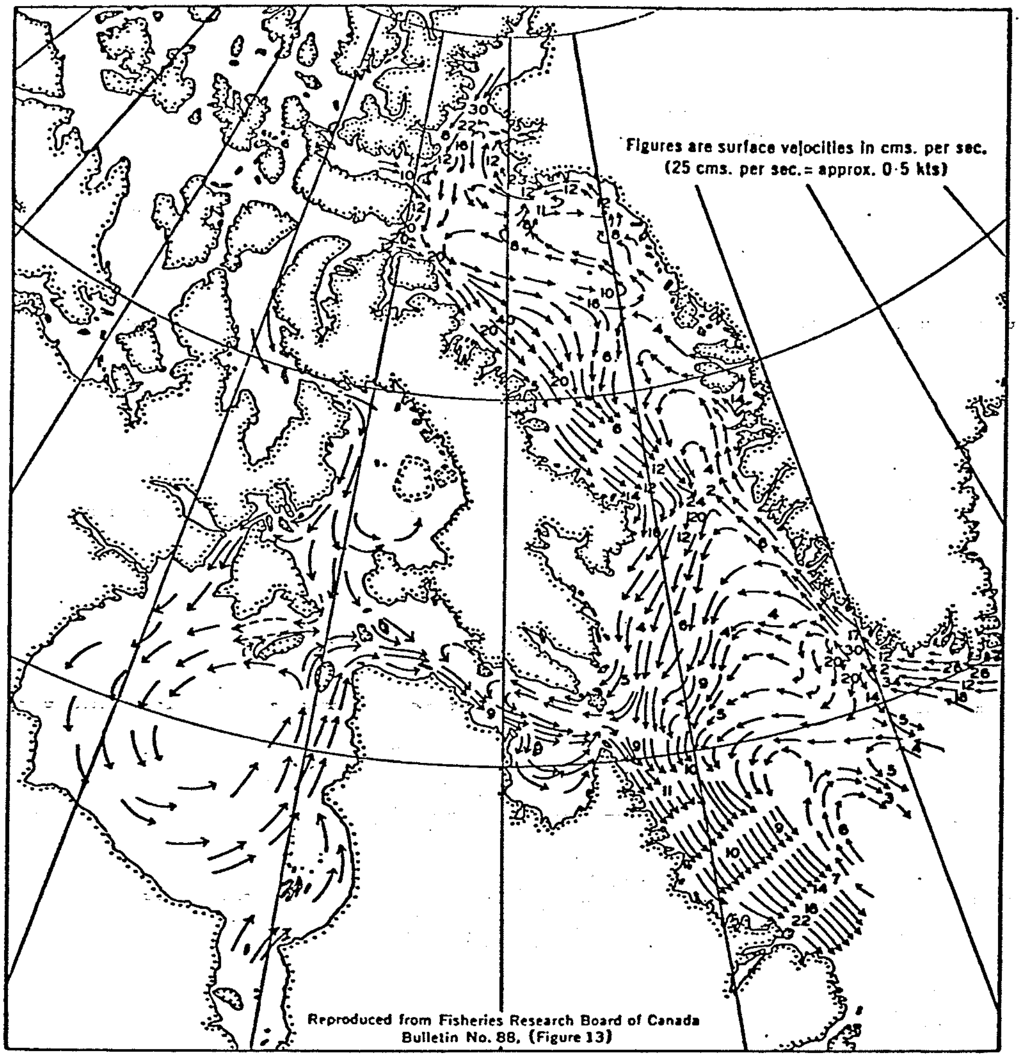


Figure B.7 Limits of main ice areas along the Hudson Bay route on November 20. *

*Source: C.N. Forward, "Sea Ice Conditions Along the Hudson Bay Route", <u>Geographical Bulletin</u> No. 8, (Ottawa: Dept. of Mines, 1956).



Figures are surface velocities in cms. per sec. (25 cms. per sec.= approx. 0·5 kts)

Reproduced from Fisheries Research Board of Canada Bulletin No. 88, (Figure 13)

Figure B.8 Surface currents in the eastern Arctic.

Source: <u>Pilot Of Arctic Canada</u> Vol. 1 2ND Edition, (Ottawa: Canadian Hydrographic Service, 1970).

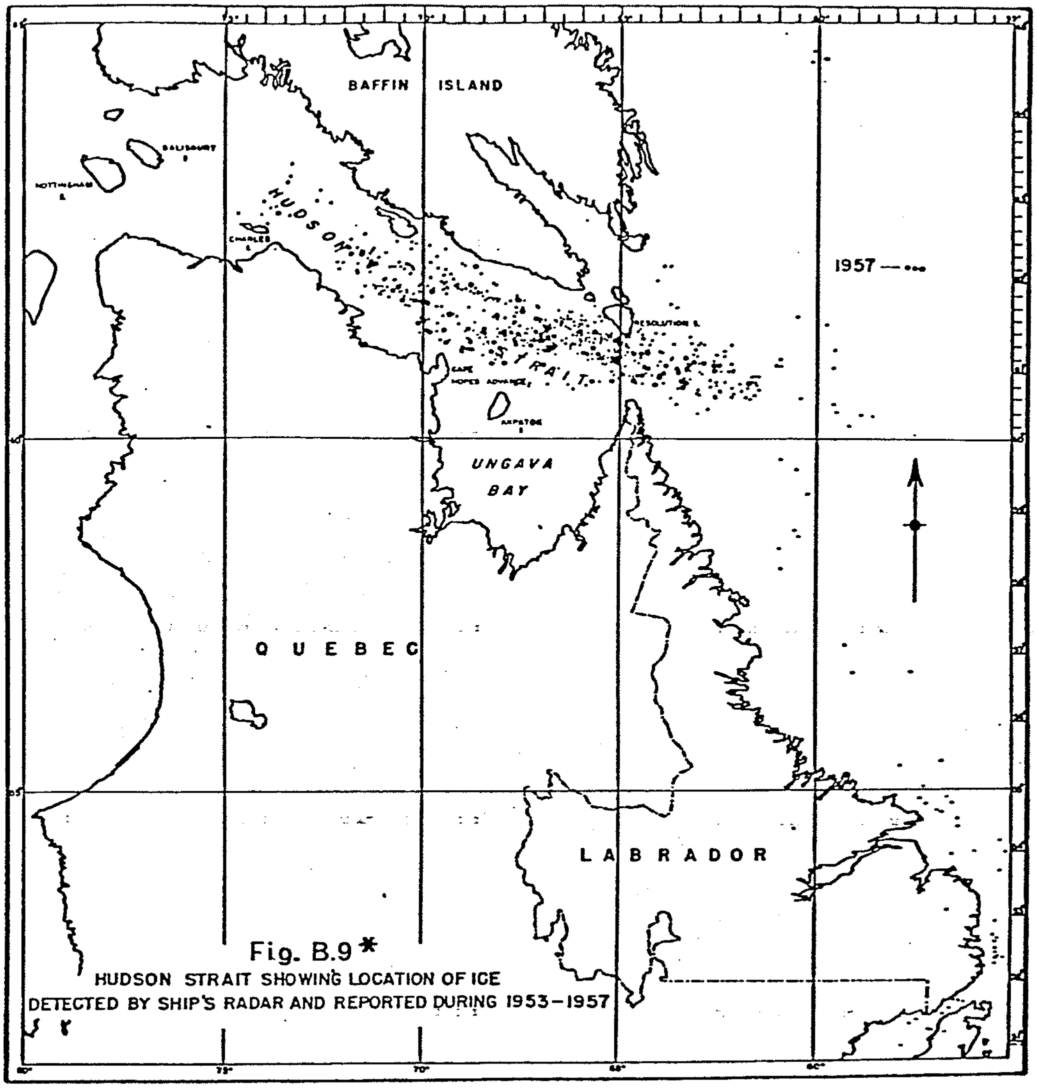


Fig. B.9 *
HUDSON STRAIT SHOWING LOCATION OF ICE
DETECTED BY SHIP'S RADAR AND REPORTED DURING 1953–1957

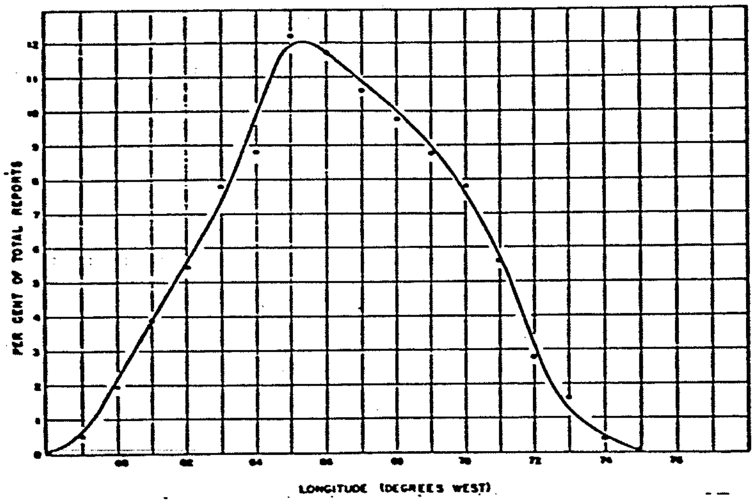


Figure B.10 Ice Density Versus Longitude
For 1953-57 Shipping Seasons *

* Source: A.D. Hood, An Analysis Of Radar Ice Reports Submitted By Hudson Bay Shipping (1953-1957), (Ottawa: National Research Council, 1966).

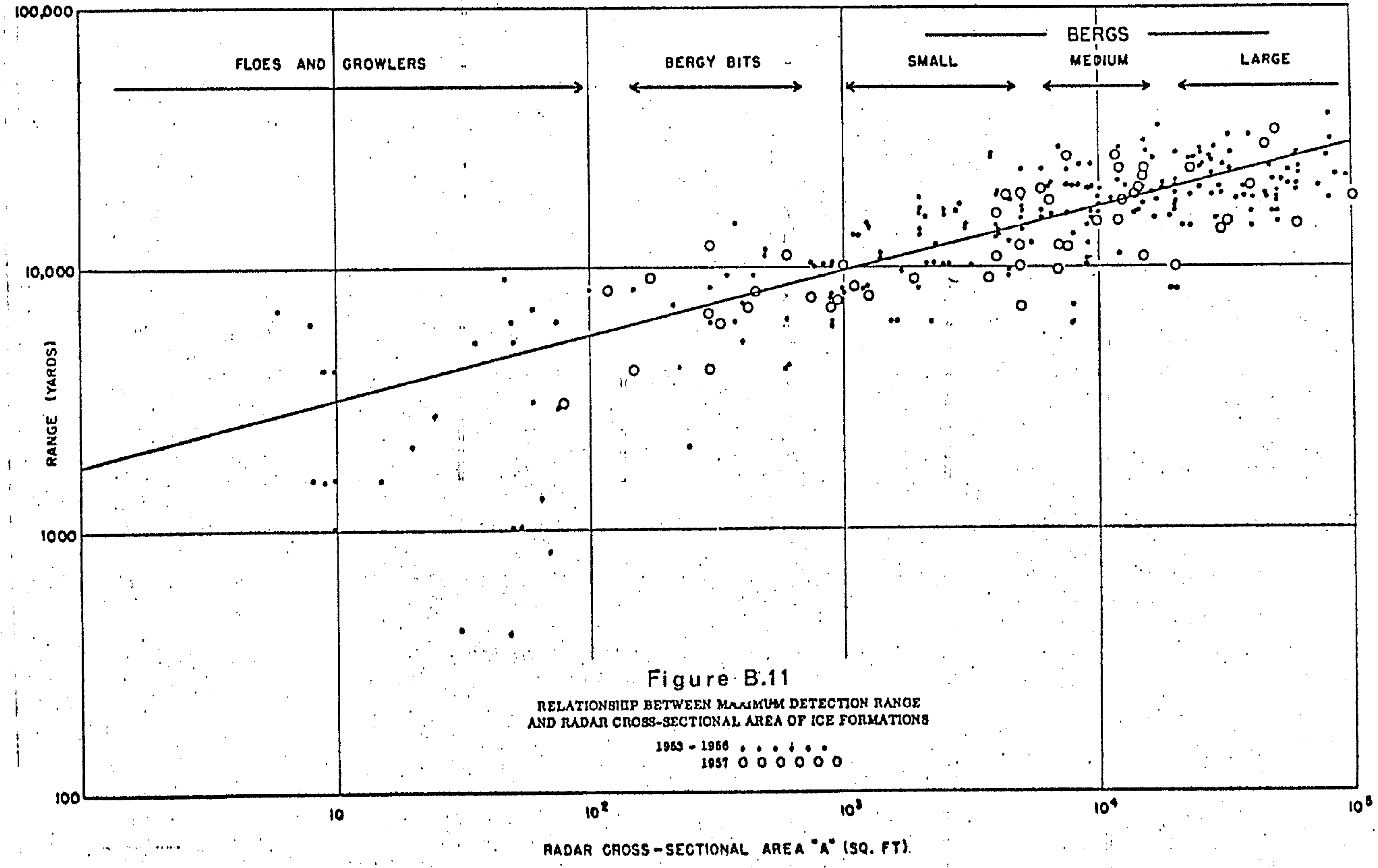


Figure B.11

RELATIONSHIP BETWEEN MAXIMUM DETECTION RANGE AND RADAR CROSS-SECTIONAL AREA OF ICE FORMATIONS

Source: A.D. Hood, An Analysis Of Radar Ice Reports Submitted By Hudson Bay Shipping (1953-1957), (Ottawa: National Research Council, 1966).

FIGURE B.12
AVERAGE MEAN MONTHLY TEMPERATURE IN °F AT THE TOWN OF CHURCHILL (1962 to 1972) AND THE CORRESPONDING CUMULATIVE DEGREE DAYS OF FROST

Source: LAKE WINNIPEG, CHURCHILL and NELSON RIVER STUDY BOARD,

LOWER CHURCHILL RIVER
POST-DIVERSION ICE REGIME STUDIES, May '74

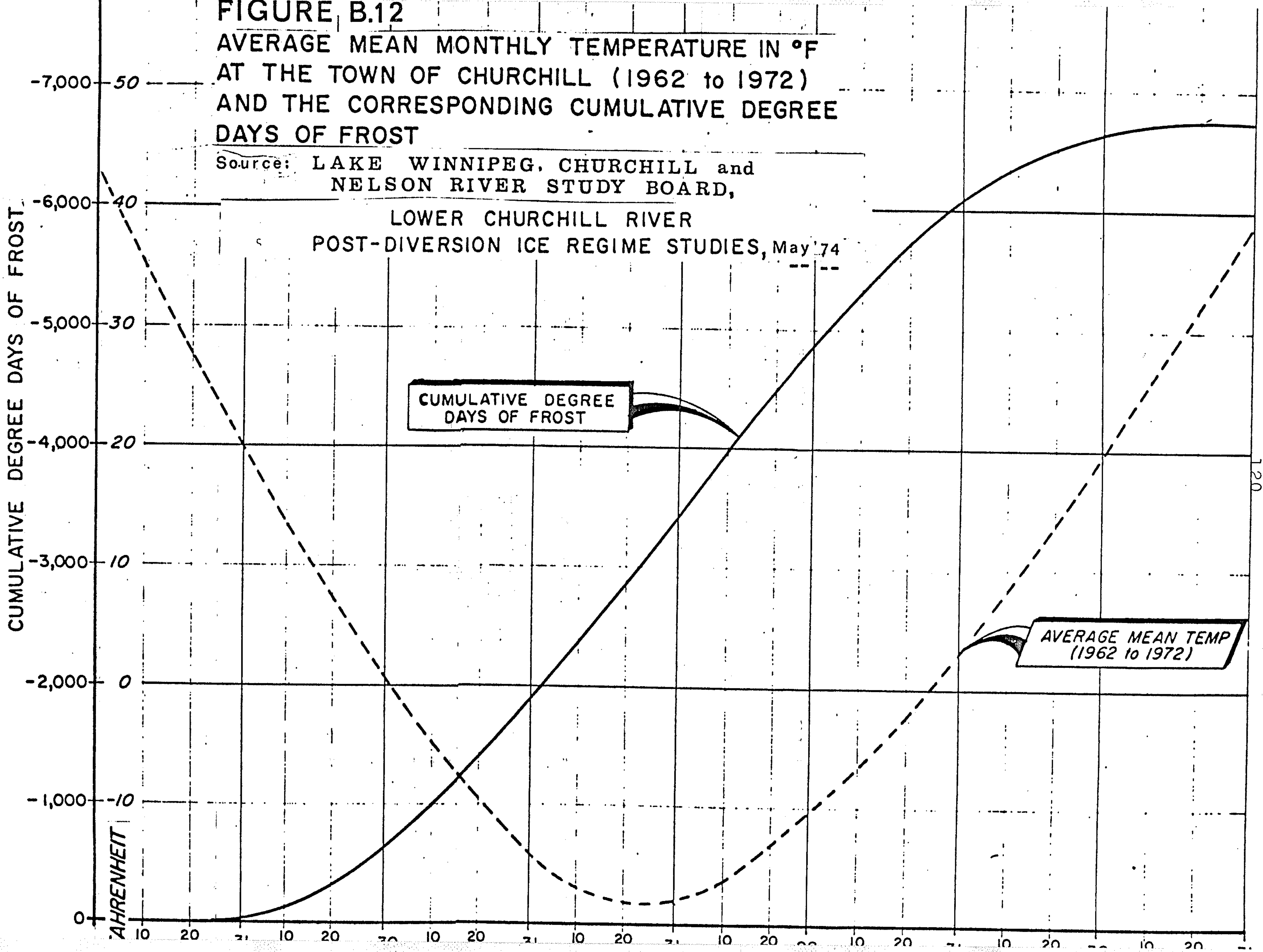


TABLE B.4 Historical Data Summary

YEAR	CHURCHILL RIVER: MEAN DISCHARGE MONTH OF OCTOBER[1] (cubic feet second)				LAST DEPARTURE DATE FOREIGN FLAG VESSEL[2]		CLOSING OF CHURCHILL HARBOUR TO NAVIGATION[3]		CLIMATIC FACTORS[4] OCTOBER					
	ISLAND FALLS 71,000 sq. mi.	GRANVILLE FALLS 82,000 sq. mi.	MISSI FALLS. 93,910 sq. mi.	CHURCHILL 108,390 sq. mi.					TEMP. °F MEAN	DIFF. FROM MEAN	PRECIPITATION TOTAL	% OF MEAN	SNOW INCHES MONTH OCT.	WIND MEAN m.p.h.
VARIABLE	V_1			V_2			V_3		V_4		V_5		V_6	
1928	13900				no		October	17	29.3	-0.2				
1929	22800	no data available			commercial		October	27	37.0	7.5				
1930	20900	28933	38062	55156	shipping		October	17	29.0	-0.5	no data available			
1931	35100	42256	54779	70006	October	2	November	3	37.1	7.6				
1932	46600	56103	69268	85276	October	10	October	14	26.0	-3.5	1.45	92	7.3	
1933	34800	39896	48843	59723	October	2	October	21	25.0	-4.5	0.94	59	4.4	
1934	37700	44161	55380	69022	October	4	October	27	31.0	1.5	3.10	198	21.2	
1935	28400	33660	42845	54014	October	2	October	15	23.4	-6.1	2.33	149	9.4	
1936	22500	25840	31800	39047	October	1	October	10	17.0	-12.5	0.67	42	6.7	
1937	10300	12279	15733	19933	August	18	October	13	29.0	-0.5	0.76	48	2.0	
1938	11300	14752	19391	25032	October	7	October	26	33.3	3.8	2.75	174	17.1	
1939	21000	24373	30293	37492	October	21	October	13	21.6	-7.9	1.24	78	12.1	
1940	10700	12306	15306	18870	August	22	October	17	29.6	0.1	2.60	164	20.2	
1941	10900	14725	21418	29557	August	19	October	24	28.4	-1.1	0.58	37	2.7	
1942	13400	15652	19593	24385	October	13	October	24	32.8	3.3	1.38	86	2.2	
1943	14300	17690	23622	30635	October	3	November	3	36.6	7.1	0.72	46	5.0	
1944	18900	24840	35235	47875	September	15	October	28	30.8	1.3	0.82	52	1.7	
1945	23900	29052	38068	49031	September	13	October	31	29.5	0.0	0.51	32	4.6	
1946	23200	25925	30693	36491	September	25	October	12	25.9	-3.6	0.51	32	4.6	
1947	19300	32219	54627	82318	September	28	November	8	38.6	9.1	1.50	117	0.2	
1948	23500	28630	37607	46523	October	10	November	9	37.0	7.5	0.68	43	0.3	
1949	34200	40462	51420	64745	October	5	October	27	25.6	-3.9	2.45	153	12.4	
1950	19100	23191	30350	39055	October	4	October	20	26.6	-2.9	2.60	164	17.4	
1951	25400	33700	46225	65887	October	4	October	18	26.2	-3.3	1.22	77	10.2	
1952	16800	20600	27250	35336	October	9	October	16	25.8	-3.7	3.12	199	25.6	
1953	18100	22200	29375	38099	October	13	October	28	32.7	3.2	0.59	38	2.9	
1954	32200	43500	63275	87321	October	7	October	29	32.2	2.7	1.77	111	14.0	
1955	26000	25600	41429	54835	October	10	October	24	31.6	2.3	2.11	134	14.8	
1956	16500	19000	23375	28695	October	13	October	23	29.0	-0.5	1.40	90	6.8	
1957	19600	24900	34175	45453	October	10	October	21	31.5	2.0	1.16	68	7.7	
1958	24400	31000	42550	56594	October	28	November	6	33.1	3.6	0.35	22	1.8	
1959	30300	37300	51200	67372	October	15	October	17	24.9	-4.6	2.58	170	26.3	
1960	33500	40100	52545	67313	October	12	October	18	27.1	-2.4	2.26	147	16.2	
1961	21200	23300	26878	31229	October	15	October	20	25.0	-4.5	2.75	174	22.0	
1962	24300	26000	34552	42519	October	11	October	25	33.1	3.6	1.49	94	7.4	
1963	25900	32500	44344	58625	October	20	November	13	36.8	7.3	1.16	68	7.4	
1964	29500	38300	52600	70475	October	12	October	29	29.9	0.4	0.44	28	3.4	
1965	29600	34000	41350	50287	October	14	October	27	29.9	0.4	1.89	116	8.6	19.2
1966	21300	23500	27648	32524	October	14	October	28	29.4	-0.1	0.84	54	7.6	15.5
1967	18800	23700	34876	43688	October	21	October	27	29.0	-0.5	1.36	88	13.7	16.7
1968	20200	25900	35932	42016	October	22	November	4	33.1	3.6	1.79	112	5.7	12.1
1969	21600	32600	51900	75280	October	20	November	13	28.5	-1.0	1.84	114	9.8	15.5
1970	21000	28700	40672	56236	October	26	October	29	29.1	-0.4	3.97	251	28.1	15.7
1971	29000	45400	74540	109520	October	19	October	27	32.6	3.1	1.80	113	2.9	13.0
1972	25100	32200	44696	59748	October	24	October	25	20.7	-8.8	1.02	65	10.5	16.4
MEANS	23300			51400			October	25	29.5		1.58		9.9	

1. Island Falls - 1928-1972, Historical Streamflow Summary, Saskatchewan to 1970, Environment Canada, Inland Waters Branch, Water Survey of Canada, Ottawa. (recorded streamflow)

- Granville Falls - 1951-1972, Historical Streamflow Summary, Manitoba to 1973, Environment Canada, Inland Waters Branch, Water Survey of Canada, Ottawa. (recorded streamflow)

Missi and Churchill - 1930-1972, Manitoba Hydro System Planning simulation Sequence G1/18-M (ratio of catchment areas).

2. Annual Reports-NHB, 1931-1959. 1960-1972 in Churchill - Canada's National Harbour of the North, Ottawa, 1972.p.29.

3. Allen, W. and Cudbird, B., Freeze-Up and Break-Up Dates of Water Bodies in Canada, Toronto, 1971.p.72. These dates show the last possible date considered safe by the Pilot to hold a ship in the harbour.

4. Department of Transport, Ice- Summary and Analysis: Hudson's Bay and Approaches,1955-1972, Meteorological Branch, Ottawa. From 1926-1955, raw data was collected from files of the Meteorological Branch in Winnipeg.

APPENDIX C

Shore Aids to Navigation on the Hudson Bay Route

TABLE C.1

HUDSON STRAIT AND BAY

No.	Name	Position Latitude N. Longitude W.	Colour of light	Character	Height in feet (metres) above high water	Nominal range	Character of apparatus	Description of structure Height in feet (metres) above ground	Year established or last altered	Remarks Fog Signals
Ungava Bay										
1434 *H57*	Button Islands... Radiobeacon.....	NE. extreme of Goodwin I. 60 41 45 64 37 36	W	Fl.	180 (54.9)	8	Electric....	Aluminum square skeleton tower. 31 (9.4)	1965 1970	Flash 1 sec., eclipse 5 sec.
Frobisher Bay										
1435	*White Top Ledge light buoy*	SW. of Ledge 63 42 41 68 30 31	R	Fl.	.....	.....	Electric....	Red, boat type	1961	
1436	*Polaris Reef light buoy*	S. of Reef 63 43 10 68 31 06	R	Fl.	.....	.....	Electric....	Red, boat type	1961	
1437	*Black Ledge light buoy*	W. of Ledge 63 43 35 68 31 36	R	Fl.	.....	.....	Electric....	Red, boat type	1961	
1438 *H56*	Radio Island (Resolution island) Radiobeacon.....	W. side of Radio I. 61 18 28 64 53 16	W	Fl.	129 (39.3)	7	Electric....	Aluminum skeleton tower, fluorescent orange daymark. 23 (7.0)	1932 1970	Flash 1 sec., eclipse 5 sec.
1439 *H52*	Cape Hopes Advance	61 04 44 69 33 32	W	Fl.	270 (82.3)	5	Electric....	Red and white skeleton tower, fluorescent orange daymark. 20 (6.1)	1932 1971	Flash 1 sec., eclipse 5 sec.
1440 *H48*	Wales Island.....	E. extremity of Island.... 61 51 38 71 58 00	W	Fl.	273 (83.2)	8	D, electric..	Red and white tower..... 20 (6.1)	1932 1968	Flash 1 sec., eclipse 5 sec.

HUDSON STRAIT AND BAY

No.	Name	Position Latitude N. Longitude W.	Colour of light	Character	Height in feet (metres) above high water	Nominal range	Character of apparatus	Description of structure Height in feet (metres) above ground	Year established or last altered	Remarks Fog Signals
1441 *H50*	Ashe Inlet....... Radiobeacon.....	E. end of Rabbit I. 62 32 00 70 33 35	W	Fl.	240 (73.2)	8	D, electric..	Red and white square skeleton tower, fluorescent orange rectangular daymark. 20 (6.1)	1915 1970	Flash 1 sec., eclipse 5 sec.
1442 *H44*	Charles Island, East End Radiobeacon.....	62 36 28 73 56 12	W	Fl.	200 (61.0)	7	Electric....	Red and white square skeleton tower. 21 (6.4)	1932 1972	Flash 1 sec., eclipse 5 sec.
1443 *H42*	Charles Island, West End	62 42 30 74 40 00	W	Fl.	68 (20.7)	8	D, electric..	Red and white skeleton tower, fluorescent orange rectangular slat-work daymark. 58 (17.7)	1932 1966	Flash 1 sec., eclipse 5 sec. Radar reflector.
1443.3 *H41*	Arctic Island	On centre of island 62 14 28 74 45 44	W	Fl.	97 (29.6)	8	Electric....	Red and white square skeleton tower, fluorescent orange rectangular daymark. 22 (6.7)	1966	Flash 1 sec., eclipse 5 sec.
1443.6 *H41.2*	Deception Bay range	On top of cliff 62 10 36 74 45 48	W	F.	227 (69.2)	.....	Electric....	Red and white square skeleton tower, fluorescent orange rectangular daymark. 22 (6.7)	1966	Visible in line of range
1443.7 *H41.21*		173°30' 676 feet (206.0) from front.	W	F.	270 (82.3)	.....	Electric....	Red and white square skeleton tower, fluorescent orange rectangular daymark. 22 (6.7)	1966	
1444 *H40*	Nottingham Island Radiobeacon.....	On S. extremity of island. 63 05 10 77 57 00	W	Fl.	86 (26.2)	10	D, gas	Red and white square skeleton tower. 36 (11.0)	1932 1972	Flash 1 sec., eclipse 5 sec. Radar reflector.
1445 *H38*	Digges Islet	On NW. islet of the Digges Islands. 62 35 14 78 06 38	W	Fl.	91 (27.7)	10	Electric....	Red and white square skeleton tower, fluorescent orange square daymark. 26 (7.9)	1915 1972	Flash 1 sec., eclipse 5 sec. Radar reflector.
1446 *H36*	Mansel Island.... Radiobeacon.....	N. extremity of island.... 62 25 00 79 36 30	W	Fl.	46 (14.0)	10	Electric....	Red and white square skeleton tower. 36 (11.0)	1915 1972	Flash 1 sec., eclipse 5 sec. Radar reflector.

HUDSON STRAIT AND BAY

No.	Name	Position Latitude N. Longitude W.	Colour of light	Character	Height in feet (metres) above high water	Nominal range	Character of apparatus	Description of structure Height in feet (metres) above ground	Year established or last altered	Remarks Fog Signals
1441 *H50*	Ashe Inlet....... Radiobeacon.....	E. end of Rabbit I. 62 32 00 70 33 35	W	Fl.	240 (73.2)	8	D, electric..	Red and white square skeleton tower, fluorescent orange rectangular daymark. 20 (6.1)	1915 1970	Flash 1 sec., eclipse 5 sec.
1442 *H44*	Charles Island, East End Radiobeacon.....	62 36 28 73 56 12	W	Fl.	200 (61.0)	7	Electric....	Red and white square skeleton tower. 21 (6.4)	1932 1972	Flash 1 sec., eclipse 5 sec.
1443 *H42*	Charles Island, West End	62 42 30 74 40 00	W	Fl.	68 (20.7)	8	D, electric..	Red and white skeleton tower, fluorescent orange rectangular slatwork daymark. 58 (17.7)	1932 1966	Flash 1 sec., eclipse 5 sec. Radar reflector.
1443.3 *H41*	Arctic Island	On centre of island...... 62 14 28 74 45 44	W	Fl.	97 (29.6)	8	Electric....	Red and white square skeleton tower, fluorescent orange rectangular daymark. 22 (6.7)	1966	Flash 1 sec., eclipse 5 sec.
1443.6 *H41.2*	Deception Bay range	On top of cliff.......... 62 10 36 74 45 48	W	F.	227 (69.2)	.....	Electric....	Red and white square skeleton tower, fluorescent orange rectangular daymark. 22 (6.7)	1966	Visible in line of range
1443.7 *H41.21*		173°30' 676 feet (206.0) from front.	W	F.	270 (82.3)	.....	Electric....	Red and white square skeleton tower, fluorescent orange rectangular daymark. 22 (6.7)	1966	
1444 *H40*	Nottingham Island Radiobeacon.....	On S. extremity of island. 63 05 10 77 57 00	W	Fl.	86 (26.2)	10	D, gas.....	Red and white square skeleton tower. 36 (11.0)	1932 1972	Flash 1 sec., eclipse 5 sec. Radar reflector.
1445 *H38*	Digges Islet.....	On NW. islet of the Digges Islands. 62 35 14 78 06 38	W	Fl.	91 (27.7)	10	Electric....	Red and white square skeleton tower, fluorescent orange square daymark. 26 (7.9)	1915 1972	Flash 1 sec., eclipse 5 sec. Radar reflector.
1446 *H36*	Mansel Island.... Radiobeacon.....	N. extremity of island.... 62 25 00 79 36 30	W	Fl.	46 (14.0)	10	Electric....	Red and white square skeleton tower. 36 (11.0)	1915 1972	Flash 1 sec., eclipse 5 sec. Radar reflector.

HUDSON STRAIT AND BAY

No.	Name	Position Latitude N. Longitude W.	Colour of light	Character	Height in feet (metres) above high water	Nominal range	Character of apparatus	Description of structure Height in feet (metres) above ground	Year established or last altered	Remarks Fog Signals
1447 *H36.1*	Cape Acadia (Mansel I.) Radiobeacon.....	S. extremity of island.... 61 35 00 79 48 30	W	Fl.	77 (23.5)	10	Electric....	Square skeleton tower; fluorescent orange daymarks on S. and W. sides. 63 (19.2)	1963 1970	Flash 1 sec., eclipse 5 sec. Radar reflector.
1448 *H32*	Coats Island..... Radiobeacon.....	On Carys Swan Nest, SE. point of island. 62 10 20 83 08 00	W	Fl.	41 (12.5)	7	D, gas	Red and white skeleton tower; fluorescent orange slatwork daymark. 36 (11.0)	1932 1970	Flash 1 sec., eclipse 5 sec. Shoal water surrounds this point and shoul not be approached nearer than 5 miles. Radar reflector.
1449 *H33*	Cape Pembroke ..	NE. end of Coats I....... 62 54 30 81 53 30	W	Fl.	165 (50.3)	10	Electric....	Square skeleton tower; fluorescent orange daymark. 36 (11.0)	1964 1970	Flash 1 sec., eclipse 5 sec.
1450 *H33.4*	Walrus Island....	Centre of island......... 63 13 30 83 39 00	W	Fl.	180 (54.9)	8	Electric....	Triangular skeleton tower; fluorescent orange daymark. 32 (9.8)	1964	Flash 1 sec., eclipse 5 sec.
1451 *H34*	Bear Island......	On E. side of entrance to Coral Harbour. 64 00 30 83 13 01	W	Fl.	66 (20.1)	8	D, electric..	Red and white square skeleton tower, fluorescent orange rectangular daymark. 39 (11.9)	1943 1970	Flash 1 sec., eclipse 5 sec. Radar reflector.
1452 *H35*	Coral Harbour.... Radiobeacon.....	In Munn Bay, Southampton Harbour. 64 07 33 83 15 13	W	Fl.	75 (22.9).	10	D, gas	Red and white square skeleton tower. 31 (9.4)	1943 1970	Flash 1 sec., eclipse 5 sec. Radar reflector.
1453 *H22*	Chesterfield Inlet Radiobeacon	On top of E. radio tower.. 63 20 06 90 42 32	W	Fl.	121 (36.9)	.....	Electric....	Tower	1953	Flash 1 sec., eclipse 11 sec.
1454	***Churchill Harbour light and bell buoy***	58 49 40.5 94 06 17.5	W	Fl. (Mo.A.)	.....	.....	Electric....	Black and white vertical stripes.	1949 1973	Radar reflector.
1455	***Merry Rock light and bell buoy 1***	NW. of Merry Rock....... 58 47 30 94 12 20.5	G	Fl.	.....	.....	Electric....	Black, marked "1"......	1931 1969	
1456	***Merry Rock light buoy 2***	58 47 41 94 12 24.5	R	Fl.	.....	.....	Electric....	Red, marked "2"........	1964 1968	

No.	Name	Position Latitude N. Longitude W.	Colour of light	Character	Height in feet (metres) above high water	Nominal range	Character of apparatus	Description of structure Height in feet (metres) above ground	Year established or last altered	Remarks Fog Signals
1457 *H28*	Fort Prince of Wales range	58 47 39.5 94 12 56	W	F.	16 (4.9)	.....	Electric....	Mast; fluorescent orange daymark.	1963 1968	
1458 *H28.1*		343°25' 1,325 feet (403.9) from front.	W	F.	27 (8.2)	.....	Electric....	Mast; fluorescent orange daymark.	1963 1968	
1459 *H29*	Ship Point range	58 47 28.5 94 13 23	W	F.	17 (5.2)	.....	Electric....	Mast; fluorescent orange daymark.	1963 1968	
1460 *H29.1*		317°35' 700 feet (213.4) from front.	W	F.	30 (9.1)	.....	Electric....	Mast; fluorescent orange daymark.	1963 1968	
1461 *H27*	Churchill range ..	58 47 01 94 14 00	W	F.	73 (22.3)	.....	D, electric..	White tripod tower; white slatwork daymark.	1960 1968	
1462 *H27.1*		236°25' 5,350 feet (1630.7) from front.	W	F.	152 (46.3)	.....	D, electric..	Aluminum tripod tower; fluorescent orange slatwork daymark.	1960 1968	
1463	*Merry Rock light buoy 4*	58 47 23 94 12 57	R	Fl.	.....	.....	Electric....	Red, marked "4"........	1964 1968	
1464	*Cape Merry light buoy 3*	58 47 17.5 94 12 37.5	G	Fl.	.....	.....	Electric....	Black, marked "3"......	1963 1969	
1465	*Cape Merry light buoy 5*	58 47 10 94 12 34	G	Fl.	.....	.....	Electric....	Black, marked "5"......	1963 1969	
1466	*Cape Merry light buoy 6*	58 47 02.5 94 12 49	R	Fl.	.....	.....	Electric....	Red, marked "6"........	1963 1968	
1467	*Churchill wharf Approach light buoy 7*	58 46 51 94 12 12	G	Fl.	.....	.....	Electric....	Black, marked "7"......	1963 1969	
1468	*Churchill wharf light buoy 9*	58 46 46 94 11 58	G	Fl.	.....	.....	Electric....	Black, marked "9"......	1963 1969	
1469	*Churchill wharf light buoy 8*	58 46 43.5 94 12 14	R	Fl.	.....	.....	Electric....	Red, marked "8"........	1963 1968	
1470	*Churchill wharf light buoy 10*	S. end of wharf.......... 58 46 17 94 11 41	R	Fl.	.....	.....	Electric....	Red, marked "10".......	1966 1969	
1471 *H26*	Churchill Harbour Radiobeacon.....	On E. side of harbour.... 58 46 29.5 94 11 23	R	Fl.	218 (66.4)	.....	Electric....	On top of grain elevator..	1952 1968	Flash every 5 sec.

TABLE C. 2

New Aids to Navigation on the Hudson Bay Route, 1953 - 75, Inclusive

No.	Name	Position Latitude N. Longitude W.	Description of New Apparatus	Year Established
1434	Button Island	NE extreme of Goodwin I. 60 41 45 64 37 36	Light Radiobeacon	1965
1442	Charles Island	E. end of Island 62 36 28 73 56 12	Radiobeacon	1953
1443.3	Arctic Island	On Centre of Island 62 14 28 74 45 44	Light	1966
1443.6	Deception Bay Range	On top of cliff 62 10 36 74 45 48	Light	1966
1443.7		173° 30' 676 feet (206.0) from front	Light	1966
1447	Cape Acadia (Mansel I.)	S. extremity of Island 61 35 00 79 48 30	Light Radiobeacon Radar reflector	1963
1449	Cape Pembroke	NE. end of Coates I. 62 54 30 81 53 30	Light	1964
1456	Merry Rock light buoy 2	58 47 41 94 12 24.5	Light and Bell Buoy	1964
1457	Fort Prince of Wales range	58 47 39.5 94 12 56	Light	1963
1458		343° 25' 1,325 feet (403.9) from front	Light	1963
1459	Ship Point range	58 47 28.5 94 13 23	Light	1963
1460		317° 35' 700 feet (213.4) from front	Light	1963

New Aids to Navigation on the Hudson Bay Route 1953 - 75, Inclusive

No.	Name	Position Latitude N. Longitude W.	Description of New Apparatus	Year Established
1461	Churchill Range	58 47 01 94 14 00	Light	1960
1462		236° 25' 5,350 feet (1630.7) from front	Light	1960
1463	Merry Rock Light buoy 4	58 47 23 94 12 57	Light buoy	1964
1464	Cape Merry light buoy 3	58 47 17.5 94 12 37.5	Light buoy	1963
1465	Cape Merry light buoy 5	58 47 10 94 12 34	Light buoy	1963
1466	Cape Merry light buoy 6	58 47 02.5 94 12 49	Light buoy	1963
1467	Churchill wharf Approach light buoy 7	58 46 51 94 12 12	Light buoy	1963
1468	Churchill wharf light buoy 9	58 46 46 94 11 58	Light buoy	1963
1469	Churchill wharf light buoy 8	58 46 43.5 94 12 14	Light buoy	1963
1470	Churchill wharf light buoy 10	S. end of wharf 58 46 17 94 11 41	Light buoy	1966
	Churchill Harbour	On E. side of harbour 58 45 43 93 57 12.5	Radiobeacon	

TABLE C. 3

Altering of Established Aids to Navigation
On The Hudson Bay Route
1953 - 75, Inclusive

		Position			
No.	Name	Latitude N. Longitude W.	* +	Description of Apparatus	Year Changed
1441	Ashe Inlet	E. end of Rabbit I. 62 32 00 70 33 35	*	Radiobeacon	1970
			+	Size of light tower increased from 191 to 240 feet. Tower structure improved.	1970
1443	Charles Island	W. end of Island 62 42 30 74 40 00	*	Radar Reflector	1966
			+	Size of light tower increased from 45 to 68 feet. Tower structure improved.	1966
1444	Nottingham Island	On S. extremity of Island 63 05 10 77 57 00	+	Size of light tower increased from 50 to 85 feet. Tower structure improved.	1958
			*	Radar reflector	
			*	Radiobeacon	1972
1445	Digges Islet	On NW. islet of the Digges Islands	+	Size of light tower increased from 65 to 91 feet. Tower structure improved.	
			*	Radar reflector	
1446	Mansel Island	N. extremity of Island 62 25 00 79 36 30	+	Size of light tower increased from 41 to 46 feet. Tower structure improved.	1958
			*	Radiobeacon	1972
			*	Radar Reflector	1956
1448	Coates Island	SE. point of Island 62 10 20 83 08 00	*	Radiobeacon	1970
1455	Merry Rock light and bell buoy 1	NW. of Merry Rock 58 47 30 94 12 20.5	+	Light added to buoy	1969

Altering of Established Aids to Navigation
On The Hudson Bay Route
1953 - 75, Inclusive

No.	Name	Position Latitude N. Longitude W.	* +	Description of Apparatus	Year Changed
1461	Churchill Range	58 47 01	+	Size of light tower increased from 43 to 73 feet. Tower structure improved.	1968
1462		236° 25' 5,350 feet (1630) from front	+	Size of light tower increased from 125 to 152 feet. Tower structure improved.	1968

* Addition

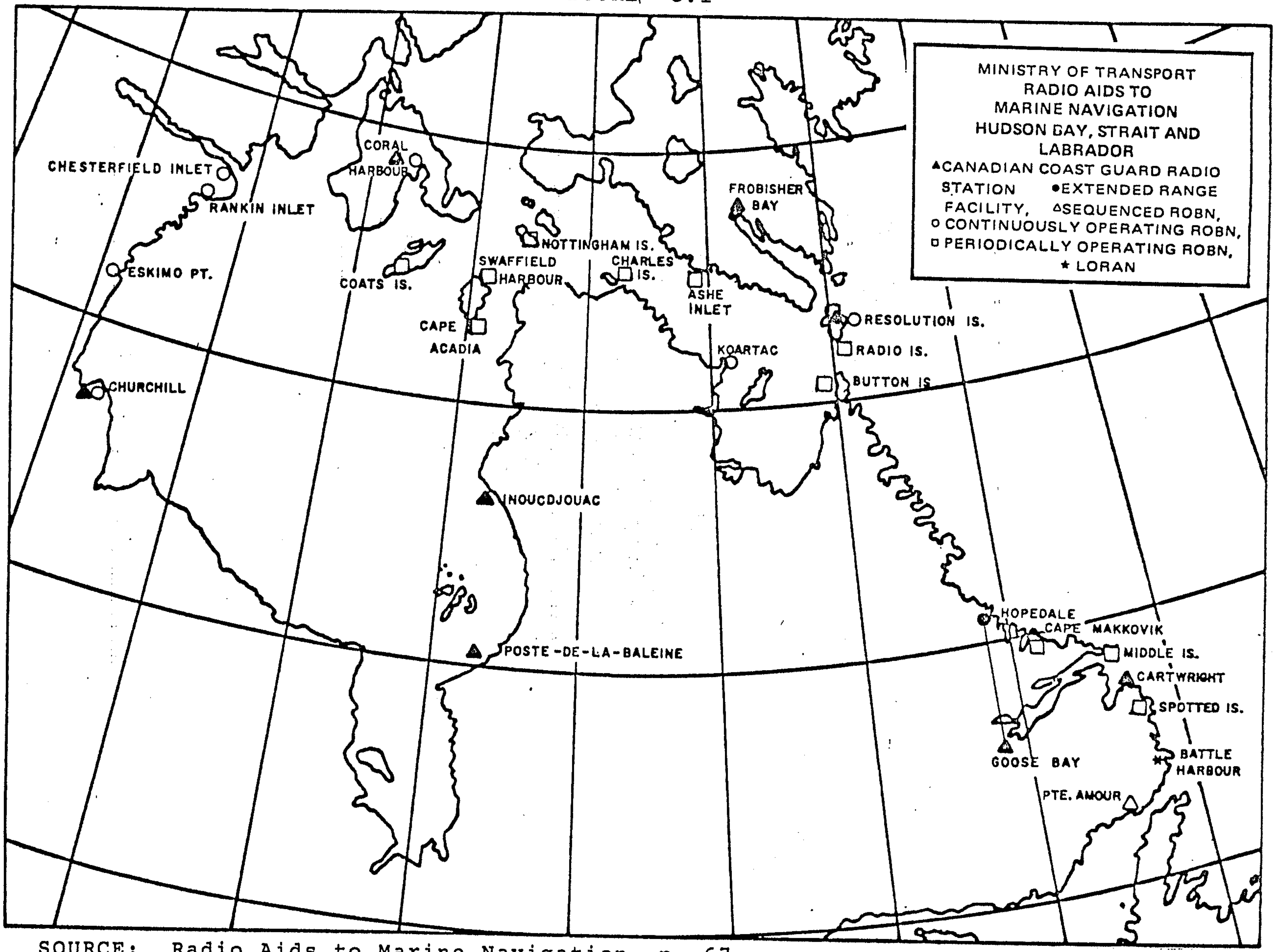
\+ Alteration

TABLE C. 4

RADIOBEACON STATIONS

1 Station Name & Location	2 Freq.	3 Range Nautical Miles	4 One and/or Two Letter Identifier	5 Remarks
KOARTAC, P.Q. 61 02 44 N 69 37 54 W	285	100	•••• •—	Open year round.
CHURCHILL, MAN. 58 45 43 N 93 57 12.5 W	305	150	—•—— ——•—	Open year round.
CHURCHILL, MAN. 58 46 27.5 N 94 10 38 W	356	75	——•—	Open year round.
RESOLUTION ISLAND, N.W.T. 61 35 37N 64 37 42W	292	50	•—• •	Navigation season only. Bearings taken in the arc 170 through west to 340 may be subject to large error.
COATS ISLAND, N.W.T. (Cary's Swan Nest Point) 62 10 20 N 83 08 00 W	302	100	•—	Navigation season only.
RADIO ISLAND, N.W.T. (Resolution Island) 61 18 33 N 64 53 17 W	304	100	•—•	Navigation season only.
CHARLES ISLAND, N.W.T. 62 36 28 N 73 56 12 W	298	100	—•—•	Navigation season only.
NOTTINGHAM ISLAND, N.W.T. 63 05 10 N 77 57 00 W	309	75	—•	Navigation season only.
BUTTON ISLANDS, N.W.T. 60 41 40 N 64 37 33 W	312	100	—•••	Navigation season only.
CAPE ACADIA, N.W.T. (Mansel Island) 61 35 00 N 79 48 30 W	316	100	—••	Navigation season only.
ASHE INLET, N.W.T. (Big Island) 62 32 00 N 70 33 35 W	320	100	•———	Navigation season only.
SWAFFIELD HARBOR, N.W.T. (Mansel Island) 62 25 00 N 79 36 30 W	324	75	—•—	Navigation season only.
CHESTERFIELD INLET, N.W.T. 63 20 30 N 90 42 30 W	341	60	—•—• •••	Open year round.

FIGURE C.1



SOURCE: Radio Aids to Marine Navigation, p. 67.

APPENDIX D

The Constraints For Determining Marine Insurance Coverage

1. Marine Insurance Rates

The constraints for marine insurance rates and reasons for the constraints are as follows:

a. Extra risk on the Hudson Bay route.

". . . Normally the trade from Churchill will be catered for by tramp vessels. The vast majority of such vessels are insured on whole world policies by the year, these policies being subject to what are known as Institute Warranties. Under these warranties, the terms of which are settled by the Joint Hull Committee, a shipowner convenants that his ship shall not voyage in certain defined trades which the underwriters regard as involving extra risk. The route of Churchill is one of these trades. In the form of policy there is a clause providing for the suspension of any of these Warranties on the payment of an additional premium. If during the year covered by the insurance, a shipowner desires to send his ship into prohibited waters, he pays the additional premium, the amount of which is fixed on the recommendation of the Joint Hull Committee. The basal Premium for year's insurance is arrived at by competition."[1]

b. Aids to Navigation Used on the Hudson Bay route.

". . .They (the Joint Hull Committee) were . . . impressed by the fact two Canadian Government icebreakers equipped with salvage apparatus were now stationed in the Strait and at Churchill respectively, and that the wireless direction finding stations along the route were now in use . . ."
". . .On the assumption that no charge would be made for bearings given by the direction finding stations (and as stated in paragraph 11 above, no such charge will be made) and having regard also to the provision of such stations and of icebreakers by the Canadian Government, the Joint Hull Committee have agreed to reduce the rate of additional premiums . . . in respect of vessels passing Cape Chidley inwards on and after (the opening date) . . . and leaving the last loading port in Hudson Bay on or before (the closing date) . . ."[2]

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[1] Imperial (Commonwealth) Shipping Committee, Second Report on Hudson Bay Marine Insurance Rates, 1931, (Great Britain: Her Majesty's Stationery Office, 1931), p. 10.

[2]. Op.cit., p. 11.

". . . Between 5th August and 10th August the underwriters have required the masters of vessels passing into the Strait at Cape Chidley to consult the Master of the Canadian Government vessel N.B. McLean regarding ice conditions; vessels entering the Strait between 5th and 10th August did so at their own risk unless they had been advised that conditions were satisfactory . . ."[3]

It should be noted, as illustrated by Table A. 2, that the latter clause has been in effect since 1936 on vessels proceeding into Hudson Strait at the beginning of the season.

"We (CSC) have previously expressed the view that the Hudson Bay and Strait areas are adequately charted and equipped with navigational aids and that the route can be considered as safe as the St. Lawrence. We have also referred to the keen cooperation of the Canadian authorities in the provision, and improvement, of facilities for the safety of ships voyaging to and from Churchill, and to the fact that shipowners are promoting the safety of their ships on the route to an increasing extent by the installation of the gyro compass, direction-finding and radar equipment. Taking these facts into consideration and having regard to the long record of successful voyages to Churchill, we feel justified in reiterating our view that the Hudson Bay route bears favourable comparison with the St. Lawrence route."[4]

c. Aids to Navigation Used on Vessels

"These rates are in every case subject to the provision that vessels should be properly fitted and equipped for the use of wireless direction finding apparatus . . ."[5]

". . . the Joint Hull Committee have agreed to a further reduction of the additional premium . . . only in the case of vessels equipped with a gyro compass in addition to wireless direction apparatus."[6]

"The basic rates under the Hudson Bay Scale shall in future apply to vessels equipped with a gyro compass . . . provision is to be made for gyro compasses to be inspected by the makers prior to the vessel leaving for Hudson Bay . . . . In the case of the vessels not equipped with a gyro compass, the rates . . . shall be increased . . ."[7]

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3 Commonwealth Shipping Committee, <u>Op.cit</u>., Tenth Report 1951, p. 3.

4 <u>Op. cit</u>., Fourteenth Report 1955, pp. 4-5.

5 Imperial (Commonwealth) Shipping Committee, <u>Op.cit</u>., Second Report 1931, p. 11.

6 <u>Op. cit</u>., Third Report 1932, p. 5.

7 <u>Op.cit</u>., Eighth Report 1937, p. 3.

". . . the rates for vessels fitted with Gyro Compass to be reduced (in all columns) by 25%.[8]

d. Perils on the Hudson Bay Route

"The three principal factors to be taken into account in considering navigation conditions along the route are ice, fog, and the behaviour of the magnetic compass."[9]

". . . the exceptional circumstances on account of which the warranty is imposed - fog, ice, and magnetic disturbance - are known and have been provided against by the gyro compass, direction finding by radio and the very efficient services of the Canadian patrol vessels."[10]

e. The Characteristics of Vessels and Personnel Used

". . . the Chairman of the Joint Hull Committee has also pointed out that the . . . rates are only to be regarded as current for the 1931 season and are minimum rates. Underwriters reserving the right to quote a higher rate for any vessel that in their opinion falls below a proper standard of efficiency."[11]

". . . the foregoing minimum rates shall apply only to well found ships with experienced officers."[12]

f. The Small Number of Vessels Using the Route Each Season

". . . so far as physical risks are concerned we (Commonwealth Shipping Committee) are convinced that the Hudson route is no more dangerous, and in some respects less dangerous, than the St. Lawrence route. As against this there still remains the fact that with the present small number of voyages a single loss in a season is a serious matter for the underwriters."[13]

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[8] *Op. cit.*, Eleventh Report 1952, p. 5.

[9] *Op.cit.*, Third Report 1932, p. 1.

[10] *Op.cit.*, Ninth Report 1939, p. 2.

[11] *Op.cit.*, Second Report 1931, p. 11.

[12] *Op.cit.*, Fourth Report 1933, p. 5.

[13] *Op.cit.*, Eighth Report 1937, p. 2.

". . . It is clear, however, that before any substantial reduction in the rate of premium for suspending the warranty to Churchill can be secured, an increased number of voyages to and from Churchill will be necessary . . ."[14]

". . . When giving this opinion (that the Hudson Bay route need not be considered more hazardous than the St. Lawrence route) we (C.S.C.) were, of course, conscious of the fact that the Hudson Bay additional premiums were much greater than those on the St. Lawrence route, that the premiums charged must depend to a certain extent on the number of ships risked, and that far more tonnage had in the past used and would, of course, continue to use the St. Lawrence route. It was for this reason that we (C.S.C.) stated that an increase in the number of voyages to and from Churchill would be necessary before any substantial reduction in the rate of premiums could be secured."[15]

g. The Last Change in Marine Insurance Rates

"Once again our Report deals with a successful season of navigation in which the number of ships and tonnage of cargoes handled were higher than previously . . . The new formula based on the tonnage employed last year (1955), represents a reduction of approximately 10 percent on the additional Premiums payable under the scale."[16]

h. Casualties

". . . No major casualty occurred during the 1951 season despite a record number of 21 voyages made and the Committee are calling the attention of Underwriters to this fact in order that it may be taken into consideration by them when reviewing the position for the forthcoming season. . . An advance copy of this Report was forwarded to the Joint Hull Sub-Committee in order that the facts of the position therein disclosed might be taken into consideration by them when reviewing the position for the forthcoming seasons, and I (Chairman) have now been informed that the market has decided that the Additional Premiums for the Hudson Bay shall be altered . . ."[17]

2. The Shipping Season

The constraints for the period of navigation and reasons

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[14] Op.cit., Ninth Report 1939, p. 2.

[15] Op.cit., Tenth Report 1951, p. 2.

[16] Op.cit., Fifteenth Report 1956, p. 5.

[17] Op.cit., Eleventh Report 1952, p. 3.

for the constraints are as follows:

a. Freezing Dates

> "The conditions which are determined are those of the beginning and close of the season. It would appear from what has been said that at the beginning of the season the difficulties to be apprehended are chiefly in the approaches to the Bay from the ocean, but at the close are local to the neighbourhood of Churchill itself. The average period in each year from which the Bay is safe for shipping lies, therefore, between the freezing (melting) of the entries at the beginning and the freezing of the shore waters at the end."[18]

b. Slush Ice in Churchill Harbour

> "At the end of the season the first event is usually the formation of slush ice in the latter half of October in the brackish water at the mouth of the Churchill river. This ice which is due to floating snow, usually thaws several times before it consolidates into a serious impediment. The two tugs at Churchill are both reinforced for ice and should have no trouble in keeping a way open for a belated ship. The statement may therefore be made that the natural close of the season comes gradually at this point and with ample notice."[19]

In a meeting with five members of the Warranters Sub-Committee of the Joint Hull Committee, authors of the Hedlin, Menzies report obtained the impression that

> "The Joint Hull Committee would be receptive to the suggestion of extending insurance coverage to a later date once the slush ice problem had been solved and the latest facts regarding ice conditions were available to them."[20]

c. Information Available and Consultation

> "We (I.S.C.) explained that, from the information available, the first week in October appeared to be by no means dangerous for navigation, and the Joint Hull Committee have therefore also agreed to extend the limit for sailing from Churchill . . ."[21]

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[18] Op.cit., General Report 1930, p. 2.

[19] Op.cit., Seventh Report 1937, p. 9.

[20] Hedlin, Menzies and Associates, Port of Churchill - Potential for Development, (Canada, Department of Transport, 1969), 2.92.

[21] Imperial (Commonwealth) Shipping Committee, Op.cit., Second Report 1931, p. 11.

"At the meeting between our Chairman and the Underwriters a suggestion was made that the Canadian Government might perhaps care to organize observation of the formation and movement of the ice which comes from Foxe Channel. It was suggested that the assistance of the Exquimaux might perhaps be enlisted, with the permanently staffed Nottingham Island Wireless Station as a base. If as a result of such observations during a series of years, it would become possible to give accurate and early advices of approaching ice, the underwriters would be prepared to consider the adoption of moveable opening and closing dates for the season."[22]

". . .the way is adequately charted and equipped with the usual aids to navigation, and the exceptional circumstances on account of which the warranty is imposed - ice, fog and magnetic disturbance - are known and have been provided against by the gyro compass, direction finding by radio and the very efficient services of the Canadian patrol vessels. . . ."[23]

"The evidence we have collected about conditions in the Hudson Strait and Bay during the 1950 season has been brought to the notice of the Underwriters to assist them in their review of the position for the forthcoming season."[24]

This evidence included: some results of the previous report; risks involved; a comparison of the St. Lawrence and Hudson Bay routes; activity on the Hudson route; reports of ship Masters'; and aids to navigation on the Hudson route.

Following is part of the Eleventh report by Clement Jones, Chairman of the Commonwealth Shipping Committee, on his visit to Churchill in 1952.

"An Englishman, visiting Churchill for the first time and for a short time, would be rash indeed were he (I - that is, Clement Jones) to start preaching about the proper dates for the entry and departure of ships. What he (I) can do is to consult the views of reliable men who have had years of experience. Mr. Twolan has been Manager of the Port for 23 years, since 1928. He has been daily acquainted with the weather, the ships and their cargoes. He has expressed his considered opinion that it would be safe for a vessel to arrive at Cape Chidley on July 23rd, and safe to leave Churchill on October 15th . . ."[25]

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[22] Op.cit., Seventh Report 1936, p. 13.

[23] Op.cit., Ninth Report 1939, p. 2.

[24] Op.cit., Tenth Report 1951, p. 6.

[25] Op.cit., Eleventh Report 1952, App. III, p. 11.

Based on an advance copy of the Eleventh report forwarded to the Joint Hull Sub-Committee,

"I (Mr. Jones) have now been informed that the Market (Insurance) has decided that the Additional Premium for Hudson Bay shall be altered as follows: . . .

(2) The commencing period to be altered from 26th July (in the current Schedule) (passing Cape Chidley) to 23rd July,"[26]

In addition, a meeting involving members of the Warrantees Sub-Committee of the Joint Hull Committee and Hedlin, Menzies and Associates resulted in the following impressions.

"The Committee seemed willing to co-operate in bringing about any justifiable changes in hull insurance provided that adequate information was available to them.

The Committee would be prepared to consider the insurance of ice-strengthened vessels beyond the normal season when the time comes that this sould be required."[27]

d. Salvage Equipment at Churchill

"With the sole exception, therefore, of the difficulty which might arise of securing adequate salvage if a vessel should be wrecked late in the season, it is the view of the committee that the Hudson Bay route need be considered as more risky than the St. Lawrence".[28]

e. The Last Change in Shipping Season

"In our last three Reports, we have remarked that the possibility of a ship being caught by ice in the Hudson Bay or Strait after departure from Churchill at the end of the season must be regarded as a remote one. . . It appears that the evidence we have accumulated over a number of years that the navigational hazards of the route are generally much lighter at the end of the season, and apparently for some time after the close of the season, than they are at the beginning."[29]

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[26] Op.cit., p. 5.

[27] Hedlin, Menzies, Op.cit., 2-92.

[28] Imperial (Commonwealth) Shipping Committee, Op.cit., Ninth Report 1939, p. 2.

[29] Op.cit., Fourteenth Report, p. 2.

APPENDIX E

Casualties of Vessels Using the Hudson Bay Route

1. Total Losses on the Hudson Bay Route

In 1932, the S.S. "Bright Fan" became a total loss after striking an iceberg when passing through the Strait outward bound from Churchill. A formal investigation before a Canadian Judge and two Montreal Assessors found that the court was "unable to exonerate the Master and First Officers of the 'Bright Fan' from default contributing to the loss of the ship in failing to see that...a lookout was maintained."[1]

In 1936, the S.S. "Avon River" ran into a severe gale on 15 September. On 16 September, she became unmanageable and was driven onto the outer reef of Mansel Island. "In the Report of the Preliminary Inquiry held at the insistance of the Canadian Government at Montreal, the wreck of the S.S. Avon River was attributed to the very severe weather conditions - heavy gale and mountainous seas - which the ship encountered when in ballast. No negligence was found on the part of the officers and crew, and everything possible was done to save the ship. ...the Board of Trade in London . . . expressed the view that in the circumstance described the loss was unavoidable and was due, not to any special perils of the route which the ship was following, but to the unusually severe weather conditions which were experienced through the world in the latter part of 1936, during which an unusually large number of ships were lost."[2]

In 1963, a Yugoslav vessel, the M.V. "Kostela" foundered in Hudson Strait and became a total loss on 4 August. On the morning of 3 August, soundings showed water in the No. 1 port and starboard bilges and No. 2 deep tanks. Pumping was started but after two hours the suction became blocked with grain. The crew attempted to reach shallow water and beach the vessel but was unsuccessful. The loss of the vessel was not attributed to ice damage or to any specific danger of the route. It can only be surmissed that there was some inherent weakness which caused the "Kostela" to spring a leak which could not be controlled by

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[1] Imperial (Commonwealth) Shipping Committee, Fourth Report on Hudson Bay Marine Insurance Rates, 1933, (Great Britain: Her Majesty's Stationery Office, 1933), p. 3.

[2] Op.Cit., Eigth Report, 1937, pp. 3-4.

the pumps.[3]

2. Minor Casualties on the Hudson Bay Route

As noted by the following reports, the majority of minor casualties on the Hudson Bay route occurred due to ice conditions early in the shipping season.

In 1952, first arrivals meet with a unusually large ice floe in the Bay "but none of them sustained more than mere superficial damage to hull or propellor.[4] . . . Normally the ice field would have been in the Bay and ships could have navigated round it, but on this occasion the persistent N.E. winds drove it shorewards."[5]

As reported by the Commonwealth Shipping Committee on the 1954 season, "the earlier vessels on the inward passage met with stretches of field ice some of which had to be traversed and which caused in afew cases slight damage to the plates of propellor blades . . ."[6] Another vessel, the M.V. 'Anna C.' developed a defect on her radar set on the in voyage. The vessel struck an iceberg, suffering damage to the stern post, the starboard anchor and part of the bow. After examination the vessel proceeded to London."[7]

At the opening of the 1957 season, abnormally severe ice conditions at the eastern end of Hudson Strait produced casualties on ten vessels. "Of these,six suffered propellor damage involving chipping and bending of the blades, and seven sustained hull indentations in hull plating to tearing away of bow plating."[8]

In 1958, the S.S. "Lord Tweedsmuir" had intended to load a grain cargo in Churchil but went aground off the port and suffered damage as a result. This casualty "does not appear to have been caused by the climatic hazards of the route."[9]

In 1970, the M.V. "Tamworth" obtained minor damages due

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[3] W.A.C.Catinus, Senior Marine Officer, Casualty Investigations, Ministry of Transport Canada, Ottawa, Correspondence, 15 July 1976.

[4] Commonwealth Shipping Committee, Op.Cit., Twelfth Report, 1953, p. 4.

[5] Op.Cit., p. 5.

[6] Op.Cit., Fourteenth Report, 1955, p. 2.

[7] Op.Cit., p. 3.

[8] Op.Cit., Seventeenth Report, 1958, p. 3.

[9] Op.Cit., Eighteenth Report, 1959, p. 2.

to high winds and the light characteristic of the vessel.[10]

In 1974, the M.V. "Eleonora F" and M.V. "Agia Erini II" were grounded in Churchill harbour as a result of fog. The damage to the Eleonora consisted of a hole to the forepeak while the Agia Erini II obtained damage to her forepeak and forward double bottoms.[11] In both cases, the vessels continued their voyages.

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[10] Ministry of Transport Canada records.

[11] Ibid.

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GLOSSARY

AES, Atmospheric Environment Service

ASPPR, Arctic Shipping Pollution Prevention Regulations

CCGS, Canadian Coast Guard Service

Continuous ice, Ice in an unbroken, solid state.

CSC or ISC, Commonwealth (Imperial) Shipping Committee

CWB, Canadian Wheat Board

Dwt., Deadweight

Bergy-bit, A medium-sized piece of ice, generally less than 5 metres above seas level originally from glacier ice, but occasionally a massive piece of sea ice or disrupted hummocked ice.

First-year winter ice, Ice of not more than one winters growth originating from young ice. It has a thickness of more than 30 cm. to approximately 6 metres.

Grey ice, Young ice 10-15 cm. thick. Less than nilas and breaks on swell. Usually rafts under pressure.

Grey-white ice, Young ice 15-30 cm. thick. Under pressure more likely to ridge than to raft.

Growler, Smaller piece of ice than a bergy-bit; it has a small portion of its structure above water and at all times all of the ice structure is under water. A typical growler is actually a minature berg that projects a few feet out of the water.

GRT, Gross Registered Tonnage

Ice concentration, The amount or concentration of ice in an area as defined by 1/10 through 3/10, 4/10 through 6/10, 7/10 through 9/10, and 10/10.

Ice forecasting, Includes the use of climatic and reconnaissance data for the prediction of the formation and movement of ice.

Iceberg, A large mass of floating ice, more than 5 metres above sea level, which has broken away either from a glacier or from an ice-shelf fromation.

Insured value, The value, at the commencement of the risk, of the ship, cargo, and other disbursements (as listed in Section 16 of the Marine Insurance Act, 1906) incurred to make the ship fit for voyage.

LANDSAT, Land satellite, formerly known as ERTS, Earth Resources Technology Satellite.

Lead, A navigable passage through pack-ice. A crack is any fracture in sea-ice not sufficiently wide to be described as a lead.

Medium floe ice, Pack ice of from 100 to 500 m. across.

Navigation season, The period of time in which navigation is possible.

New and Nilas ice, New ice is recently formed ice; it is composed of ice crystals which are only weakly frozen together. Nilas ice is a thin elastic crust of ice, easily bending on waves. Dark nilas is under 5 cm. in thickness and is very dark in colour. Light nilas is more than 5 cm. in thikness and lighter in colour than dark nilas.

NHB, National Harbours Board

NOAA, National Oceanic and Atmospheric Administration satellite (formerly ESSA), an agency of the U.S. Department of Commerce, which operates the National Environment Satellite Service.

Open Water, A large area of freely navigable water in which sea ice is present in concentrations less than one-tenth.

Pancake ice, Pieces of newly formed ice usually approximately circular, about 5 cm. to 9 metres across, and with raised rims due to the pieces striking against each other as aresult of wind and swell.

Permanent ice, New ice which will not dissipate until breakup.

Polar ice, Extremely heavy sea ice, up to 9 metres or more in thickness, or more than one winter's growth.

Rafted/Ridged ice, A type of pressure ice formed by one flow over-riding around.

Rotten ice, Ice which has become honeycombed in the course of melting and which is in an advanced state of disintegration.

s.d., Found in insurance schedules; is the British currency for shilling and pence.

Sea clutter, Weather disturbances on or over sea water as seen by radar on merchant vessels.

Shipping Season, The period of the navigation season for which merchant vessels are covered by London Marine Insurance coverage with the exception of self-insured vessels of East European countries.

Slush ice, An accumulation of frazil ice crystals or spicules which remain separate or only slightly frozen together. It forms a thin layer and gives the sea surface a greyish or leaden-tinted colour.

Small floe ice, Pack ice of from 20 to 100 m. across.

Spicules, Fine plates of ice suspended in water.

Strengthened vessels, Vessels which have part or all of their hulls strengthened (to various degrees) for navigation in various thicknesses of ice as stipulated by the Arctic Shipping Pollution Prevention Regulations.

TIROS, Short name for Television and Infra-red Observation Satellite, a meteorological satellite.

Unstrengthened Vessels, Vessels which do not have any part of their hulls strengthened for navigation in winter ice conditions; however, these vessels may have the size and power to navigate in young ice, which seems to be the trend on the Hudson Bay route during the 1970's.

VHRR, Very High Resolution Radiometer

Young ice, Newly formed level ice generally in the transition stage of development from nilas and first-year ice, 5 to 30 cm. in thickness. May be subdivided into grey ice and grey-white ice.