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RESPONSE TO INFORMATION REQUEST DFO 16

EFFECTS OF ICE BREAKING ON SEA ICE AND INTERACTIONS WITH CLIMATE VARIABILITY AND CHANGE

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1.0 INTRODUCTION

Baffinland Iron Mines Corporation (Baffinland) has prepared a Draft Environmental Impact Statement (DEIS) for the development of the Mary River Project which was submitted to the Nunavut Impact Review Board (NIRB) in December 2010. Following their initial review of the DEIS, further information has been requested by various reviewers.

One of the information requests put forward by Fisheries and Oceans Canada (DFO), labelled as DFO – 16, requested greater in-depth analysis of the effects of ice-breaking on sea ice. DFO also requested further detail on the potential interactions of ice-breaking and climate variability and change (CVC), specifically in regards to sea ice as an ecosystem component for marine mammals, marine fish, primary and secondary producers. The following information is presented in response to IR DFO-16.

Ice pans are formed, merged, broken and then re-formed in a cycle that responds to the natural forces of waves, swell, currents, tide, temperature and wind. Pack ice is not anchored to land and is dynamic. Ice can form initially in situ under relatively low air temperature and calm or light wind conditions, or by the break-up of landfast ice (ice anchored to land) as a consequence of onshore swell followed by reversal of wind direction. In areas like Hudson Strait, the strong tidal currents render the ice very mobile and pans are regularly broken up by ocean swell, then forced together by the action of wind and currents so that ice congeals to form large thick pans. The dynamics of pack ice formation have been described by LeDrew and Winsor (Environment Canada, 1979). Within such a dynamic environment, the passage of a vessel is a minor contributor to this dynamic process.

The effects of the Project Ore carriers on pack ice will be considerably less than on landfast ice. The primary effect of vessel passage will be the breaking of individual floes into two or more smaller ones, as well as the formation of some brash ice. In moving pack ice (such as occurs in Hudson Strait) the breaking of floes will have little effect on the distribution or movement of the ice. In low pack ice concentrations where the vessels will be breaking ice only part of the time, the effects will be even less. Evidence of the ship track will disappear a short distance behind the vessel as the ice moves, closes and re-forms due to wind and currents.

For the purpose of this report the discussion of sea ice pertains to pack ice only.

2.0 EXISTING KNOWLEDGE

An Initial Environmental Assessment (IEE) conducted by the Canadian Coast Guard (CCG, 1990) considered the potential effects of year-round ice breaking operations on the biophysical, socio-economic and the physical environment in the Canadian Arctic. The following discussion draws from the material provided in that document.

By design, an icebreaker disrupts the local ice cover through which it passes. Smaller pans will be pushed aside, while larger pans are broken. The nature of the disruption is influenced by a variety of ship-related as well as environmental factors. When a ship passes through ice, the bow breaks ice pieces from the surrounding ice sheet. These pieces are deflected downwards and to the sides. As the ship progresses, much of the fractured ice is drawn back into the wake of the ship. The ship's track through the ice is characterized by an accumulation of various sizes of ice fragments, the size of the fragments largely determined by conditions of the ice itself. Additionally, the concentration of ice pieces is equally variable, with areas of higher and lower ice density along the ship track. (CCG, 1990)

Studies conducted in Baffin Bay, Lancaster Sound and Strathcona Sound demonstrated that track width varied with general ice conditions and thickness (Dick and Chueng, 1987). In thin ice, wide cusps can form at the shoulder of the ship and, hence create a relatively wider channel. In thicker ice such cusps were narrower and located further forward along the bow, resulting in a relatively narrower channel. In consolidated and landfast ice, the track width is close to the breadth of the ship. The ice piece size distribution within the ship track will vary as a function of hull shape and environmental conditions such as the nature and size of the ice floes (Danielewicz *et al.* 1983).

The results of several studies (Hotzel and Noble, 1979, Strandberg *et al.,* 1985; and Dickens, 1983) suggest that the potential effects of icebreaker passage on ice break-up are few and would result in disturbances within the range of natural temporal variability in the break-up process.

3.0 PROPOSED SHIPPING ROUTE

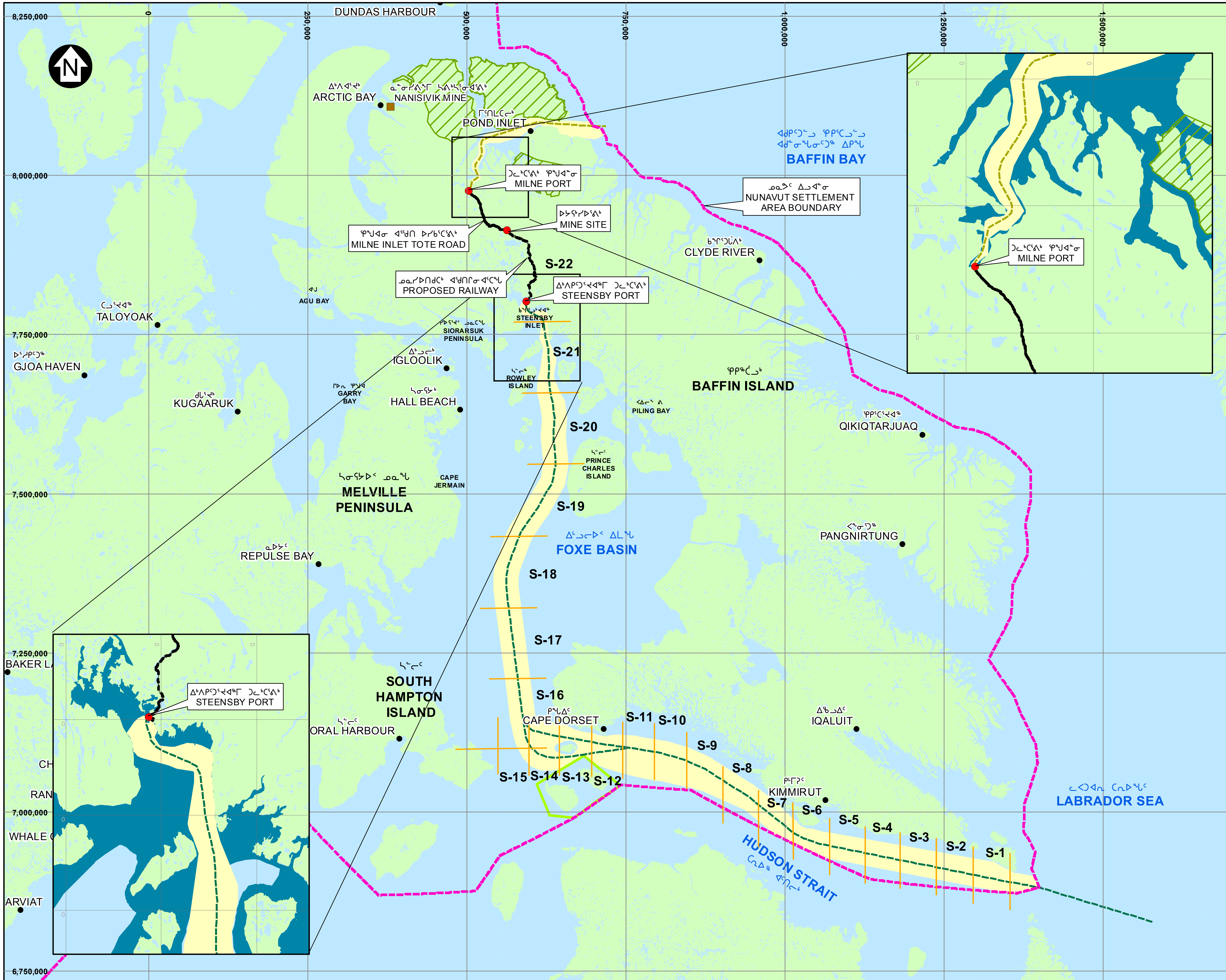
The records of the Canadian Ice Service (CIS) Ice Atlas (Environment Canada 2006) were used to characterise the ice cover along sections of the ships route from Hudson Strait through Foxe Basin to Steensby Inlet. Monthly ice data (total ice concentration, partial ice concentration and ice classification) for the Hudson Bay and Eastern Arctic regions were extracted for the years 1982 to 2011.

The proposed shipping route was divided into 22 sections based on latitude and longitude as per the data gathered from the CIS Ice Archive (Environment Canada, 2006) (Figure 3-1). The area of each section and the proportion represented by a single ship track are presented in Table 3-1.

The proportionate area of a single track was calculated in terms of the Local Study Area (LSA) (i.e., the 50 km band along the shipping route). As shown in Table 3-1 a single ship track represents a maximum of 0.2 % of the total area of its respective section.

Table 3-1 The Ship Track by Section

	Section																					
	S-1	S-2	S-3	S-4	-S-5	S-6	S-7	S-8	S-9	S-10	S-11	S-12	S-13	S14	S-15	S-16	S-17	S-18	S-19	S-20	S-21	S-22
Area LSA (km^2)	2,500	2,500	2,500	2,500	7,500	2,500	2,500	2,500	2,500	3,500	3,500	3,500	3,500	2,500	2,500	3,750	3,750	3,750	3,750	3,750	1,875	2,431
Area Ship Track (km^2)	2.65	2.65	2.65	2.65	7.95	2.65	2.65	2.65	2.65	2.65	2.65	2.65	2.65	2.65	2.65	3.98	3.98	3.98	3.98	3.98	3.98	3.44
% LSA	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.08	0.08	0.08	0.08	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1



SAVED: Z:\11 - GIS DATA\Baffinland-IM\Project Figures\MXD\SKMT-STJ-001 Figure 2-1 IR-15H.mxd; Aug 17, 2011

LEGEND:

- COMMUNITY
- NANISIVIK MINE (DECOMMISSIONED)
- MILNE INLET TOTE ROAD
- PROPOSED RAILWAY ALIGNMENT
- NUNAVUT SETTLEMENT AREA BOUNDARY
- NOMINAL SHIPPING ROUTE - YEAR-ROUND
- NOMINAL SHIPPING ROUTE - OPEN WATER SHIPPING ONLY
- AREA OF EQUAL USE AND OCCUPANCY NUNAVUT AND NUNAVIK
- PROBABLE EXTENT OF YEAR-ROUND SHIPPING
- WATER
- SIRMILIK NATIONAL PARK
- MAXIMUM EXTENT OF LANDFAST ICE (SEE NOTE 3)
- Ice Classification Sections

NOTES:

1. BASE MAP: © HER MAJESTY THE QUEEN IN RIGHTS OF CANADA, DEPARTMENT OF NATURAL RESOURCES (2004). ALL RIGHTS RESERVED.
2. COORDINATE GRID IS SHOWN IN UTM (NAD83) ZONE 17 AND IS IN METRES.
3. ICE EXTENTS: CANADIAN ICE SERVICE
4. SECTIONS BASED ON DATA RETRIEVED FROM CANADIAN ICE SERVICE ARCHIVE

SCALE 50 25 0 50 100 150 200 250 km

BAFFINLAND IRON MINES CORPORATION

MARY RIVER PROJECT

Figure 3-1
Proposed Shipping Route - Ice Classification Sections

P/A NO. REF NO. REV 0

4.0 SHIP-PAN INTERACTION

The CIS Ice Atlas was used to provide an appreciation of the number of pans that could be struck during a single ship transit. The average ice composition was calculated for each section of the shipping route for each month. These data were then used to determine the percentage of ice present in each section, as well as average ice thickness class and average range of pan size. Pan area was calculated using the average range of pan length by multiplying the maximum length by the minimum length (e.g., 0.5 km x 2 km = 1 km^2). By comparing the partial ice composition of the area of a single ship passage to the average pan area identified within each section of the shipping route, an approximate number of pans that would interact with the ship was calculated. The results for each section of the shipping route for each month can be found in Appendix A.

The primary effect of shipping on the pack ice is the breaking of individual pans into two or more smaller pieces or the formation of brash ice (CCG, 1990). In months where pack ice is minimal, should ice breaking occur, the effects would not be detectable. A measurable interaction will only occur with respect to larger pans of ice as they are most likely to be broken by the ship, whereas smaller pans of ice would be pushed to the side and not broken. The months of February, June, July, and December account for 94% of all the estimated pans to be struck annually throughout the shipping route (Table 4-1). These months are expected to see more ship-pan interactions due to the large number of ice pans present.

Table 4-1 Characteristics and Number of Ice Pans Estimated to be Struck per Month by Project Vessels

Month	Range of Average Ice Thickness Class (cm)	Range of Average Pan Length (km)	Estimated Number of Pans to be Struck by a Single Project Vessel transit per Month	Estimated Number of Pans to be Struck Annually
January	<10 – 70-120	0 – 10	26	5,304
February	<10 – 70-120	0.02 – 10	612	124,848
March	10-15 – 70-120	0.5 - 10	7	1,428
April	<10 – 70-120	0.5 - 10	21	4,284
May	<10 - >120	0.5 - 10	18	3,672
June	10-15 - >120	0.02 - 10	303	61,812
July	10-15 - >120	0 - 2	178	36,312
August	10-15 – 70-120	0.5 - 2	2	408
September	0	0	0	0
October	0	0	0	0
November	10-15 – 30-70	0.5 – 2	29	5,916
December	<10 – 30-70	0 – 2	626	127,704
Annual Total	0	0	1,822	371,688

The month of January was originally noted as an anomaly in the data due to the drastic decrease in number of pan estimated to be struck compared to December and February. Upon further review, while the total number of pans estimated to be struck has decreased compared to other winter months, the overall area of pack ice interaction has increased. In the month of January a single vessel will transit through approximately 520 km^2, or 26 pans, of pack ice. This compared to the month of February where a single vessel with transit through approximately 91 km^2, or 612 pans, of pack ice. The difference between these two months lies in the fact that the ice pans present in the month of January were much larger (2 – 10 km in length on average) compared to the ice pans present in February (0.02 – 0.1 km in length of average).

The months of November and December will have an increase in ice pans due to the weather conditions. As these months represent the early winter season, the pans will gradually form due to the freezing temperatures and minimal solar radiation. All the pans for November (29) were determined to have an average pan length of 0.5 – 2 km. The interaction effect would likely result in the pans being split into two or more pieces. The majority of the pans for December (450) were determined to have an average pan length of 0.1 – 0.5 km. The interaction effect would likely result in the pans being pushed to the side of the ship rather than being split into two or more pieces.

The month of February also has an increase in ice pans due to the presence of numerous small pans in Sections S-1, S-7, S-8 and S-9 (Appendix A). The majority of the pans (600) were determined to be 0.02 – 0.1 km in length. As the remainder of the shipping route contained pans with a length of 0.5 – 10 km, the areas of small pan concentration may be due to the larger sea ice pans contacting each other and breaking apart as a result of the high energy environment within this region of the Hudson Strait.

The warmer months of June and July will see an increase in the number of pans but a decrease in the overall area due to the increasing temperatures and greater levels of solar radiation causing the sea ice to break apart. As the ice breaks up, the pans will begin to be moved by the wind and current, and become smaller and smaller, resulting in an increase in the total number of pans and will likely result in an increase in the number of ship-pan interactions. The majority of the pans (410) estimated to be struck in these two months have a pan length of less than 0.5 km. Given the small size of the pans, the interaction effect would likely result in the pans being pushed to the side of the ship rather than being split into two or more pieces.

In the month of August it is estimated that the ship will interact with only two pans. This minimal interaction between the ships and the pans is due to the same weather conditions as in the months of June and July. As the pans of ice would be between 0.5 and 2 km in length with varying ice thickness, the potential interactions with these pans are likely to include splitting the pans in two or more pieces.

The months of January, March, April and May will see less than 75 pans of sea ice throughout the entire shipping route for a single one-way trip (Table 4-1). While this number is drastically lower than those of February, June, July, and December, the pack ice present in January, March, April and May is larger in comparison. The average length of the ice pans in these months is 2 - 10 km, with an average area of 20 km^2 per pan. While these pans are larger, fewer of them will be struck, yet the total area will be larger (approximately 520 km^2 of pack ice in a single voyage in January versus 95 km^2 of pack ice in a single voyage in the month of February). Due to the length of the pans the interaction effect will likely result in the pans being split into two or more pieces.

The months of September and October did not have any sea ice present throughout the shipping route and therefore no interactions are expected to occur in these two months.

4.1 Steensby Inlet

Extensive discussion with regards to the 90 km shipping route through Steensby Inlet (Sections S-21 and S-22) was included in Section 2.6.2.1 of Volume 8 of the DEIS and was determined that the ship travelling this 90 km stretch will only interact with at most 0.7% of the landfast ice present in the RSA. Landfast ice has been excluded from this consideration.

4.2 Effects of Year Round Shipping

As shipping will be occurring year round with approximately 102 round trips, (204 one way transits), concern has been expressed that the effects on pack ice may accumulate. Table 4-1 depicts the estimated number of pans to be struck in a month per year of shipping.

Observations made from the *MV Arctic* in the Hudson Strait noted that the ship track quickly disappeared after roughly 6 hours, and satellite imagery interpretation suggested that in the span of 1.5 hours, 3 km of a 17 km ship track had already closed in making the presence of the ship track brief over a small area (Baffinland, 2010). The thickness and size of the pack ice pans present will also play a role in the time the ship track is present, as thick ice typically causes narrow ship tracks that are close to the bow of the ship, as mentioned in Section 2.1. As pack ice is dynamic and in constant motion, and that high winds and current are present in Foxe Basin and Hudson Strait, pack ice will eventually move into the ship track. Given this small window, potentially narrow ship track, dynamic nature of pack ice and wind and current conditions within Hudson Strait and Foxe Basin, it is unlikely that the ship track would remain present for the following ship.

5.0 CLIMATE VARIABILITY AND CHANGE

The concern has been expressed by DFO that climate variability and change will diminish sea ice habitat (seasonal duration, consolidation, thickness, extent), thereby making the remaining sea ice more valuable to ecosystem components that rely on it (i.e., marine mammals, marine fishes, primary and secondary producers).

There is no definitive methodology for projecting the extent of changes to ice cover expected to occur during the 21st century. The International Arctic Science Committee presented the results of five models which predicted changes in mean annual northern hemisphere sea ice extent between 2000 and 2100 and showed projections ranging from a 12% to 46% decrease (IASC 2010). These projections should be considered in light of the 25 year project life of the Mary River Project.

As concluded in the DEIS, under current conditions, the extent of interaction between pack ice and Project related shipping will be negligible – less than 1% of the local study area and less than 0.5% of the regional study area. Under a worst case climate change scenario using the maximum value predicted for a reduction in sea ice extent by 2100 (46%) these proportions may increase, however, the area of disturbance would remain negligible, i.e., less than 2% and 1% in relation to either the local or regional study areas respectively.

The potential 2% increase in the relative area of disturbance due to a decrease in pack ice extent resulting from climate variability and change is negligible. Therefore, there is no incremental effect of Project shipping on sea ice or on the ecosystem components dependent on it, as a result of climate variability and change.

6.0 CONCLUSION

Based on the information reviewed above regarding ship-pan interactions and climate variability and change the following conclusions have been identified.

Using the data collected from CIS Ice Archive, the approximate number of ice pans that may interact with a ship passage was calculated. The 204 ship transits were calculated to interact with approximately 371,688 pans throughout the entire year. The interaction with these pans is minimal in the context of the RSA, which as described in Table 8-2.1 in Section 2.6.2.1 of Volume 8 of the DEIS, a single ship transit will disrupt 0.02% of the pack ice area. Should all 371,688 pans be split over the course of a year, this would still result in a negligible effect on sea ice within the RSA.

The ice pans in the months of January, March, April, and May are anticipated to be split into two or more pieces as the majority of the pans are large (> 0.5km in length) (CCG, 1990). While the total number of pans expected to be struck is low in these months compared to other winter months (December and February), the total area of pack ice that a ship will transit through is comparable (approximately 68.5 km^2 of pack ice in March) or higher (520 km^2 in January versus 91 km^2 in February).

The ice pans in the months of August and November are also anticipated to be split into two or more pieces. The overall interaction in these two months is lower compared to other months due to the lack of ice pack present. In November pack ice has just started to form and as such is only present in a few sections (S-14-S-22). In the month of August pack ice is anticipated to be present in only one section (S-13). Due to the limited amount of pack ice present in these two months, the overall interaction is negligible.

October and September was identified as having no pack ice present throughout the proposed shipping route, and as such, no interactions are anticipated to occur.

For the remaining four months (February, June, July and December), the main interaction anticipated is the pushing of the pans to the side as the majority of the pans are small (<0.5 km in length). These months also are anticipated to see a much higher level of interaction, with the highest possibility to interact with approximately 626 pans throughout the proposed shipping route due to the length of these pans (typically 0.02 to 0.1 km in length). As these pans have a wide range of ice thickness, there is the possibility of some of them splitting into two or more pieces, however given their size and numbers this is not anticipated to cause a substantial effect. As the ship pushes these pans to the side they will eventually redistribute along the shipping route due to the wind and the current, as previously mentioned in Section 2.1, in moving pack ice conditions, the breaking of pans will have little effect on their distribution (CCG, 1990).

While pack ice will be broken by the ore carrier, a ship track is not anticipated to remain present for an extended period of time. Given that pack ice dynamic by nature, and the characteristics of Foxe Basin and Hudson Strait, the interaction effect with regards to continual shipping and the presence of ship tracks is negligible.

An evaluation of the potential influence of climate variability and change on the interaction between icebreaking and sea ice was also conducted. It was concluded that the potential 2% increase in the relative area of disturbance due to a decrease in pack ice extent resulting from climate variability and change is negligible. Therefore, there is no incremental effect of Project shipping on sea ice or on the ecosystem component dependent on it, as a result of climate variability and change.

As a result of the detailed analysis conducted in this report, the disruption of pack ice caused by ice breaking and interactions with CVC should remain a Subject of Note given the lack of significant interaction effects.

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APPENDIX A
SEA ICE TABLE

Sea Ice Table

Shipping Route Sections

Month	Average Ice Data	S-1			S-2			S-3 – S-5			S-6		
		Pan Characteristics			Pan Characteristics			Pan Characteristics			Pan Characteristics		
January	Average Ice Thickness Class (cm)	15-30	30-70	<10	15-30	30-70	<10	15-30	30-70	<10	30-70	15-30	<10
	Range of Average Pan Length (km)	0.5-2.0	0.5-2.0	Unk[2]	0.5-2.0	0.5-2.0	Unk[2]	0.5-2.0	0.5-2.0	Unk[2]	2-10	0.5-2.0	Unk[2]
	Average Pan Area (km^2)	1.0	1.0	No Form[1]	1.0	1.0	No Form[1]	20.0	1.0	No Form[1]	20.0	1.0	No Form[1]
	Percentage of Pans in Section	30	60	10	30	60	10	60	30	10	60	30	10
	Average Number of Pans Estimate to be Struck	0.8	1.6	N/A	0.8	1.6	N/A	0.24	2.4	N/A	0.08	0.8	N/A
February	Average Ice Thickness Class (cm)	70-120	30-70	15-30	70-120	30-70		70-120	30-70		70-120	30-70	
	Range of Average Pan Length (km)	2-10	0.5-2.0	0.02-0.1	2-10	0.5-2.0		2-10	0.5-2.0		2-10	0.5-2.0	
	Average Pan Area (km^2)	20	1	0.002	20	1		20	1		20	1	
	Percentage of Pans in Section	20	70	10	20	70		60	40		60	40	
	Average Number of Pans Estimate to be Struck	0.025	1.9	150	0.025	1.9		0.24	3.3		0.08	1.1	
March	Average Ice Thickness Class (cm)	70-120	30-70	10-15	70-120	30-70	10-15	70-120	30-70	10-15	70-120	30-70	10-15
	Range of Average Pan Length (km)	2-10	0.5-2.0	2-10	2-10	2-10	2-10	2-10	2-10	2-10	2-10	2-10	2-10
	Average Pan Area (km^2)	20	1	20	20	20	20	20	20	20	20	20	20
	Percentage of Pans in Section	60	20	20	50	30	20	50	30	20	50	30	20
	Average Number of Pans Estimate to be Struck	0.08	0.5	0.025	0.065	0.04	0.025	0.195	0.12	0.075	0.075	0.025	0.04
April	Average Ice Thickness Class (cm)	10-15	70-120		10-15	<10		>120			10-15	70-120	
	Range of Average Pan Length (km)	2-10	0.5-2.0		2-10	0.5-2.0		2-10			0.5-2.0	0.5-2.0	
	Average Pan Area (km^2)	20	1		20	1		20			1	1	
	Percentage of Pans in Section	70	30		70	30		100			80	20	
	Average Number of Pans Estimate to be Struck	0.095	0.8		0.095	0.8		0.4			2.1	0.5	

Month	Average Ice Data	S-7 – S-9			S-10			S-11 – S-13			S-14 – S15	
		Pan Characteristics			Pan Characteristics			Pan Characteristics			Pan Characteristics	
January	Average Ice Thickness Class (cm)	30-70	15-30	<10	30-70	15-30	<10	30-70	15-30	<10	70-120	30-70
	Range of Average Pan Length (km)	2-10	0.5-2.0	2-10	2-10	0.5-2.0	2-10	2-10	0.5-2.0	2-10	2-10	2-10
	Average Pan Area (km^2)	1.0	1.0	20.0	1.0	1.0	20.0	20.0	1.0	20.0	20.0	20.0
	Percentage of Pans in Section	70	20	10	70	20	10	70	20	10	20	80
	Average Number of Pans Estimate to be Struck	5.7	1.5	0.045	1.9	0.5	0.015	0.285	1.5	0.045	0.05	0.21
February	Average Ice Thickness Class (cm)	70-120	30-70	15-30	70-120	30-70		70-120	30-70	10-15	70-120	10-15
	Range of Average Pan Length (km)	2-10	2-10	0.02-0.1	2-10	2-10		2-10	2-10	2-10	2-10	2-10
	Average Pan Area (km^2)	20	20	0.002	20	20		20	20	20	20	20
	Percentage of Pans in Section	20	70	10	60	40		20	50	20	80	20
	Average Number of Pans Estimate to be Struck	0.075	0.285	450	0.08	0.055		0.08	0.2	0.08	0.21	0.05
March	Average Ice Thickness Class (cm)	70-120	30-70	10-15	70-120	30-70	10-15	70-120	10-15		70-120	10-15
	Range of Average Pan Length (km)	2-10	2-10	2-10	2-10	2-10	2-10	2-10	2-10		2-10	2-10
	Average Pan Area (km^2)	20	20	20	20	20	20	20	20		20	20
	Percentage of Pans in Section	60	10	30	60	10	30	80	20		80	20
	Average Number of Pans Estimate to be Struck	0.24	0.045	0.12	0.08	0.015	0.04	0.315	0.075		0.21	0.05
April	Average Ice Thickness Class (cm)	10-15	70-120		10-15	70-120		10-15	70-120		70-120	
	Range of Average Pan Length (km)	0.5-2.0	0.5-2.0		0.5-2.0	0.5-2.0		2-10	2-10		0.5-2.0	
	Average Pan Area (km^2)	1	1		1	1		20	20		5	
	Percentage of Pans in Section	80	20		80	20		80	20		100	
	Average Number of Pans Estimate to be Struck	6.3	1.5		2.1	0.5		0.315	0.09		1.06	

Month	Average Ice Data	S-16			S-17			S-18			S-19		
		Pan Characteristics			Pan Characteristics			Pan Characteristics			Pan Characteristics		
January	Average Ice Thickness Class (cm)	30-70	<10	15-30	30-70	70-120	15-30	30-70	15-30	<10	30-70	15-30	<10
	Range of Average Pan Length (km)	2-10	2-10	0.5-2.0	2-10	2-10	0.5-2.0	2-10	0.5-2.0	2-10	2-10	0.5-2.0	2-10
	Average Pan Area (km^2)	20	20.0	1.0	20.0	20.0	1.0	20.0	1.0	20.0	20.0	1.0	20.0
	Percentage of Pans in Section	30	60	10	30	60	10	80	10	10	80	10	10
	Average Number of Pans Estimate to be Struck	0.06	0.11	0.4	0.06	0.11	0.4	0.16	0.4	0.02	0.16	0.4	0.02
February	Average Ice Thickness Class (cm)	10-15	70-120	30-70	10-15	70-120	30-70	10-15	70-120	30-70	10-15	70-120	30-70
	Range of Average Pan Length (km)	2-10	2-10	2-10	2-10	2-10	2-10	2-10	2-10	2-10	2-10	2-10	2-10
	Average Pan Area (km^2)	20	20	20	20	20	20	20	20	20	20	20	20
	Percentage of Pans in Section	10	60	30	10	60	30	10	60	30	10	60	30
	Average Number of Pans Estimate to be Struck	1.7	0.11	0.06	0.02	0.11	0.06	0.02	0.11	0.06	0.02	0.11	0.06
March	Average Ice Thickness Class (cm)	10-15	70-120		10-15	70-120		10-15	70-120		10-15	70-120	
	Range of Average Pan Length (km)	2-10	0.5-2.0		2-10	0.5-2.0		2-10	0.5-2.0		2-10	0.5-2.0	
	Average Pan Area (km^2)	20	1		20	1		20	1		20	1	
	Percentage of Pans in Section	80	20		80	20		80	20		80	20	
	Average Number of Pans Estimate to be Struck	0.16	0.8		0.16	0.8		0.16	0.8		0.16	0.8	
April	Average Ice Thickness Class (cm)	10-15	70-120		10-15	70-120		10-15	70-120		10-15	70-120	
	Range of Average Pan Length (km)	2-10	0.5-2.0		2-10	0.5-2.0		2-10	0.5-2.0		2-10	0.5-2.0	
	Average Pan Area (km^2)	20	1		20	1		20	1		20	1	
	Percentage of Pans in Section	80	20		80	20		80	20		80	20	
	Average Number of Pans Estimate to be Struck	0.16	0.8		0.16	0.8		0.16	0.8		0.16	0.8	

Month	Average Ice Data	S-20			S-21		S-22	
		Pan Characteristics			Pan Characteristics		Pan Characteristics	
January	Average Ice Thickness Class (cm)	30-70	70-120	15-30	<10		<10	
	Range of Average Pan Length (km)	0.5-2.0	2-10	0.5-2.0	Unk[2]		Unk[2]	
	Average Pan Area (km^2)	1.0	20.0	1.0	FI[3]		FI[3]	
	Percentage of Pans in Section	80	10	10	100		100	
	Average Number of Pans Estimate to be Struck	3.2	0.02	0.4	N/A		N/A	
February	Average Ice Thickness Class (cm)	70-120	30-70	10-15	<10		<10	
	Range of Average Pan Length (km)	2-10	2-10	2-10	Unk[2]		Unk[2]	
	Average Pan Area (km^2)	20	20	20	FI[3]		FI[3]	
	Percentage of Pans in Section	70	20	10	100		100	
	Average Number of Pans Estimate to be Struck	0.14	0.04	0.02	N/A		N/A	
March	Average Ice Thickness Class (cm)	10-15	70-120		>120		>120	
	Range of Average Pan Length (km)	2-10	0.5-2.0		Unk[2]		Unk[2]	
	Average Pan Area (km^2)	20	1		FI[3]		FI[3]	
	Percentage of Pans in Section	80	20		100		100	
	Average Number of Pans Estimate to be Struck	0.16	0.8		N/A		N/A	
April	Average Ice Thickness Class (cm)	10-15	70-120		>120		>120	
	Range of Average Pan Length (km)	2-10	0.5-2.0		Unk[2]		Unk[2]	
	Average Pan Area (km^2)	20	1		FI[3]		FI[3]	
	Percentage of Pans in Section	80	20		100		100	
	Average Number of Pans Estimate to be Struck	0.16	0.8		N/A		N/A	

Shipping Route Sections

Month	Average Ice Data	S-1		S-2			S-3 – S-5		S-6		S-7 – S-9		S-10	
		Pan Characteristics		Pan Characteristics			Pan Characteristics		Pan Characteristics		Pan Characteristics		Pan Characteristics	
May	Average Ice Thickness Class (cm)	>120		10-15	70-120		>120		>120	<10	10-15	70-120	10-15	70-120
	Range of Average Pan Length (km)	2-10		2-10	0.5-2.0		2-10		0.5-2.0	0.5-2.0	0.5-2.0	0.5-2.0	0.5-2.0	0.5-2.0
	Average Pan Area (km^2)	20		20	1		20		1	1	1	1	1	1
	Percentage of Pans in Section	100		70	30		100		80	20	60	40	60	40
	Average Number of Pans Estimate to be Struck	0.135		0.095	0.8		0.4		2.1	0.5	4.8	3.3	1.6	1.1
June	Average Ice Thickness Class (cm)	10-15	70-120	10-15	70-120	>120	10-15	70-120	>120		10-15	70-120	>120	
	Range of Average Pan Length (km)	0.5-2.0	0.1-0.5	0.5-2.0	.02-.1	0.5-2.0	0.5-2.0	0.5-2.0	0.5-2.0		2-10	0.5-2.0	0.5-2.0	
	Average Pan Area (km^2)	1	0.05	1	0.002	1	1	1	1		20	1	1	
	Percentage of Pans in Section	60	30	40	20	40	80	20	100		60	40	100	
	Average Number of Pans Estimate to be Struck	1.6	16	1.1	250	1.1	6.3	1.5	2.7		0.24	3.3	2.7	
July	Average Ice Thickness Class (cm)	30-70	>120	No Ice Present			No Ice Present		No Ice Present		No Ice Present		No Ice Present	
	Range of Average Pan Length (km)	Unk[2]												
	Average Pan Area (km^2)	9												
	Percentage of Pans in Section	10	10											
	Average Number of Pans Estimate to be Struck	N/A												
August	Average Ice Thickness Class (cm)	No Ice Present		No Ice Present			No Ice Present		No Ice Present		No Ice Present		No Ice Present	
	Range of Average Pan Length (km)													
	Average Pan Area (km^2)													
	Percentage of Pans in Section													
	Average Number of Pans Estimate to be Struck													

Month	Average Ice Data	S-11 – S-13	S-14 – S15	S-16		S-17		S-18		S-19		S-20		S-21	S-22
		Pan Characteristics	Pan Characteristics	Pan Characteristics		Pan Characteristics		Pan Characteristics		Pan Characteristics		Pan Characteristics		Pan Characteristics	Pan Characteristics
May	Average Ice Thickness Class (cm)	>120	>120	10-15	70-120	10-15	70-120	10-15	70-120	10-15	70-120	10-15	70-120	>120	>120
	Range of Average Pan Length (km)	2-10	2-10	2-10	0.5-2.0	2-10	0.5-2.0	2-10	0.5-2.0	2-10	0.5-2.0	2-10	0.5-2.0	Unk[2]	Unk[2]
	Average Pan Area (km^2)	20	20	20	1	20	1	20	1	20	1	20	1	FI[3]	FI[3]
	Percentage of Pans in Section	100	100	90	10	90	10	90	10	90	10	90	10	100	100
	Average Number of Pans Estimate to be Struck	0.4	0.265	0.18	0.4	0.18	0.4	0.18	0.4	0.18	0.4	0.18	0.4	N/A	N/A
June	Average Ice Thickness Class (cm)	>120	>120	10-15	70-120	10-15	70-120	10-15	70-120	10-15	70-120	>120		>120	>120
	Range of Average Pan Length (km)	0.5-2.0	0.5-2.0	0.5-2.0	0.5-2.0	0.5-2.0	0.5-2.0	0.5-2.0	0.5-2.0	0.5-2.0	0.5-2.0	Unk[2]		Unk[2]	Unk[2]
	Average Pan Area (km^2)	20	20	1	1	1	1	1	1	1	1	FI[3]		FI[3]	FI[3]
	Percentage of Pans in Section	100	100	90	10	90	10	90	10	90	10	100		100	100
	Average Number of Pans Estimate to be Struck	0.4	0.265	3.6	0.4	3.6	0.4	3.6	0.4	3.6	0.4	N/A		N/A	N/A
July	Average Ice Thickness Class (cm)	>120	No Ice Present	10-15	70-120	10-15	70-120	10-15	70-120	10-15	70-120	10-15	70-120	>120	>120
	Range of Average Pan Length (km)	0.1-0.5		0.5-2.0	0.5-2.0	0.5-2.0	0.5-2.0	0.5-2.0	0.5-2.0	0.5-2.0	0.5-2.0	0.5-2.0	0.5-2.0	Unk[2]	Unk[2]
	Average Pan Area (km^2)	0.05		1	1	1	1	1	1	1	1	1	1	FI[3]	FI[3]
	Percentage of Pans in Section	0		40	30	40	30	90	10	90	10	90	10	100	100
	Average Number of Pans Estimate to be Struck	160		1.6	1.2	1.6	1.2	3.6	0.4	3.6	0.4	3.6	0.4	N/A	N/A
August	Average Ice Thickness Class (cm)	No Ice Present	No Ice Present	No Ice Present		No Ice Present		No Ice Present		No Ice Present		10-15	70-120	No Ice Present	No Ice Present
	Range of Average Pan Length (km)											0.5-2.0	0.5-2.0		
	Average Pan Area (km^2)											1	1		
	Percentage of Pans in Section											20	20		
	Average Number of Pans Estimate to be Struck											0.8	0.8		

		Shipping Route Sections												
		S-1	S-2	S-3 – S-5	S-6	S-7 – S-9			S-10			S-11 – S-13		
Month	Average Ice Data	Pan Characteristics	Pan Characteristics	Pan Characteristics	Pan Characteristics	Pan Characteristics			Pan Characteristics			Pan Characteristics		
September	Average Ice Thickness Class (cm)	No Ice Present	No Ice Present	No Ice Present	No Ice Present	No Ice Present			No Ice Present			No Ice Present		
	Range of Average Pan Length (km)													
	Average Pan Area (km^2)													
	Percentage of Pans in Section													
	Average Number of Pans Estimate to be Struck													
October	Average Ice Thickness Class (cm)	No Ice Present	No Ice Present	No Ice Present	No Ice Present	No Ice Present			No Ice Present			No Ice Present		
	Range of Average Pan Length (km)													
	Average Pan Area (km^2)													
	Percentage of Pans in Section													
	Average Number of Pans Estimate to be Struck													
November	Average Ice Thickness Class (cm)	No Ice Present	No Ice Present	No Ice Present	No Ice Present	No Ice Present			No Ice Present			No Ice Present		
	Range of Average Pan Length (km)													
	Average Pan Area (km^2)													
	Percentage of Pans in Section													
	Average Number of Pans Estimate to be Struck													
December	Average Ice Thickness Class (cm)	No Ice Present	No Ice Present	No Ice Present	No Ice Present	10-15	<10		15-30	10-15	<10	15-30	10-15	<10
	Range of Average Pan Length (km)					0.02-0.1	Unk[2]		0.5-2.0	0.1-0.5	Unk[2]	0.5-2.0	0.1-0.5	Unk[2]
	Average Pan Area (km^2)					0.002	No Form[1]		1	0.05	No Form[1]	1	0.05	No Form[1]
	Percentage of Pans in Section					10	80		50	10	40	50	10	40
	Average Number of Pans Estimate to be Struck					450	N/A		1.3	6	N/A	3.9	18	N/A

		Shipping Route Sections										
		S-14 – S15		S-16			S-17			S-18		
Month	Average Ice Data	Pan Characteristics		Pan Characteristics			Pan Characteristics			Pan Characteristics		
September	Average Ice Thickness Class (cm)	No Ice Present		No Ice Present			No Ice Present			No Ice Present		
	Range of Average Pan Length (km)											
	Average Pan Area (km^2)											
	Percentage of Pans in Section											
	Average Number of Pans Estimate to be Struck											
October	Average Ice Thickness Class (cm)	No Ice Present		No Ice Present			No Ice Present			No Ice Present		
	Range of Average Pan Length (km)											
	Average Pan Area (km^2)											
	Percentage of Pans in Section											
	Average Number of Pans Estimate to be Struck											
November	Average Ice Thickness Class (cm)	15-30	10-15	15-30	10-15	30-70	15-30	10-15	30-70	15-30	10-15	30-70
	Range of Average Pan Length (km)	0.5-2.0	0.5-2.0	0.5-2.0	0.5-2.0	0.5-2.0	0.5-2.0	0.5-2.0	0.5-2.0	0.5-2.0	0.5-2.0	0.5-2.0
	Average Pan Area (km^2)	1	1	1	1	1	1	1	1	1	1	1
	Percentage of Pans in Section	50	50	30	40	30	30	40	30	30	30	40
	Average Number of Pans Estimate to be Struck	2.65	2.65	1.2	1.6	1.2	1.2	1.6	1.2	1.2	1.2	1.6
December	Average Ice Thickness Class (cm)	30-70	15-30	15-30	10-15	30-70	15-30	10-15	30-70	15-30	10-15	30-70
	Range of Average Pan Length (km)	0.5-2.0	0.5-2.0	0.5-2.0	0.1-0.5	0.5-2.0	0.5-2.0	0.1-0.5	0.5-2.0	0.5-2.0	0.1-0.5	0.5-2.0
	Average Pan Area (km^2)	1	1	1	0.05	1	1	0.05	1	1	0.05	1
	Percentage of Pans in Section	30	70	30	40	30	30	40	30	30	40	30
	Average Number of Pans Estimate to be Struck	1.53	3.7	1.2	32	1.2	1.2	32	1.2	1.2	32	1.2

		Shipping Route Sections											
		S-19			S-120			S-21			S-22		
Month	Average Ice Data	Pan Characteristics			Pan Characteristics			Pan Characteristics			Pan Characteristics		
September	Average Ice Thickness Class (cm)	No Ice Present			No Ice Present			No Ice Present			No Ice Present		
	Range of Average Pan Length (km)												
	Average Pan Area (km^2)												
	Percentage of Pans in Section												
	Average Number of Pans Estimate to be Struck												
October	Average Ice Thickness Class (cm)	No Ice Present			No Ice Present			30-70			30-70		
	Range of Average Pan Length (km)							Unk[2]			Unk[2]		
	Average Pan Area (km^2)							FI[3]			FI[3]		
	Percentage of Pans in Section							0			0		
	Average Number of Pans Estimate to be Struck							N/A			N/A		
November	Average Ice Thickness Class (cm)	15-30	10-15	30-70	15-30	10-15	30-70	15-30	10-15	30-70	15-30	10-15	30-70
	Range of Average Pan Length (km)	0.5-2.0	0.5-2.0	0.5-2.0	0.5-2.0	0.5-2.0	0.5-2.0	0.5-2.0	0.5 - 2.0	0.5-2.0	0.5-2.0	0.5-2.0	0.5-2.0
	Average Pan Area (km^2)	1	0.05	1	1	0.05	1	1	1	1	1	1	1
	Percentage of Pans in Section	30	30	40	30	30	40	30	30	40	30	30	40
	Average Number of Pans Estimate to be Struck	1.2	1.2	1.6	1.2	1.2	1.6	1.2	1.2	1.6	1.2	1.2	1.6
December	Average Ice Thickness Class (cm)	15-30	10-15	30-70	15-30	10-15	30-70	30-70			30-70		
	Range of Average Pan Length (km)	0.5-2.0	0.1-0.5	0.5-2.0	0.5-2.0	0.1-0.5	0.5-2.0	Unk[2]			Unk[2]		
	Average Pan Area (km^2)	1	0.05	1	1	0.05	1	FI[3]			FI[3]		
	Percentage of Pans in Section	40	20	40	40	20	40	100			100		
	Average Number of Pans Estimate to be Struck	1.6	16	1.6	1.6	16	1.6	N/A			N/A		

Notes

1. No Form = Brash Ice
2. Unk = Unknown
3. FI = Landfast Ice