4.1.2 Biological Components

In the Beaufort Sea, the Beaufort Shelf break (i.e. the interface between Mackenzie River plume waters and marine waters), and the Cape Bathurst polynya are ecologically and biologically significant to the productivity and are influenced primarily by physical oceanographic features (Cobb *et al.*, 2008). The diverse range of conditions present in the coastal areas provide suitable habitat for a diversity of fish species, both marine and freshwater, amongst the southern Beaufort Sea and provides seasonal and year-round habitat for several species of marine mammals (e.g. beluga and bowhead whales). Finally, the marine birds use the offshore, inshore and both of these areas in the Beaufort Sea. The recurring polynya that forms off Cape Bathurst and the associated flaw leads off Banks Island and the Mackenzie Delta are considered critical staging grounds within this area.

Productive regions and important habitats within the CAA include Resolute Passage, Lancaster Sound, and the North Water Polynya. The North Water Polynya is considered to be the most productive ecosystem north of the Arctic Circle and has been an important resource for the Inuit for at least 5,000 years. Despite its importance as an oceanic thoroughfare and its extensive shelf habitat, general status and trends of productivity, ecological diversity, and oceanographic processes are poorly understood compared to the other marine ecosystems.

The HJBFB is characterized by high biodiversity and contains multiple important habitats for seabirds, anadromous fish, and marine mammals. Coastal areas are key staging, breeding, and feeding areas for migrant birds, and the largest aggregation of beluga whales in the world (<40,000 individuals) is located in western Hudson Bay (DFO, 2010).

Species distributions in the NLS have been linked to the oceanographic environment (current, temperature, bottom habitat, availability of food). The biological environment of the NLS is as diverse as its physical environment in many respects. For example, species that prefer cooler waters are often found off Labrador and northeastern Newfoundland, while more temperate water species are found in the more southerly areas of the Grand Banks. However, the northern portion of the Grand Banks is recognized as a region of mixing between cold water and temperate communities, and the system as a whole shares many species including key trophic and commercially important species (Templeman, 2010).

The Mackenzie River's watershed is considered one of the largest and most intact ecosystems in North America, especially in the north. There are 53 known species of fish in the basin, none of them endemic. Migratory birds use the two major deltas in the Mackenzie River basin (i.e., Mackenzie Delta and the inland Peace-Athabasca Delta) as important resting and breeding areas (MRBB, 2003).

Phytoplankton are found at the base of all aquatic food chains. The carrying capacity of marine ecosystems (e.g. diversity, abundance and recruitment) is highly dependent on variations in the abundance, timing and composition of the plankton. Phytoplankton also plays a crucial role in climate change through the export of fixed carbon dioxide during photosynthesis towards the deep oceans.

There are 82 EBSAs identified by DFO in the Canadian Arctic sector (Map 4.1). They are respectively located in the Beaufort Sea (21 EBSAs), the Arctic Basin and Arctic Archipelago (6 EBSAs), the HJBFB Complex (13 EBSAs), the Eastern Arctic (16 EBSAs) and the Western Arctic (26 EBSAs). Essentially, these EBSA are used as feeding, reproductive and wintering areas as well as migratory corridors by plankton, invertebrates, fishes, marine mammals and birds, including special-status species.

The coastal zone (0-50 m depth) includes a number of small-scale ecosystems that have particularly high biodiversity as well as high primary and secondary production, that are important for wildlife and humans using these resources. It is also a reproductive, feeding and wintering area for some marine species, such as fish and marine mammals.

4.1.3 Human Components

Although the most productive, the coastal zone ecosystem is exposed to a variety of human pressures and uses (e.g., maritime shipping, hunting and fishing) that pose a significant threat to its ecological integrity and sustainability (DFO, 2010).

The coastal zone of the Arctic Coast sector has several shoreline communities; the most populated are Yellowknife, Iqaluit, Albany, Moose Cree First Nation and Cree Nation of Chisasibi. The coastal population was approximately 6,000 inhabitants in 2011. The HJBFB area is associated with approximately half the Inuit population of Nunavut and Nunavik (DFO, 2010).

As indicated above, the CPI was used as a proxy encompassing several impacts on humans, in particular fishing and hunting activities practiced for subsistence.

Due to the importance of ice-cover and the sensitivity of the Canadian Arctic ecosystem, many areas have been protected by international, federal and provincial regulations. A total of 200 protected areas, occupying 557,731.2 km^2, are present in the Arctic Coast sector. They include IBAs, marine protected areas, migratory bird sanctuaries, national parks of Canada, conservation zones, ecological reserves, heritage conservation zones, historic parks, natural environment parks, provincial parks, territorial parks and wildlife management areas (Map 4.1).

4.2 Vessel Traffic Description

With over 200 transits in 2012-2013, the Labrador Sea (sub-sector 8c) has the most traffic (Map 4.2). Baffin Bay (sub-sector 8b) and the Hudson Strait (sub-sectors 6a, 7a and 7b) also show an important mean number of transits, varying from 100 to 200 in 2012-2013.

The other sub-sectors where the mean number of transits is relatively high (between 40 and 100 per year) are in Hudson Bay (6b) and Lancaster Sound/Gulf of Boothia area (8a) (Map 4.2). This high number of transits is related to industrial activities (Churchill and Resolute ports) as well as the presence of multiple communities in the area.

Several sub-sectors have less than 40 transits per year: the Mackenzie River/Great Slave Lake (sub-sector 9), the Beaufort Sea (sector 2), the southern part of Hudson Bay, including James Bay (sub-sector 6c), as well as the Foxe Basin (sector 5), the Arctic Ocean (sector 1) and the Canadian Archipelago (sectors 3 and 4) (Map 4.2).

4.3 Spill Frequency Estimates

Due to the low incidence of spills in the Canadian Arctic, this study combines statistics from international and Canadian (country wide) sources. Table 4.1 provides frequencies of spills produced for the risk assessment for oil spills south of the 60th parallel north (WSP, 2014a). Frequencies for crude oil spills are not relevant for the Arctic as no crude oil has been transported over the last decade.

For refined cargo products, the exposure metric is the total volume shipped. The volume of refined cargo products transported in the Arctic represents 0.18% of the Canadian total for the years 2002 to 2011, so this percentage was applied to the Canadian spill frequencies to produce the estimated Arctic frequencies (Table 4.2). The frequency estimate for spills larger than 10,000 m^3 is zero for both fuel and refined cargo products (due to the lack of historical spills in this size range). As a result, no further risk calculation was performed for this category.

The actual spill record for the Canadian Arctic (Table 4.3) indicates the occurrence of one spill in the 10 to 99.9 m^3 category for “oil carried as fuel” in the last 10 years. Although this spill would cause the spill frequency to be higher to Canadian and international estimates, one single observation does not provide sufficient confidence to consider such frequency as representative of spill rate in the Canadian Arctic. Therefore, this unique spill and associated spill frequency were not applied to calculate risk values.

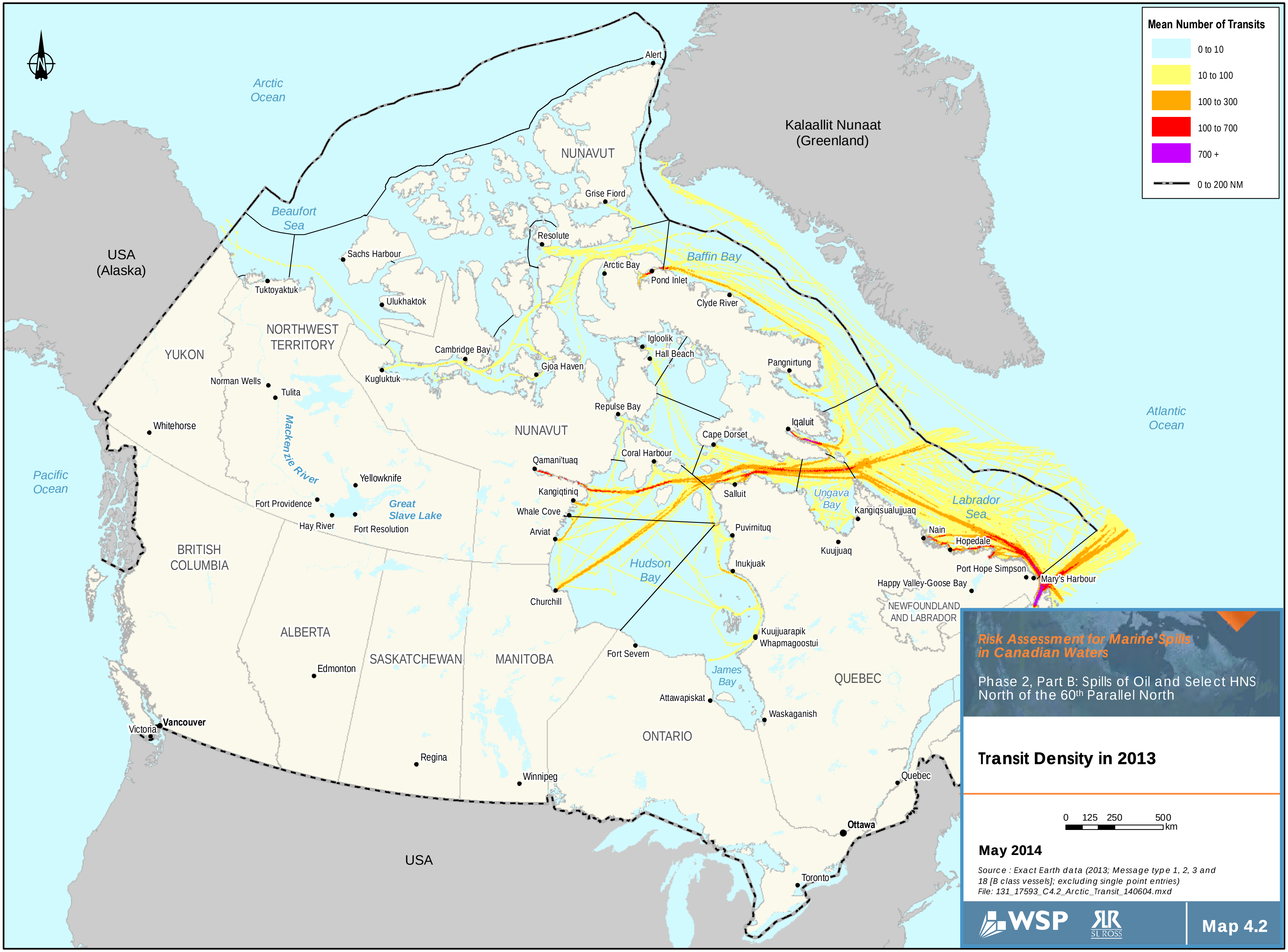

Mean Number of Transits
0 to 10
10 to 100
100 to 300
100 to 700
700 +
0 to 200 NM
Arctic Ocean
Beaufort Sea
Baffin Bay
Kalaallit Nunaat (Greenland)
USA (Alaska)
Pacific Ocean
Atlantic Ocean
Labrador Sea
Hudson Bay
James Bay
Ungava Bay
Great Slave Lake
Mackenzie River
NUNAVUT
NORTHWEST TERRITORY
YUKON
BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
QUEBEC
NEWFOUNDLAND AND LABRADOR
USA
Alert
Grise Fiord
Resolute
Arctic Bay
Pond Inlet
Clyde River
Sachs Harbour
Tuktoyaktuk
Ulukhaktok
Cambridge Bay
Gjoa Haven
Kugluktuk
Igloolik
Hall Beach
Pangnirtung
Repulse Bay
Iqaluit
Cape Dorset
Coral Harbour
Qamani'tuaq
Kangiqtiniq
Whale Cove
Arviat
Churchill
Salluit
Puvirnituq
Inukjuak
Kangiqsualujjuaq
Kuujjuaq
Nain
Hopedale
Port Hope Simpson
Mary's Harbour
Happy Valley-Goose Bay
Kuujjuarapik
Whapmagoostui
Fort Severn
Attawapiskat
Waskaganish
Norman Wells
Tulita
Whitehorse
Yellowknife
Fort Providence
Hay River
Fort Resolution
Edmonton
Vancouver
Victoria
Regina
Winnipeg
Quebec
Ottawa
Toronto
Risk Assessment for Marine Spills in Canadian Waters
Phase 2, Part B: Spills of Oil and Select HNS North of the 60th Parallel North
Transit Density in 2013
0 125 250 500 km
May 2014
Source : Exact Earth data (2013; Message type 1, 2, 3 and 18 [B class vessels]; excluding single point entries)
File: 131_17593_C4.2_Arctic_Transit_140604.mxd
WSP
SL ROSS
Map 4.2

Table 4.1 Overall Canadian Spill Frequency Estimates (from Phase 1: International and Canadian Data)

Product	Volume (m^3)			
	10 to 99.9 m^3	100 to 999.9 m^3	1,000 to 9,999.9 m^3	≥10,000 m^3
Crude	0.022	0.014	0.019	0.004
Refined Cargo Product	0.600	0.100	0.024	0.000
Fuel Oil	1.900	0.600	0.006	0.000
Total	**2.522**	**0.714**	**0.050**	**0.004**

Underlined data actual Canadian rates, otherwise worldwide data used.

Table 4.2 Overall Spill Frequency Estimates (Canada and Worldwide Data Scaled to Arctic Volumes)

Product	Volume (m^3)			
	10 to 99.9 m^3	100 to 999.9 m^3	1,000 to 9,999.9 m^3	≥10,000 m^3
Refined Cargo Product	0.0011	0.00018	0.000044	0
Fuel Oil	0.0035	0.0011	0.000011	0
Total	**0,0046**	**0,00128**	**0,000055**	**0**

Underlined data actual Canadian rates, otherwise worldwide data used.

Table 4.3 Arctic Spill Record 2004 to 2013

Product	Volume (m^3)			
	10 to 99.9 m^3	100 to 999.9 m^3	1,000 to 9,999.9 m^3	≥10,000 m^3
Refined Cargo Product	0	0	0	0
Fuel Oil	1	0	0	0
Total	**1**	**0**	**0**	**0**

Data from Transport Canada NT/NU office, Coast Guard MPIRS, and GNWT spill line.
Note: Presently no crude shipments in Arctic.

The following description and table summarize the estimated spill frequency for the Arctic coast sector and its sub-sectors. Table 4.4 presents the potential spill frequency for each of the two oil types (refined cargo products and oil carried as fuel), for each of the three spill size ranges. Summary maps indicate the combined frequency for all spill sizes and sub-sector per oil type (Maps 4.3 and 4.4).

Table 4.4 presents frequencies as “return period”, or average number of year between spills for ease of comparison.

Table 4.4 Final Arctic Spill Frequency Estimates Using Canada, and Worldwide Data (return periods)

Product	Volume (m^3)			
	10 to 99.9 m^3	100 to 999.9 m^3	1,000 to 9,999.9 m^3	≥10,000 m^3
Refined Cargo Product	920	5,500	22,900	-
Fuel Oil	*285*	920	92,000	-

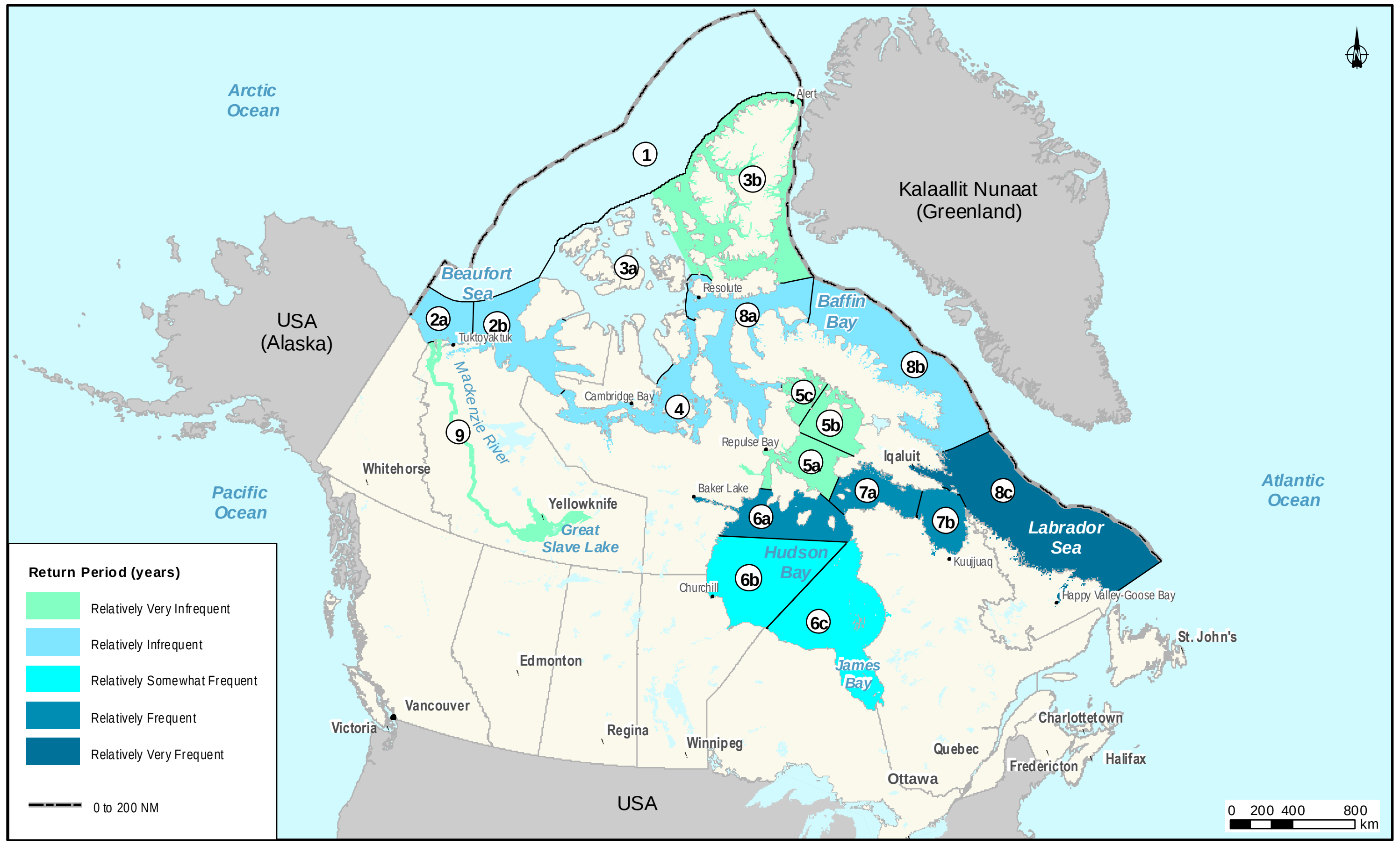
Return periods reflect the estimated years between spills (i.e., the reciprocal of the frequency).
Data from Transport Canada NT/NU office, Coast Guard MPIRS, and GNWT spill line.
Note: Presently no crude shipments in Arctic.

The oil spill risk assessment south of the 60th parallel north (WSP, 2014a) included four spills size categories: 10 to 99.9 m^3; 100 to 999.9 m^3; 1,000 to 9,999.9 m^3; and 10,000 m^3 and greater. In order to gain more insight into the overall spill frequencies, an additional smaller category was examined, namely 1 to 9.9 m^3. This spill size category is described briefly for illustrative purposes, but is not analyzed in depth for the following reasons:

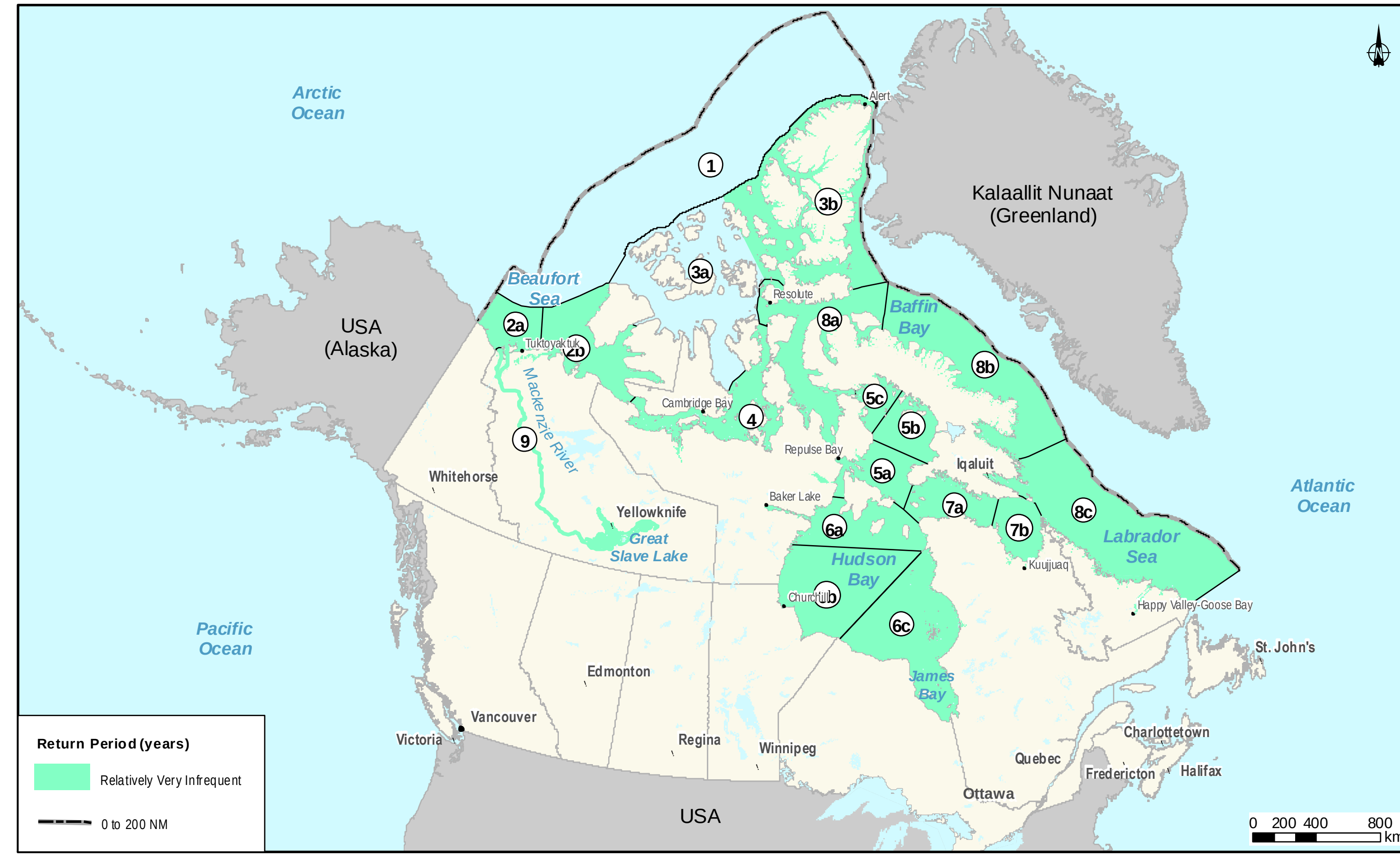
- The methodology used for this study was designed to produce a strategic assessment of the relative risks of ship-source spills in the Canadian Arctic. As the methodology assesses relative spill risk on a national level, it is not able to measure the highly localized impacts of small spills (those smaller than 10 m^3) as these spills would likely only affect an extremely small section of a given sub-sector and, as a result, would not impact the vast majority of the environmental and social resources present in the sub-sector.
- The methodology was developed using the study objective which incorporates marine governance, prevention, and response, for spills which are likely to see an active response. Currently the main cargoes and fuels in the Arctic are relatively light diesel fuel and aviation fuels, both of which dissipate readily. In most cases, small spills of these products would dissipate before an active response could be implemented.
- Spills of relatively light fuel oils, in this size range, are likely only to persist for one to two days at most, and would likely have minimal and only localized effects. Using modelling tools applied in the previous study (WSP, 2014) to predict oil behaviour over time, 5 m^3 of refined cargo will have about 10% of its volume remaining after 12hr and less than 5% after 24hr[4] as the result of losses due to evaporation and dispersion.

[4] Dissipation rates were modeled using the National Oceanic and Atmospheric Administration (NOAA) ADIOS2 model. The evaporation and natural dispersion was modeled for 10 m^3 spill of diesel fuel oil (Canada), 10 knot wind, and 5°C water temperature. It should be noted that in lesser winds, the dissipation would not be rapid, but the oil would nonetheless be largely dissipated within a few days. The presence of ice could also retard dissipation, but only if present in high concentrations.

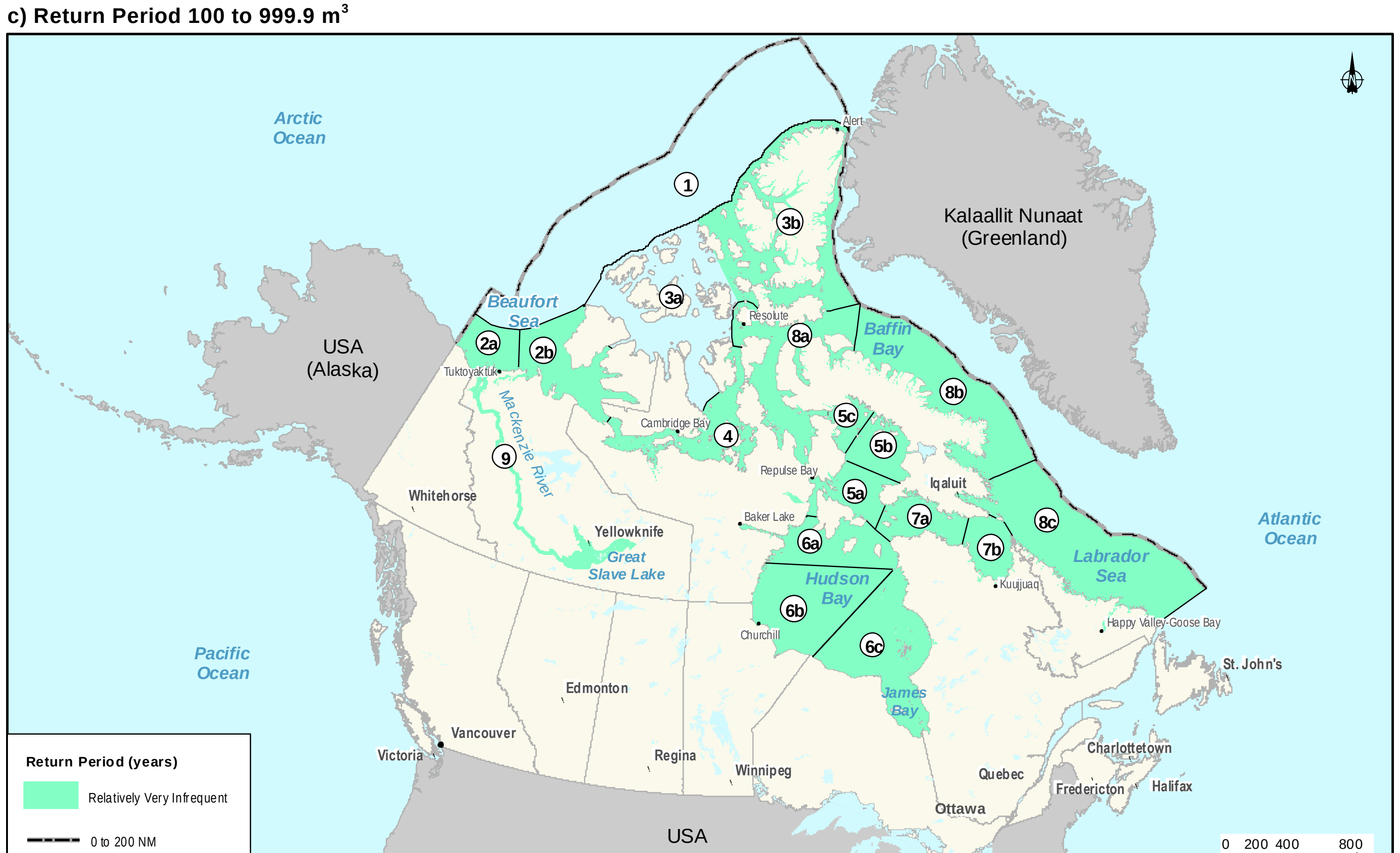
a) Return Period 1 to 9.9 m^3



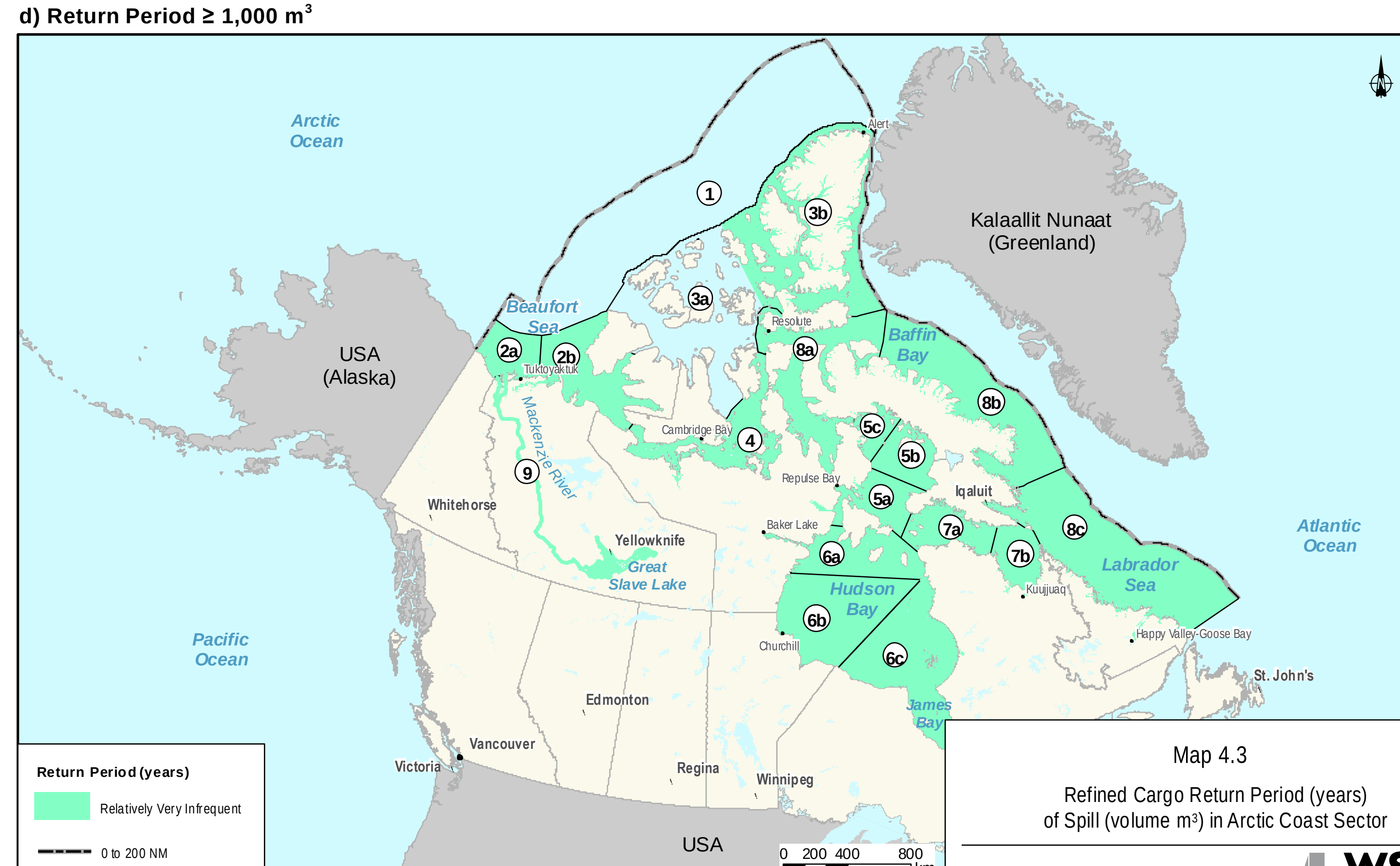
b) Return Period 10 to 99.9 m^3



c) Return Period 100 to 999.9 m^3



d) Return Period ≥ 1,000 m^3



Map 4.3

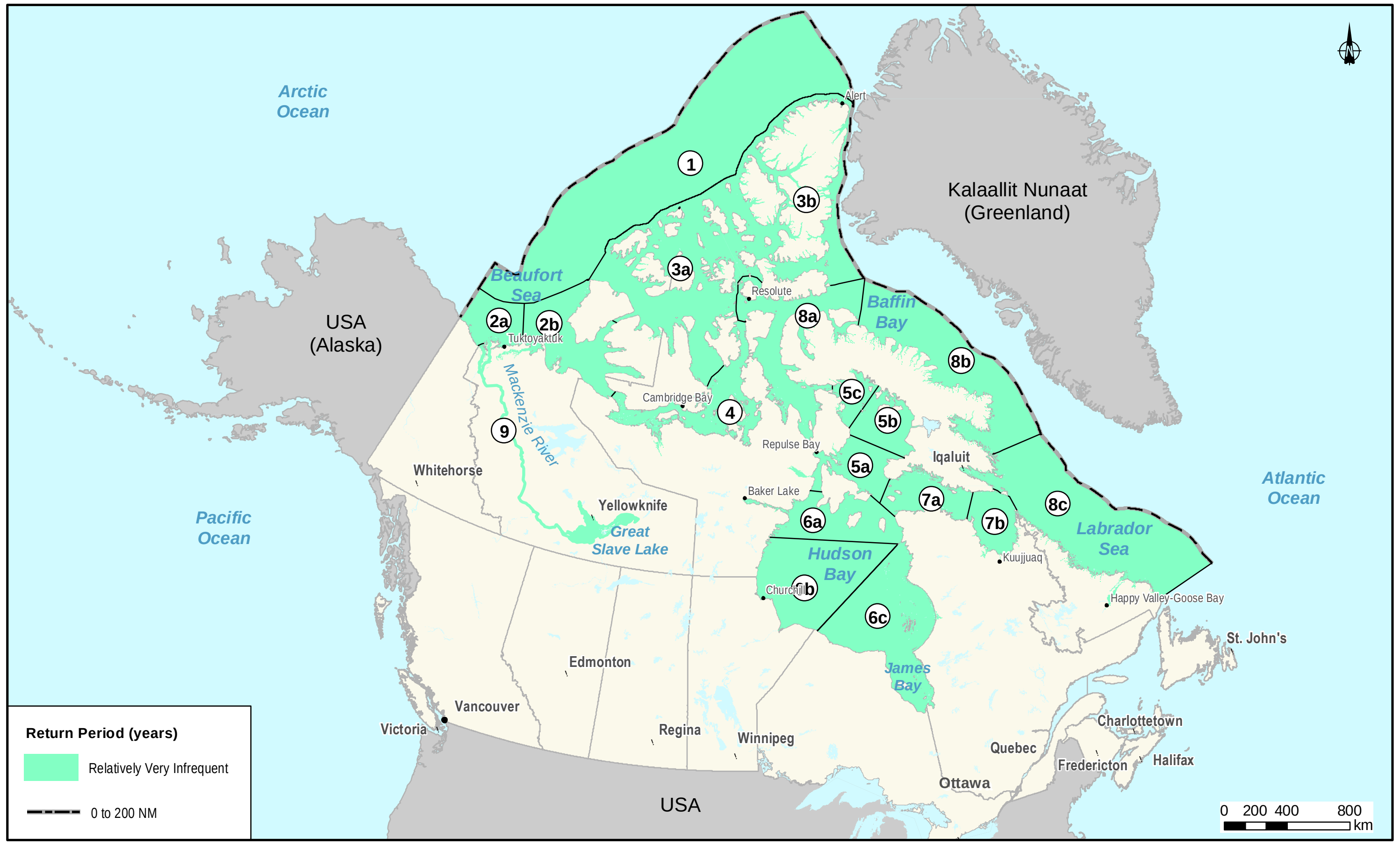
Refined Cargo Return Period (years) of Spill (volume m³) in Arctic Coast Sector

May 2014

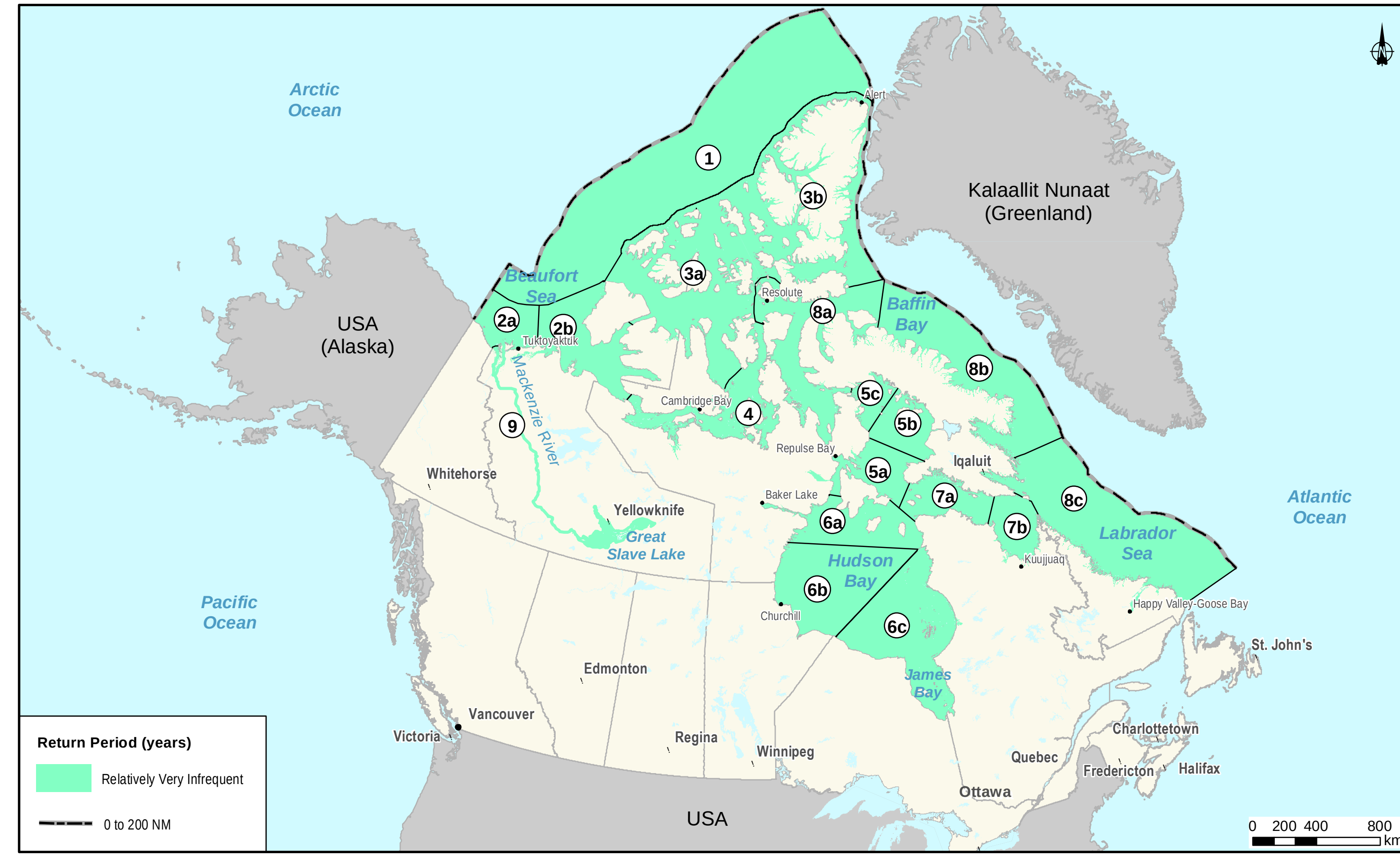
WSP

File: 131_17593_C4.3_Return_Canada_Refined_Arctic_140605.mxd

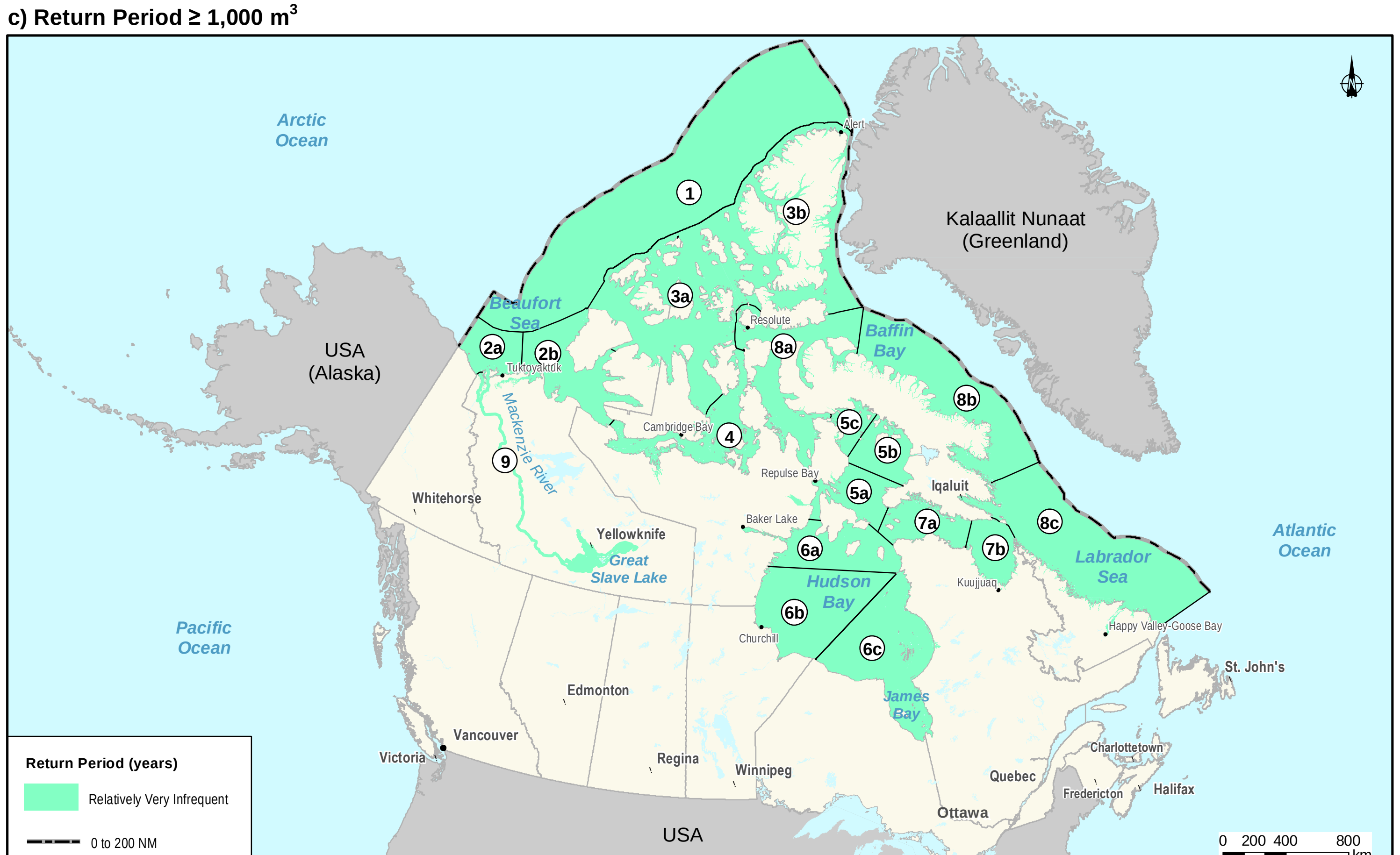
a) Return Period 10 to 99.9 m^3



b) Return Period 100 to 999.9 m^3



c) Return Period ≥ 1,000 m^3



Map 4.4

Fuel Oil Return Period (years) of Spill (volume m³) in Arctic Coast Sector

May 2014

WSP

File: 131_17593_C4.4_Fuel_Oil_Canada_Return_Arctic_140605.mxd

Spill statistics were gathered from TC's Prairie and Northern Region, CCG MPIRS, and NU/NWT spill line. In the most recent 10-year period, 2004 to 2013, there were four reported spills in the category of 1 to 9.9 m^3, all in the category of "refined cargos carried as cargo".

As to cause, there was one spill each in the categories of:

- transfer/unloading;
- grounding;
- collision; and,
- ice damage.

The average spill frequency for this category is simply the four spills divided by the 10-year period (Table 4.5).

Table 4.5 Arctic Refined Cargo Products Spill Frequency and Return Period Estimates for 1 to 9.9 m^3 Category

Total spills in Arctic water (10 years), Refined cargo products, 1 to 9.9 m^3	4
Annual spill frequency for Arctic, refined cargo products, 1 to 9.9 m^3	0.4
Return period, average number of years between spills	2.5

The calculated return periods presented in Table 4.4 represent a global estimate for the entire Arctic. Sub-sector specific frequencies are lower than the global estimate as they are adjusted for the specific number of transits within each sub-sector. Overall, the sum of sub-sector specific frequencies corresponds to the global estimate.

Overall, spill frequencies are very low for both fuel oil and refined cargo products transported as cargo for all spill categories with the exception of the 1 to 9.9 m^3 spills of refined cargo products. The return periods for this small spill size are the highest where most of the traffic occurs, that is in the Labrador Sea – Hudson Bay corridor. It is important to note that applied estimates for refined cargo products are conservative as no spill of refined cargo product has been reported in the Canadian Arctic.

Maps 4.3 and 4.4 illustrate the distribution of spill frequencies as return periods, for refined cargo products and fuel respectively. The scales used for both maps being the same, a comparison between frequencies for both products is possible.

The definition of the categories involves a natural break[5] calculation using ArcGIS (Table 4.6). Based on this method, class breaks are chosen as a function of the best grouping of similar values and in order to maximize the difference between classes. It should be noted that this breakdown reflect the frequencies calculated for the 1 to 9.9 m^3 spills of refined cargo products, which are not included in ERI calculations.

The highest spill frequencies are observed for the 1 to 9.9 m^3 spill category of refined cargo products. Based on the data from the last 10 years, no spill of oil carried as fuel is reported in the Canadian Arctic. When omitting the 1 to 9.9 m^3 spill category of refined cargo products, highest spill frequencies are observed for fuel oil (10 to 99.9 m^3), in the Labrador Sea sub-sector and connecting sub-sectors (Baffin Bay and Ungava Bay sector). The return period in sub-sector 8c (highest frequency observed; Map 4.3) is 778 years for a spill less than 100 m^3. This result is related to the supply of northern communities along the shore of Baffin Bay as well as to traffic occurring between the Labrador Sea and the northern two sub-sectors of James Bay (up to Churchill). For the other category of fuel spills, return periods range from 2,418 years to over 10 million years.

Table 4.6 Class Breakdown to Determine Return Period Classes.

Return Period Class	Natural Breakdown (years)
Refined Cargo Products and Fuel Oil	
Very High	8.1 to 16.5
High	16.5 to 30.6
Medium	30.6 to 78.6
Low	78.6 to 274.6
Very Low	274.6 to 1,831,501.8

With the exception of the 1 to 9.9 m^3 category, frequencies of spills for refined cargo products follow a similar trend (minimum and maximum) to fuel but with a significant difference in the magnitude: return periods for refined cargo products spills range from 2,928 years (sub-sector 8c, less than 99.9 m^3 spill) to several millions years (most sub-sectors in the 1,000 to 9,999 m^3 category).

4.4 Environmental Risk Results

The ERI has been calculated for each oil type (refined cargo products and fuel), along a gradient of spill volumes (3 classes from 10 to ≥1,000 m^3). The maps illustrate ERI values according to five categories of relative risk (from very low to very

5 A method of manual data classification that seeks to partition data into classes based on natural groups in the data distribution.

high). The scaling of the categories involves a natural break calculation using ArcGIS (Table 4.7). To define the scale, class breaks are chosen as a function of the best grouping of similar values and in order to maximize the difference between classes.

Table 4.7 Class Breakdown to Determine Environmental Risk Index (ERI) Classes.

ERI Class	Natural Breakdown
Refined Cargo Products and Fuel Oil	
Very High	0.0411 to 0.0974
High	0.0171 to 0.0411
Medium	0.0064 to 0.0171
Low	0.0017 to 0.0064
Very Low	<0.0000 to 0.0017

It should be noted that the relative ERI results are not included for the 1 to 9.9 m^3 oil spill size category. Consequently, it is not possible to appreciate the contribution of spill frequencies as represented on Maps 4.3 and 4.4, which include the smallest spill size category (1 to 9.9 m^3).

4.4.1 Refined Cargo Product Environmental Risk Index

4.4.1.1 1 to 9.9 m^3 Oil Spill Size

As indicated in the results on spill frequencies, limited impact of refined cargo of this spill category on the environment is expected and no ERI value was calculated.

4.4.1.2 10 to 99.9 m^3 Oil Spill Size

Map 4.5a presents the ERI values for the Arctic sector and its analysis leads to the following observations:

- There was no transport of refined cargo products in sub-sectors 1 and 3a.
- Except for sub-sector 8c, all the other Arctic Coast sub-sectors show a relatively low or very low ERI value. These results confirm that these sub-sectors are less frequently used to transport refined cargo products.
- The Labrador Sea (sub-sector 8c) has a relatively medium ERI value. Despite a relatively low ESI score, the spill frequency can explain this result.

4.4.1.3 100 to 999.9 m^3 Oil Spill Size

Based on Map 4.5b's results, the following observations can be made:

- There was no transport of refined cargo products in sub-sectors 1 and 3a.

- Sub-sectors 6a (northern part of Hudson Bay), 7a and 7b (Hudson Strait) as well as 8c (Labrador Sea) show a relatively medium ERI score. Except for sub-sector 8c, which is largely influenced by spill frequency, the relatively high ESI score obtained for the other sub-sectors significantly influences the ERI values.
- The other sub-sectors have a relatively low or very low ERI value.

4.4.1.4 ≥1,000 m^3 Oil Spill Size

Calculations for the 1,000 m^3 and greater spills (Map 4.5c) show that:

- There is no risk of 1,000 m^3 oil spill or greater in sub-sectors 1 and 3a.
- A relatively high ERI score was obtained in sub-sectors 8c (Labrador Sea) and 7b (Hudson Strait). Spill frequency and ESI score for sub-sector 7b can explain the result.
- The Hudson Bay (sub-sectors 6a, 6b and 6c) and a section of Hudson Strait (sub-sector 7a), show a relatively medium ERI value.
- ERI ranges from relatively low to very low in all other Arctic sub-sectors.

4.4.2 Fuel Environmental Risk Index

4.4.2.1 10 to 99.9 m^3 Oil Spill Size

Results for 10 to 99.9 m^3 spills (Map 4.6a) show that:

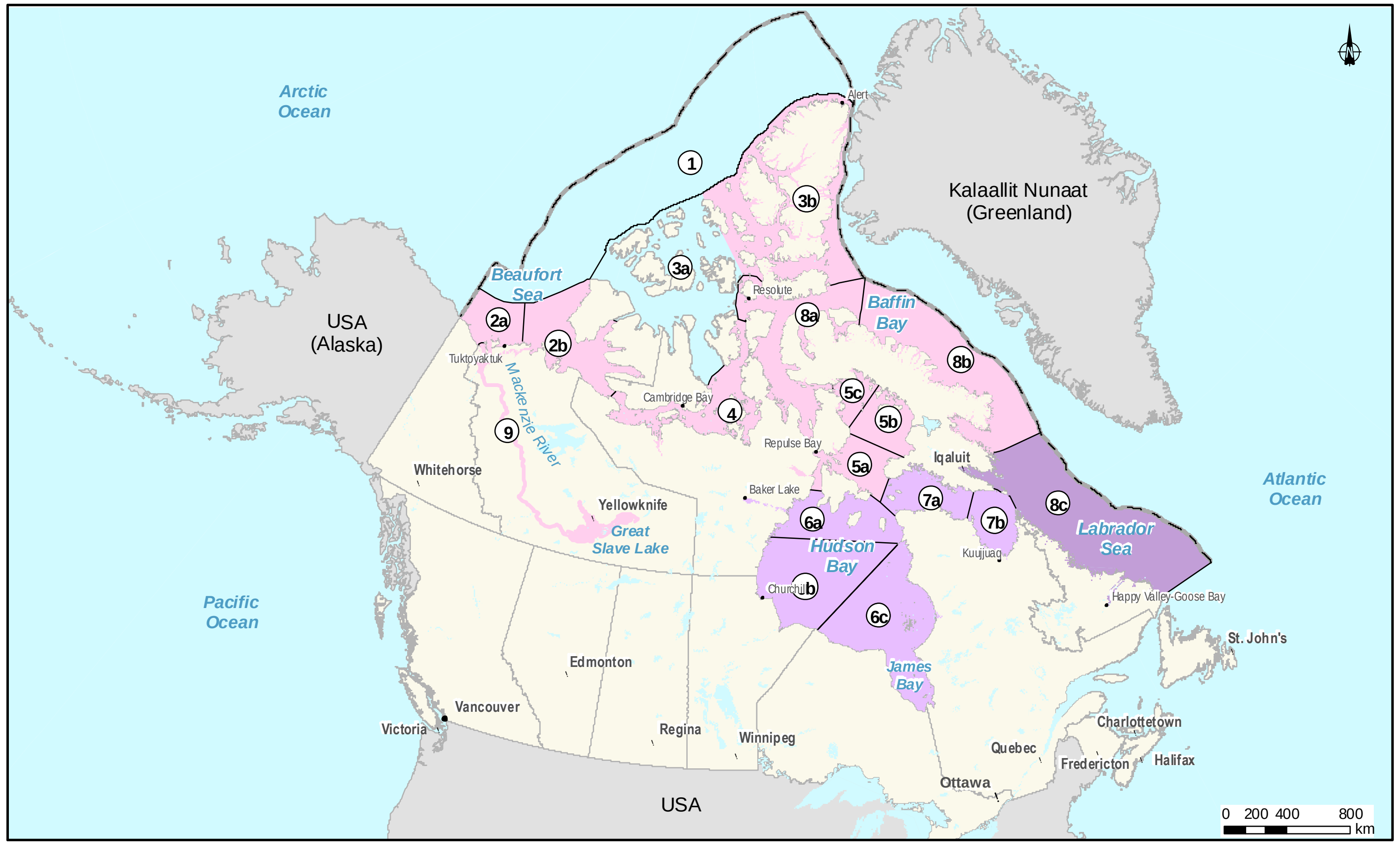
- Despite a relatively low ESI score, the sub-sector 8c shows a relatively high ERI value due to spill frequency obtained, reflecting the high marine traffic in the Labrador Sea.
- Sub-sectors with mid-range ERI values are present in Hudson Bay (sub-sector 6a), in Hudson Strait (sub-sectors 7a and 7b) and in Baffin Bay (8b). This result can be explained largely by the spill frequency. The ESI score (relatively low to very high) contributes also.
- The other sub-sectors show a relatively low or very low ERI value.

4.4.2.2 100 to 999.9 m^3 Oil Spill Size

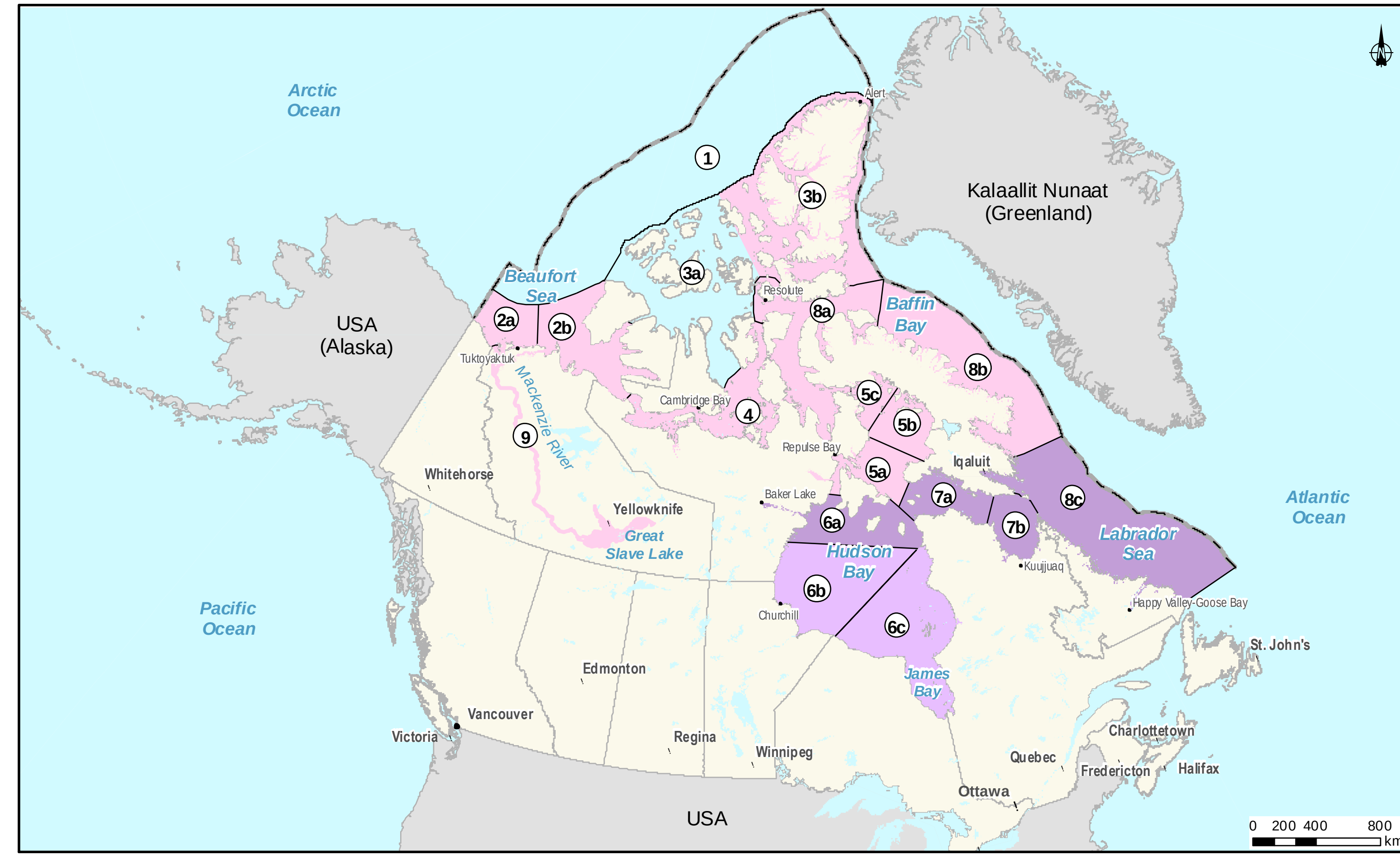
Based on Map 4.6b's results, the following observations can be made:

- The Labrador Sea (sub-sector 8c) shows a relatively very high ERI score, largely due to the high marine traffic in this sub-sector. The relatively low ESI score does not contribute significantly.

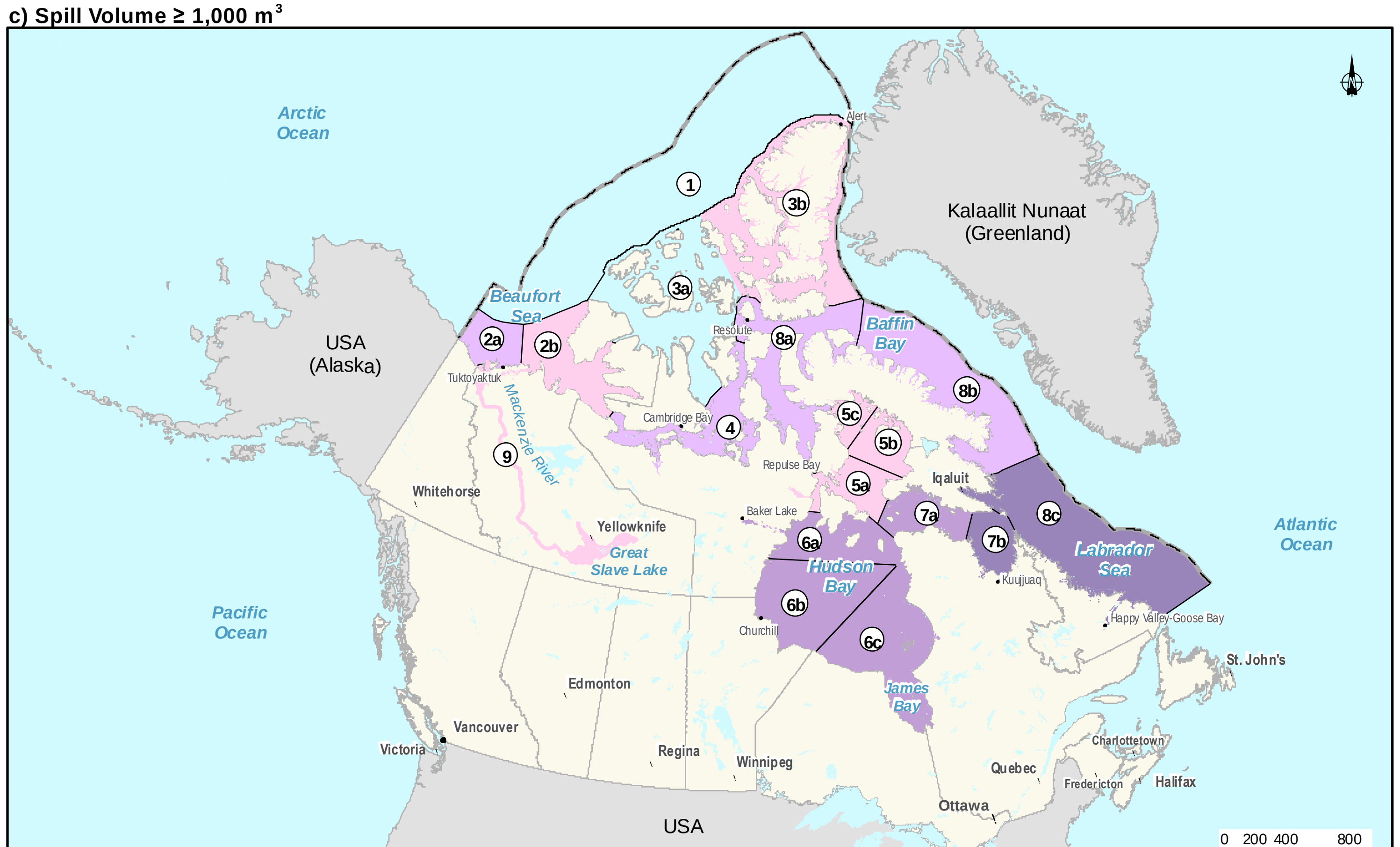
a) Spill Volume 10 to 99.9 m^3



b) Spill Volume 100 to 999.9 m^3



c) Spill Volume ≥ 1,000 m^3



ERI Scale[1]

- Relatively Very Low
- Relatively Low
- Relatively Medium
- Relatively High
- 0 to 200 NM

NOTE:

[1] ERI Scale is based on the range of values obtained for 10 to more than 1,000 m3 spill sizes whereas return periods (map 4.3 and 4.4) scales are based on 1 to 1,000 m3 spill size.

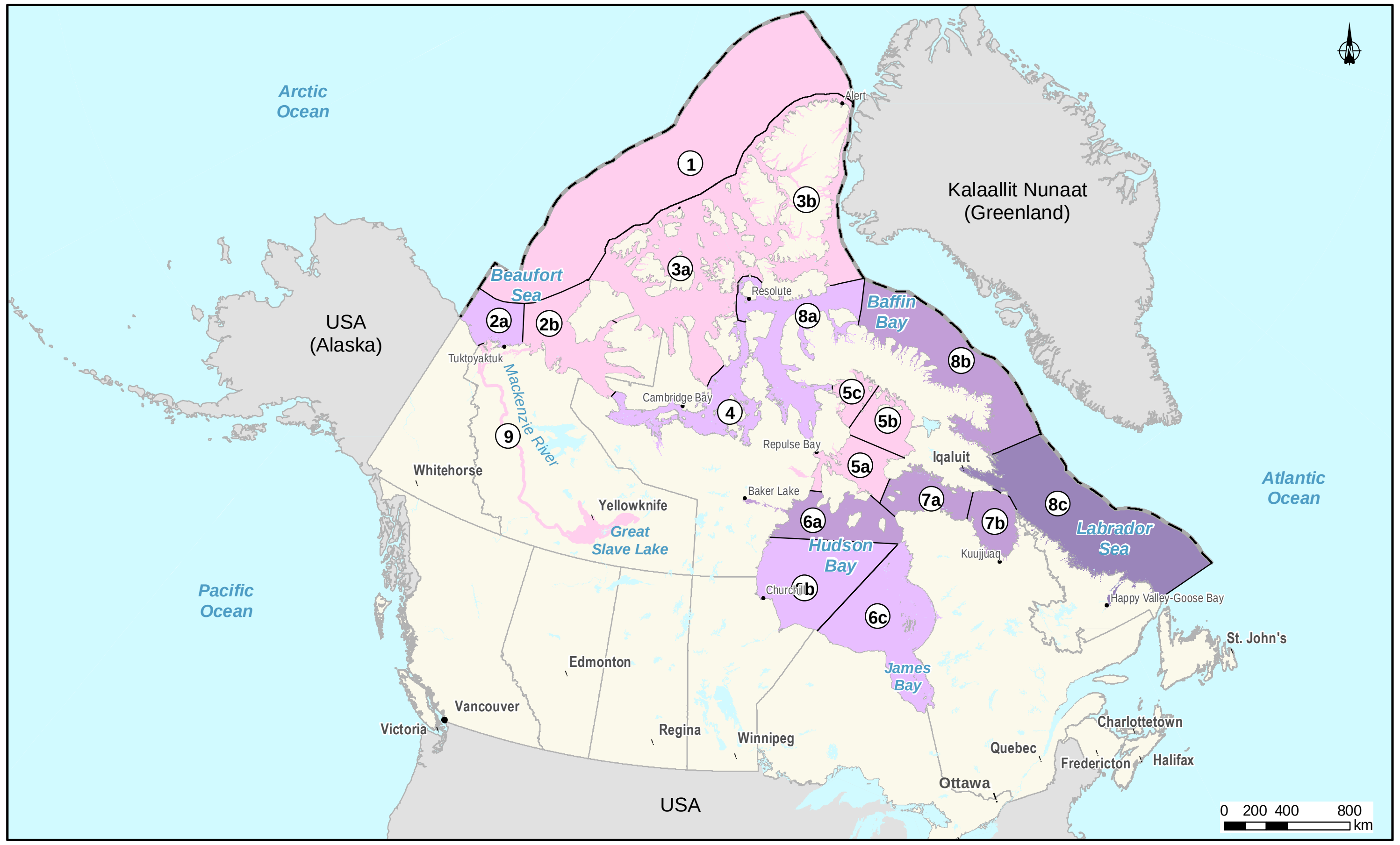
Map 4.5
Relative Environmental Risk Index (ERI)
for Refined Cargo Spill (volume m3)
in Arctic Coast Sector

May 2014

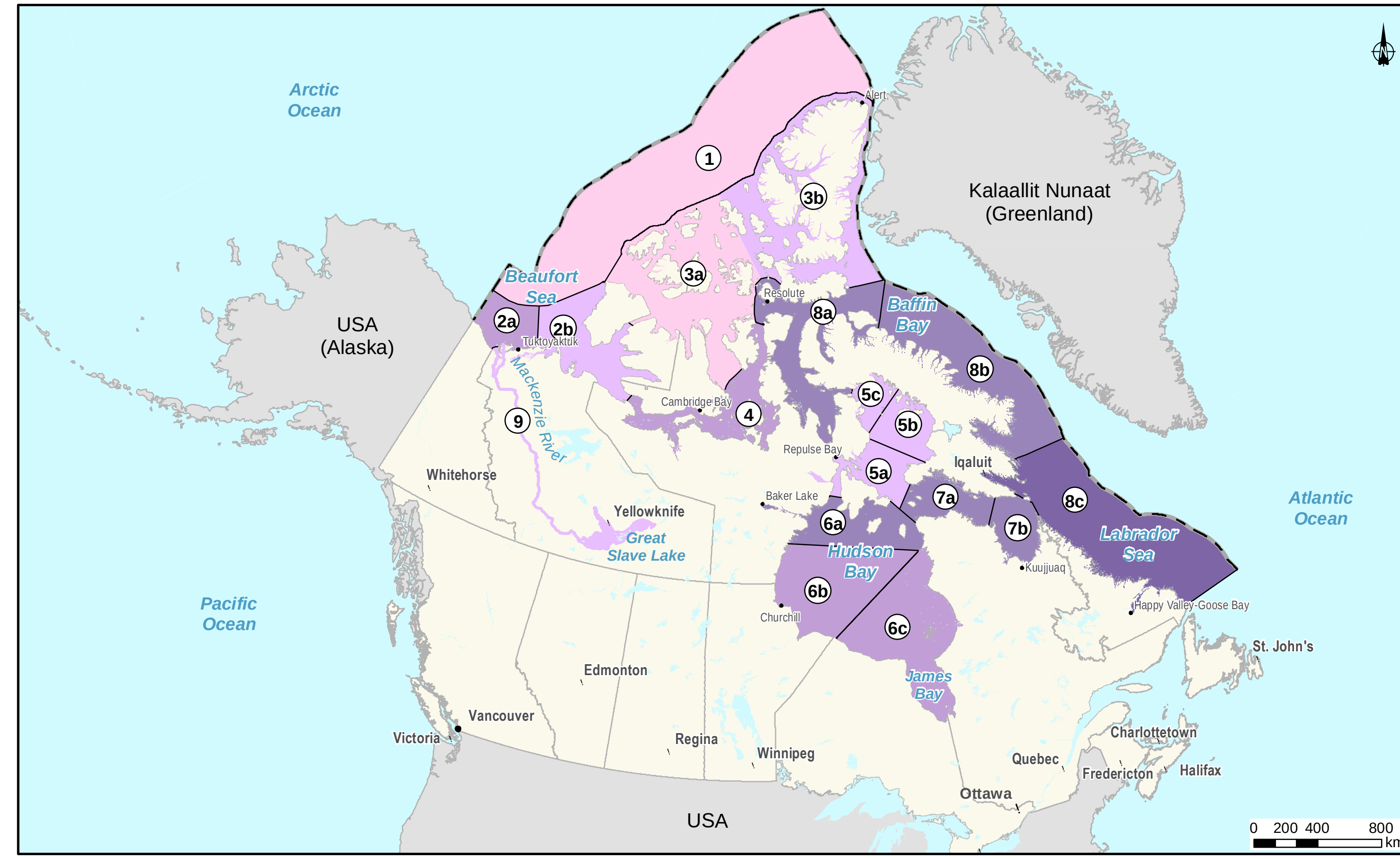
WSP

File: 131_17593_C4.5_ERI_Canada_Refined_Oil_Arctic_140605.mxd

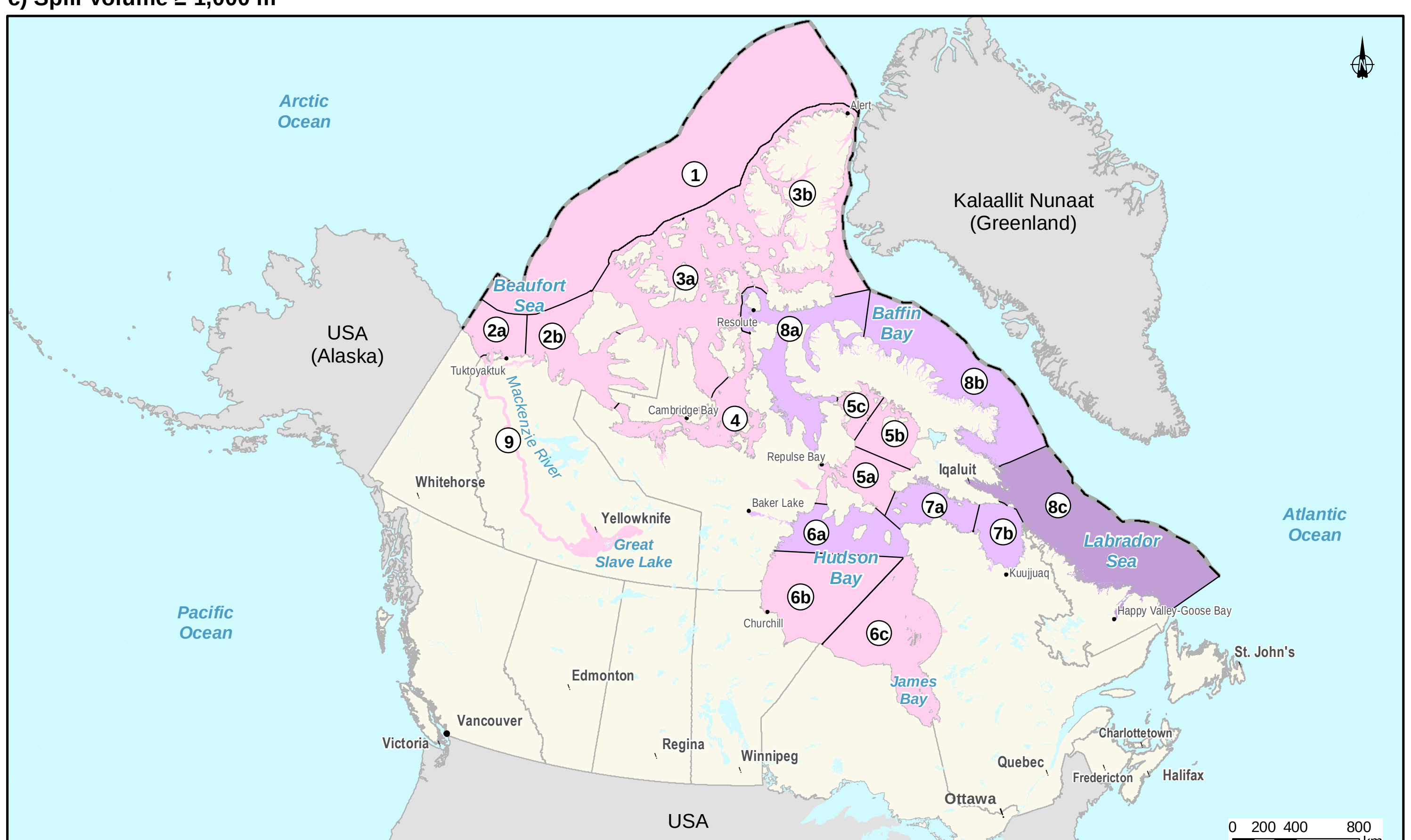
a) Spill Volume 10 to 99.9 m³



b) Spill Volume 100 to 999.9 m³



c) Spill Volume ≥ 1,000 m³



ERI Scale [1]

- Relatively Very Low
- Relatively Low
- Relatively Medium
- Relatively High
- Relatively Very High
- 0 to 200 NM

NOTE:

[1] ERI Scale is based on the range of values obtained for 10 to more than 1,000 m³ spill sizes whereas return periods (map 4.3 and 4.4) scales are based on 1 to 1,000 m³ spill size.

Map 4.6
Relative Environmental Risk Index (ERI)
for Fuel Oil Spill (volume m³)
in Arctic Coast Sector

May 2014

WSP

File: 131_17593_C4.6_ERI_Canada_Fuel_Oil_Arctic_140605.mxd

- A part of the Hudson Strait (sub-sector 6a), the Hudson Strait (sub-sectors 7a and 7b), Baffin Bay (sub-sector 8b), and Lancaster Strait and Boothia Gulf (sub-sector 8a) show a relatively high ERI score. These results are a combination of relatively high or medium ESI score and a relatively low or medium spill frequency.
- Sub-sectors 2a (Beaufort Sea), 4 (Queen Maud Gulf) and 6b and 6c (Hudson Bay) have mid-range ERI scores.
- All the other Arctic Coast sub-sectors have low or very low ERI values. Despite high or very high ESI scores in some sub-sectors, the spill frequency is low or very low.

4.4.2.3 ≥1,000 m^3 Oil Spill Size

Calculations for the 1,000 m^3 and greater spills (Map 4.6c) show that:

- Except for sub-sector 8c, all Arctic Coast sub-sectors have a relatively low or very low ERI value, due primarily to the relative very low spill frequency.
- Sub-sector 8c shows a mid-range ERI score. Despite a relatively low ESI, the spill frequency is amongst the highest across the Arctic.

4.5 Comparing Arctic and Southern ERI Values

Maps 4.7 to 4.18 compare spill frequencies (expressed as return periods) and ERI values for refined cargo and fuel oil across Canada. The objective of these maps is to demonstrate that the relative risk of marine spills in Canada for both oil categories is higher in the southern sectors of Canada due to higher traffic and volumes. Overall, the risk is higher in areas where shipping traffic occurs and these areas typically include large ports or transit channels.

At a national scale, the relative risk of spill in the Arctic is low because of low traffic and the low volume of refined cargo being transported. Although this report does not provide a comparison of ESI values, current risk values in the Arctic are not driven by a lower sensitivity than the south of Canada. If similar traffic and volumes to the south were observed in the Arctic, ERI values would likely be equivalent, if not higher, in the Arctic.

The national maps allow for a risk comparison across Canada; however it is important to highlight that the methods developed to produce ERI estimates differ between the north and south. This variation was required to accurately describe and compare ERI values in the Arctic. The main differences between the two methods are:

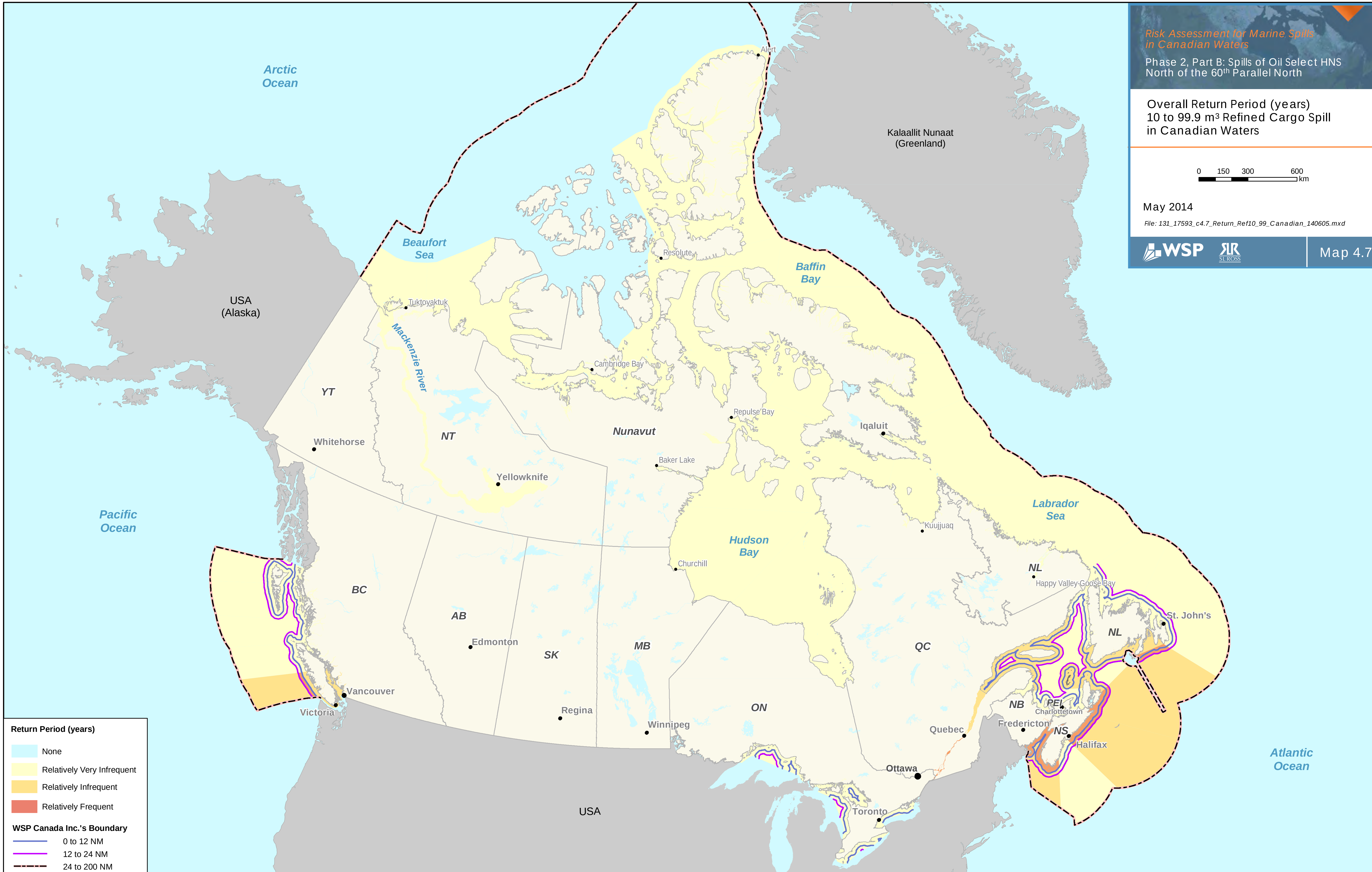
- Southern ERI estimates are related to a clean-up cost of shoreline, which required modeling of the spill size over time. Clean-up cost estimates were not available for the Arctic.
- Arctic ERI estimates are related to volumes and transits as well as spill frequency and ESI. Transits are derived from AIS track, allowing for a more accurate estimate than in the southern study where transits were estimated based on the shortest distances between port of origin and destination.
- Significant differences also exist in the ESI calculations, in particular for the PSI to consider ice conditions rather than shoreline types; and for the HRI which was modified to increase the weight on population densities.

4.6 Environmental Sensitivity

In addition to those sub-sectors with relatively very high and high ERI values, there are several sensitive sub-sectors in the Arctic Coast sector that may be affected by future increase in traffic volume (Appendix 1).

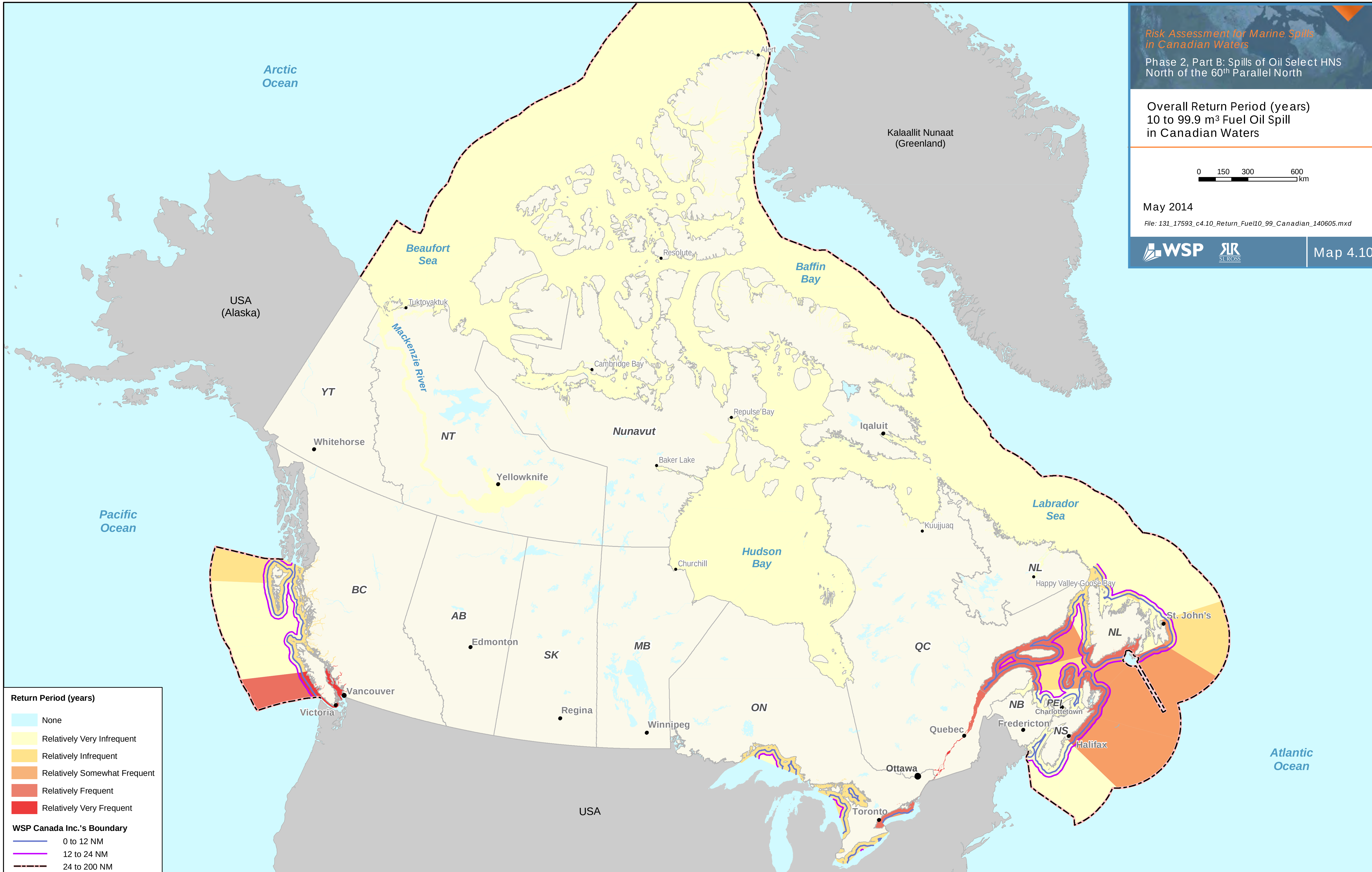
Sub-sector 6c shows a very high ESI. James Bay and the southern part of Hudson Bay are part of a semi-enclosed Arctic sea and contain unique physical and biological conditions that increase the biological productivity of the area. During the summer months, the ice free shoreline influences the PSI score. The importance of the coastal zone for many biological functions (reproduction, feeding and wintering), the presence of large-scale EBSAs, as well as many IBAs are also key features of this sub-sector. In addition, the population density is amongst the highest across the Arctic coast and contributes to the increase of the HRI score.

Sub-sectors 2a, 4, 6a, 7a, 7b, 8b and 9 have a high ESI score. This score can be explained by the ice free shoreline during the summer months and the ice cover at the beginning of the navigation season (influencing the PSI score). The importance of the coastal zone, the presence of many EBSAs and IBAs (influencing the BRI score), as well as the population density, the national freight tonnage and tourism are also key features of these sub-sectors (influencing HRI score).


Risk Assessment for Marine Spills in Canadian Waters
Phase 2, Part B: Spills of Oil Select HNS North of the 60th Parallel North
Overall Return Period (years)
10 to 99.9 m³ Refined Cargo Spill in Canadian Waters
0 150 300 600 km
May 2014
File: 131_17593_c4.7_Return_Ref10_99_Canadian_140605.mxd
WSP
SL ROSS
Map 4.7
Arctic Ocean
Beaufort Sea
Baffin Bay
Labrador Sea
Hudson Bay
Pacific Ocean
Atlantic Ocean
Kalaallit Nunaat (Greenland)
USA (Alaska)
USA
Mackenzie River
Alert
Resolute
Tuktoyaktuk
Cambridge Bay
Repulse Bay
Iqaluit
Baker Lake
Whitehorse
Yellowknife
Kuujjuaq
Churchill
Happy Valley-Goose Bay
St. John's
Vancouver
Victoria
Edmonton
Regina
Winnipeg
Ottawa
Toronto
Quebec
Fredericton
Charlottetown
Halifax
YT
NT
Nunavut
BC
AB
SK
MB
ON
QC
NL
NB
PEI
NS
Return Period (years)
None
Relatively Very Infrequent
Relatively Infrequent
Relatively Frequent
WSP Canada Inc.'s Boundary
0 to 12 NM
12 to 24 NM
24 to 200 NM


Risk Assessment for Marine Spills
in Canadian Waters
Phase 2, Part B: Spills of Oil Select HNS
North of the 60th Parallel North
Overall Return Period (years)
100 to 999.9 m³ Refined Cargo Spill
in Canadian Waters
0 150 300 600
km
May 2014
File: 131_17593_c4.8_Return_Ref100_999_Canadian_140605.mxd
Map 4.8
Arctic Ocean
Beaufort Sea
Baffin Bay
Labrador Sea
Hudson Bay
Pacific Ocean
Atlantic Ocean
Kalaallit Nunaat (Greenland)
USA (Alaska)
USA
Mackenzie River
Alert
Resolute
Tuktoyaktuk
Cambridge Bay
Repulse Bay
Iqaluit
Baker Lake
Kuujjuaq
Churchill
Happy Valley-Goose Bay
St. John's
Whitehorse
Yellowknife
Vancouver
Victoria
Edmonton
Regina
Winnipeg
Ottawa
Toronto
Quebec
Fredericton
Charlottetown
Halifax
YT
NT
Nunavut
BC
AB
SK
MB
ON
QC
NL
NB
PEI
NS
Return Period (years)
None
Relatively Very Infrequent
WSP Canada Inc.'s Boundary
0 to 12 NM
12 to 24 NM
24 to 200 NM


Risk Assessment for Marine Spills in Canadian Waters
Phase 2, Part B: Spills of Oil Select HNS North of the 60th Parallel North
Overall Period Return (years)
1,000 to 9,999.9 m³ Refined Cargo Spill in Canadian Waters
0 150 300 600 km
May 2014
File: 131_17593_c4.9_Return_Ref1000more_Canadian_140605.mxd
WSP
SL ROSS
Map 4.9
Arctic Ocean
Beaufort Sea
Baffin Bay
Labrador Sea
Hudson Bay
Pacific Ocean
Atlantic Ocean
Kalaallit Nunaat (Greenland)
USA (Alaska)
USA
Alert
Resolute
Tuktoyaktuk
Mackenzie River
Cambridge Bay
Repulse Bay
Iqaluit
Baker Lake
Kuujjuaq
Churchill
Happy Valley-Goose Bay
St. John's
YT
NT
Nunavut
Whitehorse
Yellowknife
BC
AB
SK
MB
ON
QC
NL
NB
PEI
NS
Edmonton
Regina
Winnipeg
Vancouver
Victoria
Ottawa
Toronto
Quebec
Fredericton
Charlottetown
Halifax
Return Period (years)
None
Relatively Very Infrequent
WSP Canada Inc.'s Boundary
0 to 12 NM
12 to 24 NM
24 to 200 NM


Risk Assessment for Marine Spills in Canadian Waters
Phase 2, Part B: Spills of Oil Select HNS North of the 60th Parallel North
Overall Return Period (years)
10 to 99.9 m³ Fuel Oil Spill
in Canadian Waters
0 150 300 600 km
May 2014
File: 131_17593_c4.10_Return_Fuel10_99_Canadian_140605.mxd
WSP
Map 4.10
Return Period (years)
None
Relatively Very Infrequent
Relatively Infrequent
Relatively Somewhat Frequent
Relatively Frequent
Relatively Very Frequent
WSP Canada Inc.'s Boundary
0 to 12 NM
12 to 24 NM
24 to 200 NM
Arctic Ocean
Beaufort Sea
Baffin Bay
Labrador Sea
Hudson Bay
Pacific Ocean
Atlantic Ocean
Kalaallit Nunaat (Greenland)
USA (Alaska)
USA
Mackenzie River
YT
NT
Nunavut
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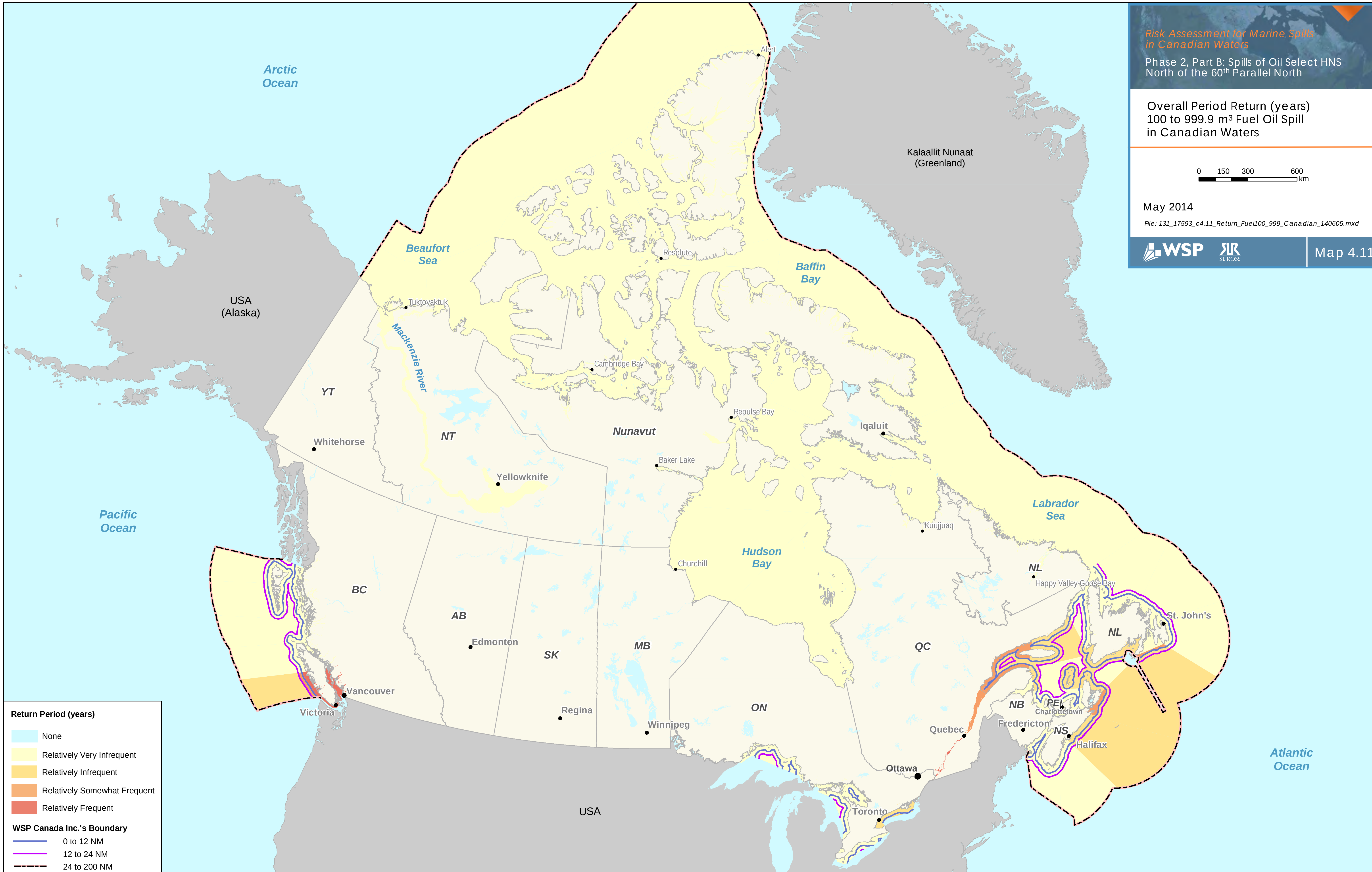
Toronto
Fredericton
Charlottetown
Halifax



Risk Assessment for Marine Spills in Canadian Waters
Phase 2, Part B: Spills of Oil Select HNS North of the 60th Parallel North
Overall Period Return (years)
100 to 999.9 m³ Fuel Oil Spill
in Canadian Waters
0 150 300 600 km
May 2014
File: 131_17593_c4.11_Return_Fuel100_999_Canadian_140605.mxd
WSP
SL ROSS
Map 4.11
Arctic Ocean
Beaufort Sea
Baffin Bay
Labrador Sea
Hudson Bay
Pacific Ocean
Atlantic Ocean
Kalaallit Nunaat (Greenland)
USA (Alaska)
USA
Mackenzie River
YT
NT
Nunavut
BC
AB
SK
MB
ON
QC
NL
NB
PEI
NS
Alert
Resolute
Tuktoyaktuk
Cambridge Bay
Repulse Bay
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St. John's
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Fredericton
Halifax
Quebec
Ottawa
Toronto
Winnipeg
Regina
Edmonton
Vancouver
Victoria
Return Period (years)
None
Relatively Very Infrequent
Relatively Infrequent
Relatively Somewhat Frequent
Relatively Frequent
WSP Canada Inc.'s Boundary
0 to 12 NM
12 to 24 NM
24 to 200 NM