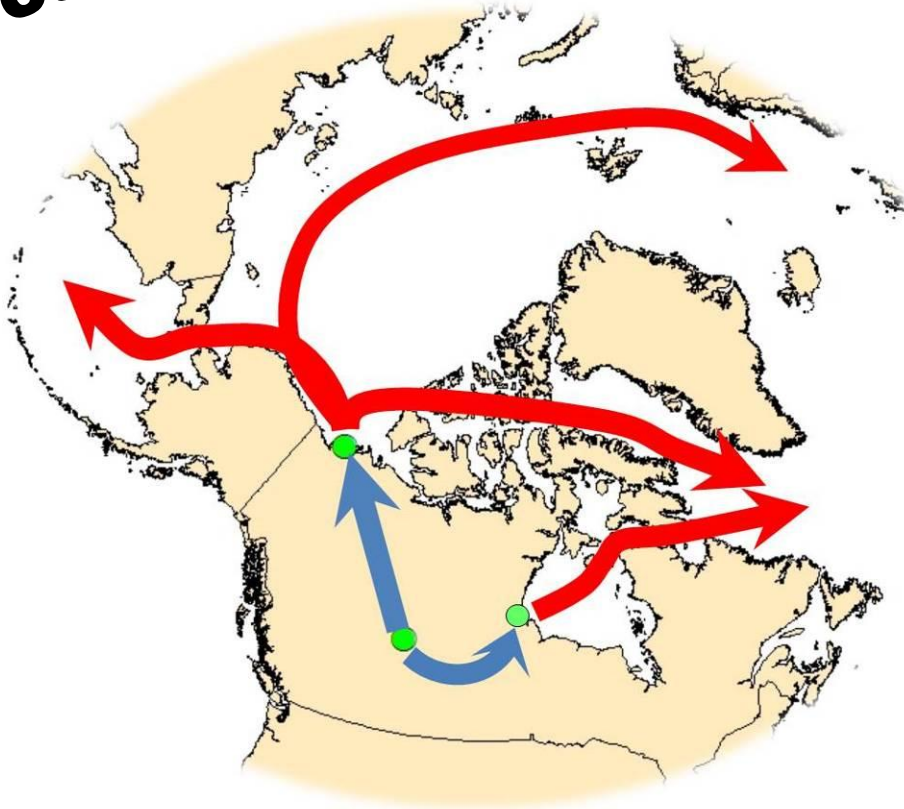


# An Arctic Energy Gateway for Alberta



Wim Jolles, Scott Tiffin

May, 2013

## SUMMARY

This document reports on the technical pre-feasibility of Alberta exporting bitumen blend from the oil sands north to the Beaufort Sea coastline and from there, by ice-class tankers, to world markets in the Asia-Pacific region and the Atlantic coasts.

### Components of the Transportation System

Components of a petroleum transport system to achieve this can include:

- Road, rail and river barging
- Pipelines for transporting dilbit and returning diluent to Fort McMurray, possibly incorporating the existing Norman Wells line
- Product storage facilities on the Arctic coast (either on land or on moored tankers), where diluent would also be separated from dilbit to return to Fort McMurray.
- Port facilities on the coast for supply and logistics. There are multiple choices for storage and port facilities in the NWT and Yukon.
- An undersea pipeline to an offshore loading terminal that would be ice resistant in design, from which tankers could travel to markets both in the Pacific and Atlantic regions.
- Alternatively, a similar scenario would see road/rail/pipeline transport of bitumen to the port of Churchill, Manitoba, for loading to ocean-going transport vessels.

### Technical Feasibility

Polar environments of extreme cold, seasonal darkness, remoteness, sea ice and icebergs create challenging construction and operation conditions. However, there is no doubt that the technology exists to make all transportation system components listed above work. In fact, all were close to being technically feasible in the early 1980s, when Alberta was the leader in offshore Arctic technology and the world Arctic petroleum industry was centred in Calgary. All components of an Arctic Energy Gateway mentioned above already exist in Arctic theatres and have been operating successfully for a number of years.

### Marine Transport Routes and Markets

The Arctic Energy Gateway consists of multiple marine routes:

- Arctic coast over Alaska and through the Bering Strait to Asia-Pacific markets
- Arctic coast over Alaska and across northern Russia to European markets
- Arctic coast through the Northwest Passage to European markets
- Churchill in Hudson Bay, Manitoba to European markets.

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All these routes are currently used, in summer, when ice conditions are the least severe and significant amounts of open water are present, or in some cases, when there is no ice. The Russian route is undergoing major investment to make it a regular commercial route with an extended season.

It is technically feasible for ships to navigate these routes at any time of year: it is only a matter of building them to the appropriate ice class and having appropriate icebreaker assistance. However, the cost of building and operating high ice class ships probably will be found to make most of these routes seasonal. The ice conditions on each route are quite different. The Alaskan- Bering Strait route has the most favourable ice conditions. The Russian route is next. The Northwest Passage experiences the most severe sea ice conditions; it also experiences icebergs, but these are a hazard easily managed by current navigational practice and technology. Hudson Bay has the least severe sea ice conditions, as it is not a High Arctic area. It is likely that any of these routes will require storage of bitumen on the coast to account for temporarily severe seasonal ice conditions. Calculating the amount of storage and the seasonality depends not only on technology but economics, environmental and regulatory regimes as well.

### **Impact of Global Climate Change**

Global climate change affects the technical assessment of an Arctic Energy Gateway. Global climate change is causing an unprecedented retreat of Arctic sea-ice which would mean that, on average, one can expect to see a marked decrease in ice severity along the west and east shipping routes. This will make the shipping season longer, require less power, lessen required icebreaker escort/support, decrease transit times, and require much less ice-reinforcement of vessel hulls. The scientific community is strongly aligned around the view that such sea-ice conditions will continue to lessen in severity; the main debate is centred only on how fast they will continue to diminish. Of course, there will be local changes along the routes that may cause more severe conditions from time to time. In addition, not all regions behave the same way: Hudson Bay ice conditions appear to be lessening only to a very small degree; icebergs in Baffin Bay will likely increase in number.

### **Social, Environmental and Regulatory Climate**

The environmental, regulatory, and political climates underpinning the pre-feasibility analysis for the Arctic Energy Portal are multifaceted. The precedent generated by the Mackenzie Gas Pipeline (MGP) proposal ultimately augments the prospective viability of an Arctic Energy Gateway. With the Mackenzie Delta operating as the hub region for this transportation proposal, support from the Government of the Northwest Territories and the Inuvialuit Regional Corporation (and an understanding of its unique regulatory processes) would be essential. Given the hydrocarbon-related economic development, and the aspirations of these governments and of their citizenry, it is quite conceivable that a transportation corridor, with Tuktoyaktuk as the sea terminus, would gain significant regional support. The GNWT seems to be firmly in favour of such development, if it can be done without undue risk to the environment and territorial economic development. In the context of regionalization of

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natural resource authority to the Territory and land claim rights holders, there is a potential for significant economic gains for the Inuvialuit.

The Government of Manitoba is actively seeking ways to revitalize and expand the Port of Churchill. On the other hand, there is a substantial environmental industry based out of Churchill around iconic marine fauna – polar bears. Rights of way for pipeline and rail links are already in existence; but to shorten and rationalize them a new pipeline would have to negotiate difficult northern terrain and cross areas of native land claims and settlement, who might feel they had little to gain from such a development.

Environmental risks associated with bulk transportation of a petroleum product through relatively unverified and hazardous routes may be the most challenging obstacle. Regulators presented with a shipping proposal through areas of ecological significance and fragility and with limited marine infrastructure may be reluctant to approve such a project at this time. Systemic weaknesses exist within the Canadian and Arctic scenarios of oil spill response. Support from analogous jurisdictions may not be necessary from a regulatory perspective, but organized and residential opposition could present additional challenges.

### **Resource Complementarities**

The Arctic Energy Gateway needs to be considered not just as an export route for Alberta bitumen, but the key to catalyze the development of massive petroleum resources in the western Arctic. These include: gas deposits in NE British Columbia, shale gas and shale oil in the Norman Wells region, Mackenzie Delta onshore gas, Beaufort Sea offshore oil and gas. In addition, major mining projects are planned in this region that either require or will benefit from the development of better land and marine logistics infrastructure.

### **A Scenario for the Arctic Energy Gateway**

Given the positive uncertainties presented by more favourable ice conditions and these massive natural resource potential in the region, it is recommended that a project to develop the Arctic Energy Gateway be conceptualized in the following manner.

#### **Phase 1 - Pilot Start-up**

The project could begin with a pilot level activity by sending dilbit to Hay River by rail for transfer to barges, which would unload at Tuktoyaktuk. The dilbit would be separated and the barges return it to Hay River. Bitumen would be stored on land or tanker somewhere in the Delta region and loaded using a temporary offshore loading terminal, to open water tankers operating in summer. Standby icebreaker escort would assist vessels to transit possible choke points along the route at season start and end.

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Only minor construction of new equipment would be required, principally, port/loading facilities for barge transport, and double-hulled barges to reduce environmental risk. Constructing purpose-designed barges would also allow for the possibility of heating the dilbit, reducing or eliminating the diluent content, and transferring directly to tankers at sea.

This startup scenario will allow for export over Alaska to Asia-Pacific markets, and for a shorter season, along the Russian route to Europe and on a test, opportunity basis for still shorter periods, through the Northwest Passage to Europe.

The annual throughput is primarily limited by the barge component at 5,940 bbl/day per spread of 6 barges which translates in a normal season to some 831,600 bbls/year and in a good year with special barges some 1.2 MM bbls/year (per spread of 6 barges). More than one spread of barges would be used to increase throughput.

In terms of technology and construction requirements, this scenario could be put into action by summer 2015.

### **Phase 2 - Ramp up Production**

A pipeline is probably the best solution to transport large volumes to the Arctic coast. Incorporating the existing Norman Wells pipeline into a line from Fort McMurray to the Mackenzie Delta might significantly speed up export of increased volumes of dilbit. Given the expected positive uncertainties about reduction in Arctic ice cover, it might be considered useful to gain more experience with terminals and tanker routes before committing to full scale design/construction, while still expanding the pilot shipment levels.

The pipeline might be a single line, transporting dilbit for export. It would be produced all year and offloaded to tankers in summer, spring and fall. In winter, product is stored, either on land or using tankers as well. The loading terminal is to be removed for winter. Icebreakers and ice class tankers complement open water vessels to allow for extended season shipping in fall and spring as well as summer.

Markets are the same as for the pilot level scenario.

Using the existing Norman Wells pipeline limits throughput to 13,900 bbl/day of bitumen.

### **Phase 3 - Year Round Production and Year Round Export**

At the appropriate time, the pipeline would be designed to be completed with the Norman Well line possibly converted for diluent return or superseded by a fully twinned pipeline line at maximum throughput. A purpose-built port, land-based storage farms and a permanent offshore loading terminal

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would be constructed on the coast. Specially designed tankers and icebreaker escort vessels would be built.

While all routes are feasible from a technology perspective, in the next decade, it is most likely that the economics will favour the Alaska route to Asia-Pacific markets for year round export. However, the existence of specially-built high ice class vessels will allow for greatly extended seasons through the other routes as well.

If a new pipeline is built, rates can be boosted to 50,000 or 100,000 bbl/day.

## **Option - Churchill Transportation System**

At the same time, or as an option, Churchill can be used. The scenario would be similar to exporting through the Delta region. A combination of road and rail would ship small quantities to Churchill for export in the summer season. It would only require the building of temporary land storage facilities at Churchill.

Export would favor European - Atlantic markets. This route could be initiated in 2014, with small test shipments even in 2013 if desired. This route could be made suitable for all year production and export by extending the pipeline infrastructure to Churchill in an analogous manner to the Delta region.

## **Benefits to Alberta**

**First**, our initial analysis suggests that the socio-political and environmental climate may be more favourable to an arctic route than to a US or BC pipeline route. Alberta promoting a northern route might gain allies rather than enemies.

**Second**, this route offers Alberta the opportunity to get to markets that are not just the US, and also to markets that are both Atlantic and Asian. The increased breadth of these market opportunities and the flexibility to choose the ones with optimal returns.

**Third**, there are major resource development synergies that the Mackenzie Valley option route offers, whose development could be accelerated if bitumen blend export infrastructure were in place.

**Fourth**, infrastructure sharing would also occur with massive mining projects in the region.

**Fifth**, given that the land transport segment of the Mackenzie Valley option would occur in the NWT, it is likely that Alberta would also benefit much more from the construction and operations phase of this segment than if a pipeline were constructed through BC or the USA. Alberta companies could also be heavily involved in designing, building and operating terminal and port facilities on the Beaufort Sea coast.

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**Sixth**, the Arctic is a frontier, requiring advanced technological innovation in many different areas. There are numerous opportunities for creation and growth of high-tech companies in Alberta to make the novel products and services this frontier industry will require. In the past, it was innovations in naval architecture and civil engineering that dominated, and Alberta was once the world leader in these fields. In the future, we will see incremental innovation in these same areas, but the main areas for radical improvements will be in these types of fields mentioned in the previous chapter: communications, software, robotics, sensors, cold weather power supplies, bioremediation of spills, new materials – all areas where Alberta could become an important player.

**Seventh**, Alberta can play a leading role in the opening of the Northwest Passage. This will be a revolution in global logistics, equal in impact to the opening of the Suez or Panama Canals. Alberta will automatically be a major player in this industry if it has already established an Arctic Energy Gateway.

**Eighth**, there are major benefits to other parts of Canada. If the Mackenzie Valley option goes ahead, the NWT will experience enormous growth in terms of industrial activity and population, which also have the potential for negative outcomes to some social sectors if not well managed. Nunavut and the Yukon could participate to a lesser degree through employment, port development and related logistical improvements. The marine industry located in BC and the East Coast will benefit especially Newfoundland and Labrador. Given that Newfoundland has a longstanding and vigorous provincial policy to exploit arctic marine resources and develop high-tech offshore business, there is obvious potential for novel forms of cooperation between the two provinces to build critical mass and dominate key global markets. Alberta could take a leadership role within Canadian confederation, on the future of the Arctic.

## Recommendations

1. Explore the concept more thoroughly, by commissioning studies at a feasibility level of the environmental, social/political and economic situations, and taking this very small technical pre-feasibility study to the next level of detail. These studies should be focussed on the design and promotion of a small scale, low risk, low profile, quick start-up pilot type of project to test stakeholder and public reaction, prove feasibility, gather operational experience to improve full system design parameters and generate revenue from export.
2. Enter into discussions with the Governments of the NWT, Yukon and Manitoba, which will be essential partners in an Arctic Energy Gateway, to discover their views on such a project, and in partnership with them, initiate contacts with northern indigenous peoples' organizations to ensure relationships are productive from the outset.
3. Begin discussions with the major oil sands industry stakeholders to assist them in realizing this is possibly not only a viable alternative for export, but possibly a far better option than what they have considered to date.

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4. Begin discussions with petroleum companies that are investigating exploration and production options for their leases in the Beaufort offshore to start developing creative collaboration that will benefit all producers.
5. Promote the concept with Asian petroleum companies, shipping companies and ship design/building companies by giving them favourable signals and general guidelines. The primary target should be China, for its ambitions to develop Arctic shipping and need to secure Arctic mineral and petroleum resources; to date they are focussing on the Russian route and links with Norway and Iceland. The secondary target should be Korea, for its ship design and building capability, as well as gas imports. Third, we would suggest Singapore, as being vitally concerned with not losing its position in world shipping management/finance, by getting involved in the Arctic.





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## 1 INTRODUCTION



Alberta seeks to send to market the massive petroleum resources it has in the Athabasca River oilsands. Both the industry and the Province have been confronted by growing, intractable, opposition to development of this resource. Alberta is now hampered by not having direct access to the sea and by having to use pipelines across jurisdictions where opponents can stop, delay, or render uneconomic such infrastructure. Even if these export routes succeed, residual negative publicity could continue to reflect badly upon Alberta.

An option that merits greater consideration is going north to access marine tankering routes that will travel through seasonally ice-covered waters. We call it the Arctic Energy Gateway. Such an integrated transportation system would consist of the following components:

- Transport from the production areas in Alberta by a combination of road, rail, barge and pipeline,
- Storage facilities at the coast, along with port and offshore loading infrastructure,
- Tankers carrying the product both east and west to world markets.

In addition, we consider the system to involve the possibility of using river barging, road, and rail transport for low volume transport, as a start-up mode in the Mackenzie Valley before a pipeline might be built.

This report examines the technological feasibility of such an export route. This report is a preliminary, high-level design of an integrated bitumen blend transport system, and an analysis to see if this system is physically possible. If the results are convincing, then the Alberta Government will need to look at the technical feasibility in more detail, do the same for the environmental, economic and socio/political issues involved, and rapidly start promoting this alternative to the appropriate governmental and industry stakeholders.

## 2 BACKGROUND

At present, Alberta has relatively little involvement with Arctic industrial activity and, as a landlocked province; it seems to have little connection to marine activity. Most Albertans have heard of the Beaufort Sea, Tuktoyaktuk, and the Mackenzie Delta, but many would be hard-pressed to locate them accurately on a map.

Yet, little more than a quarter century ago, Alberta was ***the world centre for the Arctic petroleum industry***. The offshore part of this industry was conceived in Calgary. For over 15 years, from 1970 to 1986, Alberta held almost all the technological and managerial expertise in the world to operate exploration and production of oil and gas in the High Arctic and in the Beaufort Sea.

This era of astounding activity has been largely forgotten in the province. When the industry wound down in the mid 1980s due to a combination of financial, policy, and regulatory factors, the surviving petroleum companies shed their staff and laboratories while the support companies folded or moved, and thousands of engineers, scientists, technicians, skilled operators, and managers left the province. Massive and unique data sets were abandoned or outright destroyed.

The Mackenzie Valley pipeline debate and hearings left a massive document legacy, but its memory in the public imagination seems largely to have disappeared. For the marine aspects in the Beaufort Sea, little was ever analysed or published, but what is available shows incredible amounts of audacious and radical R&D, technological innovation, and operational exploits. A PhD thesis done by one of the authors of this report (Tiffin, 1982) detailed the role of engineering companies in the process of innovating offshore structures and vessels. In this one very narrowly focused work alone, Tiffin (1982) documented up to 3 billion dollars worth of radical technological innovation. A book published by the Arctic Institute of North America (Clark et al., 1997), written by students under the guidance of Murray Todd (former President of Canadian Marine Drilling Ltd.) and Jack Gallagher (former Chairman of Dome Petroleum Limited), gives a broader, journalistic overview of the marine technologies. A few papers presented at engineering conferences (e.g. Keinonen, 2012) and a few industry memoirs (e.g. Grey and Krowchuk, 1997) fill in a few more gaps in the record.

In this period, Alberta led the world in Arctic onshore and offshore technology, Arctic logistics, management and finance of Arctic petroleum development activities, Arctic marine and terrestrial environmental protection. Calgary was the managerial, R&D, finance, and design centre; Edmonton was the operations centre for logistics and communication. This massive industry was based on the premise that the technology could be innovated to develop the fields and transport product to market, do so economically and in a way that reduced environmental risk to manageable and acceptable proportions. In the mid-1980s, the economic component of the premise deteriorated. The jury came back with a partial decision on the environmental issue, deferring the Mackenzie Valley pipeline to an unspecified future date. However, the technological ability to produce oil and gas in the Beaufort Sea and Arctic Archipelago, and to transport petroleum both to Atlantic and Pacific markets, was already well demonstrated.

The following images show some of the audacious concepts and structures that were developed in those days, some of them still working today.



Esso Caisson Retained Island



Single Steel Drilling Caisson (note co-author Wim Jolles standing on anchor buoy to the right in red survival suit)



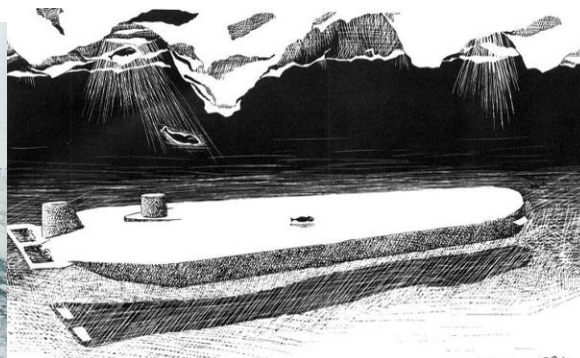
Gulf Canada icebreaking drilling barge *Kulluk*



Canmar ice-strengthened drillship with support icebreaker



Gulf Canada *Ikaluk* icebreaker



PetroCanada concept sketch for a Nuclear-powered LNG submarine tanker

Tiffin (2012), and Higginbotham et al. (2012) point out that the Government of Alberta has not been involved in these issues of Arctic offshore development since the mid 1980s, and the policy and

regulatory environment at the Federal level is not well organized or developed to support industrial action in the Arctic. But, however novel the concept of an Arctic Energy Gateway may appear, working in the Arctic offshore is deeply rooted in Alberta's geography and history. The Arctic offshore can be just as much a part of Alberta's future as it was of the recent past.

### 3 OBJECTIVES

The purpose of this study is to analyse the technical pre-feasibility of exporting bitumen blend via an Arctic Energy Gateway. The objectives are to:

- Describe the components of a multimodal transportation system, including possible interim components for an accelerated start-up, with a focus on the Mackenzie Valley-Delta region.
- Analyse the technical feasibility of the system at an initial conceptual level.
- Discuss the implications on system design and its technical feasibility of rapidly changing ice conditions in the Arctic.
- Indicate what are the main technical challenges that might need addressing, and the innovations to solve them, to make this project more feasible.
- Make a first assessment of the social, political, and environmental contexts in which this project would unfold.

In addition, Canatec has decided to add a brief summary of:

- the main benefits of such a project to Alberta
- the potential for exporting through Churchill Manitoba.



## 4 MACKENZIE VALLEY PIPELINE

### 4.1 Route Options

There are 3 basic options for transporting Alberta Oil Sands product by pipeline to a northern port, which this chapter will examine (Ausenco, 2013):

1. Short pipeline from Fort McMurray to a barge transshipment terminal at Hay River
2. Use of existing pipeline infrastructure in the region, the Norman Wells – Zama line, but with a reverse flow
3. Building a new line all the way to the Arctic coast.

### 4.2 Flow Rate Scenarios

The table below enumerates the three flow rate scenarios which will be considered for this study. These rates are expected to span a useful set of options for delineating technical feasibility.

**Pipeline Design Throughputs for Bitumen and Diluent Return:**

Option	Flow Rate	Rationale	Bitumen	Diluent
<b>New Line</b>	Low	Seasonal Delivery	50,000 bbl/d	85 m <sup>3</sup> /h
<b>New Line</b>	High	Year Round Delivery	100,000 bbl/d	170 m <sup>3</sup> /h
<b>Incorporating Norman Wells Line</b>	Maximum	Pilot or Start-up	13,900 bbl/d	104 m <sup>3</sup> /h

### 4.3 Bitumen, Diluent and Dilbit

Bitumen, unlike petroleum from traditional oil wells, is a highly viscous fluid with an API gravity that can vary from 5° to 10° API. Due to its high viscosity it cannot be pumped by long distance pipeline in raw form and must be diluted with a lower viscosity fluid otherwise called a diluent, or heated to reduce viscosity. This study is based upon using diluent, and the diluent selected is diesel fuel.

This mixture of bitumen and diluent is referred to as dilbit. The characteristics of dilbit can vary depending on the source of the bitumen. For design purposes the dilbit characteristics for each case were chosen using typical bitumen physical properties.

Diluent is produced separately from bitumen and is usually shipped to the source of the bitumen. Diluent can be recycled to reduce costs. In this study, a diluent return pipeline parallels the dilbit line and allows diluent to be transported back to the bitumen source for reuse.

### 4.4 Basic Requirements for a Dilbit Pipeline

Dilbit viscosity varies greatly with temperature and the volume concentration of bitumen. Traditionally, an operating viscosity of 325 to 350 cP is required to produce a pipeline which is both technically and



economically feasible. To achieve the required viscosity and allow for a high volume concentration of bitumen to be transported, the dilbit may be heated before it is pumped through the pipeline and the remaining pipeline insulated and heat traced or reheated along the route.

For Option 1 and 3, the pipeline is assumed to be heat traced and an operating temperature of 65°C is maintained. For Option 2, which considers the existing Norman Wells line, the operating temperature is taken to be 0°C, which means that a significantly higher portion of diluent needs to be added to keep viscosity at acceptable levels, thereby lowering the percentage of bitumen that can be transported. While the direction of flow of the Norman Wells pipeline can be reversed to allow it to be incorporated into a south-north line, it would be better to consider it for the return of diluent and a new pipeline constructed for dilbit.

#### 4.4.1 Storage

Eight hours of storage was selected at the head and terminal stations. This separates the pipeline from the upstream and downstream process facilities and allows for unplanned shutdowns.

#### 4.4.2 Design Assumptions

The following tables summarize the physical properties of Bitumen and Diluent that are used as the basis for a conceptual pipeline design.

##### Bitumen Physical Properties:

Description	Value
Bitumen SG at 65°C	1.2
Bitumen Viscosity (cP at 65°C)	2900-4700
Bitumen Viscosity (cP at 0°C)	$8.4 \times 10^6$ - $4.6 \times 10^9$

##### Diluent Physical Properties:

Description	Value
Diluent Type	Diesel Oil
Diluent SG at 65°C	0.900
Diluent Viscosity (cP at 65°C)	2.75
Diluent Viscosity (cP at 0°C)	6
Corrosion Rate (mpy)	7

For the dilbit, mixture of diluent and bitumen, it has been found that an operating viscosity of approximately 325-350 cP is required for a technically and economically feasible pipeline design (Ausenco standard practice). Staying within this viscosity range and taking into account the operating temperature of the system, two different dilbit solutions were determined for this study.

For new pipeline sections, the pipeline is assumed to be insulated and to operate at a temperature of 65°C, allowing for a 75% Cv bitumen (25% Cv diluent) to be transported.

For the existing Norman-Wells pipeline, the design of this option is restricted to the constraints of the existing pipeline. The Norman Wells pipeline is not insulated and is designed to operate at 0°C allowing for an estimated maximum 40% Cv mixture of bitumen to be transported.

A summary of the dilbit physical properties is provided in the table below.

**Dilbit Physical Properties:**

Description	Value	Source
<b>Cargo Constant</b>	0.005	Ausenco Database
<b>Dilbit SG Cv 40% Bitumen</b>	1.02	Calculation
<b>Dilbit SG Cv 75% Bitumen</b>	1.12	Calculation
<b>Dilbit Viscosity (cP at 0°C, Cv 40% Bitumen)</b>	325	Calculation
<b>Dilbit Viscosity (cP at 65°C, Cv 75% Bitumen)</b>	325	Calculation
<b>Corrosion Rate (mpy)</b>	7	Ausenco Database

**Pipeline Properties**

The table below depicts supplemental pipeline design criteria for the bitumen and diluent pipelines.

**Pipeline Design Criteria:**

Description	Value
<b>Availability (%)</b>	92
<b>Design Live (years)</b>	25
<b>Minimum Burial Depth (m below surface)</b>	1

## **Pressure Loss Calculations**

For slurry operation, pressure loss calculations are based on the Colebrook Model.

## **Design Factors**

The following design factors will be implemented as part of the pipeline design:

Design Code: ANSI B31.14  
Line Pipe: API 5L  
Design Factor: 0.72 of Specified Minimum Yield Stress  
Transient Factors: 1.10

In addition, a hydraulic gradient safety factor of 12% for centrifugal pumps will be added to all bitumen and diluent pipeline design. A safety factor of 5% will be added to the pipeline length to account for variations in the length of the pipeline.

## **Design Pressure**

The design pressure of the pipelines will not exceed 150 bar (ANSI Class 900).

## **Pipeline Insulation**

As mentioned previously, new pipelines are assumed to be insulated to minimize temperature loss, but the existing Norman Wells line will remain as it is.

## **Pipeline**

Pipeline materials and construction are selected to optimize initial cost, operating cost, operating life, and hydraulic performance of the pipeline. The pipeline is designed to have adequate steel wall thickness to withstand the steady state slurry hydraulic gradient, and adequate static head when the line is shutdown on slurry. The wall thickness is preliminary and will be finalized in the basic design phase.

The recommended external pipeline corrosion coating is factory-applied three layer polyethylene.

The pipeline will be buried for security with a minimum 1.0 m depth of cover. The final depth of cover for this project can only be decided in the next phase.

Option1 (Fort McMurray to Hay River) assumes insulation to achieve an operating temperature of 65°C.

A summary of the recommended pipeline diameters and wall thicknesses for the dilbit and diluent return lines are shown in the following two tables.

### Summary of Pipeline Design for Option 1:

Option 1		Dilbit		Diluent	
Route	Flow Rate	Pipeline diameter	Avg Wall Thickness	Pipeline diameter	Avg Wall Thickness
McMurray-Hay River	Low	16 inches	0.436 inch	8.625 inches	0.259 inch

McMurray-Hay River	High	22 inches	0.371 inch	10.75 inches	0.316 inch
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Summary of Pipeline Design for Option 2:

Option 2		Dilbit		Diluent	
Route	Flow Rate	Pipeline diameter	Avg Wall Thickness	Pipeline diameter	Avg Wall Thickness
McMurray-Zama	Max Allowed	14 inches	0.360 inch	8.625 inches	0.294 inch
Norman W-Tuk	Max Allowed	24 inches	0.368 inch	8.625 inches	0.312 inch

Summary of Pipeline Option 3

Option 3		Dilbit		Diluent	
Route	Flow Rate	Pipeline diameter	Avg Wall Thickness	Pipeline diameter	Avg Wall Thickness
McMurray-Tuk	Low	22 inches	0.454 inch	10.750 inches	0.278 inch
McMurray-Tuk	High	26 inches	0.499 inch	14 inches	0.309 inch

## 4.5 Unique Arctic Considerations

In an arctic area, with the kind of terrain that will be encountered in this region, we note the following considerations as particularly important to consider for any pipeline, and especially for pipeline carrying oil from Alberta's oil sands:

### Temperature

The operating temperature of the bitumen pipeline is key to successful pipeline operation. In order to achieve an economical dilbit blend (high vol% of bitumen) the viscosity of the dilbit must be kept low. Maintaining a temperature of 65°C along the pipeline through heating and insulation and either heat

tracing or re-heat stations ensures that the pipeline temperature will not be greatly affected by outside temperature changes.

### **Melting of Permafrost**

If the pipeline is maintained at an elevated temperature there is a chance of melting the permafrost. Analysis of the soil temperature and frost depth along the pipeline route should be performed in order to assess the pipeline burial depth and thermal design requirements.

### **Pipeline Leakage**

Any oil pipeline should be equipped with a leak detection system. This system will monitor the length of the pipeline and initiate alarms if conditions associated with a leak are detected.

In addition to the monitoring system, the pipeline should be periodically inspected with an instrumented tool to detect pitting or corrosion in the pipe wall.

For added protection at river and road crossings the pipeline will be horizontally directionally drilled (HDD). HDD uses a directional drill rig to bore a hole from one side of the crossing deep beneath the river that will surface on the other side. This type of crossing protects the pipeline from scour of the river bed.

## **4.6 State of the Art**

The technical feasibility of bitumen pipelines has already been proven through the operation of several pipelines in the Alberta region. The Cold Lake pipeline transports approximately 535,000 b/d of bitumen from the Cold Lake deposits to Edmonton. It currently stretches 986 km and is expanding in the coming years.

The Corridor Pipeline is a 1,046 km long major bitumen pipeline that transports approximately 318,200 b/d from the Fort McMurray region to Edmonton.

Both of the above pipelines are fully operational under similar climate and environmental factors to what will be experienced by a line going to the Arctic coast.

Pipelines are used as a mode of transportation for many petroleum and natural gas projects. Both the Alliance and West Coast Pipeline systems are large networks of natural gas pipelines that transport gas from the Northern regions of Canada to as far as the US. The Alliance network has been in operation since 1997 and covers approximately 3,700km. Again, these pipelines are exposed to similar environmental conditions to those discussed in this report.

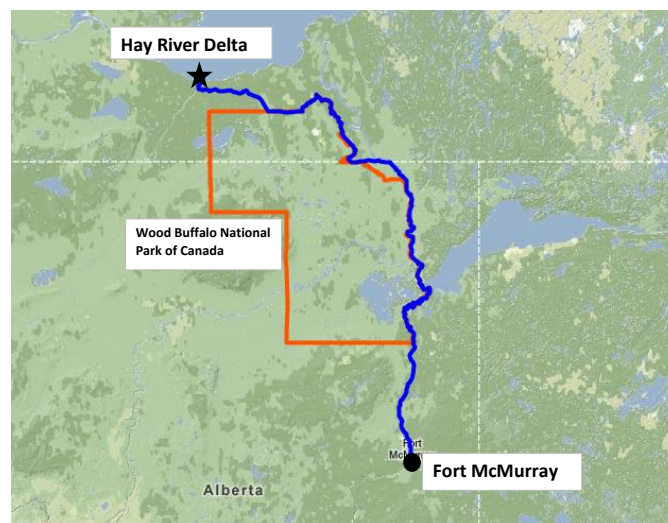
## **4.7 Routes**

Route selection was performed using Google Earth software and with the intention of minimizing both elevation change and overall pipeline length. Special attention was devoted to avoiding river and road

crossings. In addition, the routes were revised to avoid traversing sensitive habitat or designated environmental reserve areas such as the Wood Buffalo National Park. When possible, each of the pipeline routes parallels existing roads or rivers.

#### 4.7.1 Option 1 – Pilot or Seasonal Transportation System

This option is designed for a possible seasonal export project at low volumes, with a link to barge transport on the Mackenzie River. The pipeline starts from Fort McMurray, circles the Wood Buffalo National Park, and ends at the Hay River Delta where product will be stored for transshipment to barges. The route is approximately 822.5 km long. The following map depicts the proposed pipeline route for Option 1.



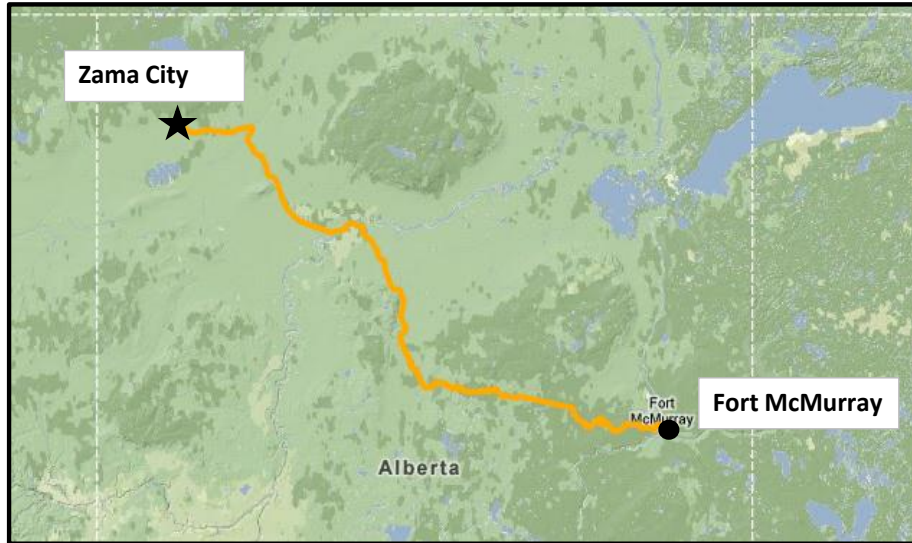
#### 4.7.2 Option 2 – Seasonal System using Existing Lines

Pipeline route Option 2 involves transportation via the existing Norman-Wells Pipeline and consists of three segments:

- A new pipeline from Fort McMurray to Zama City.
- Transport via the existing Norman-Wells Pipeline from Zama City to Norman Wells.
- A new pipeline from Norman Wells to Tuktoyaktuk.

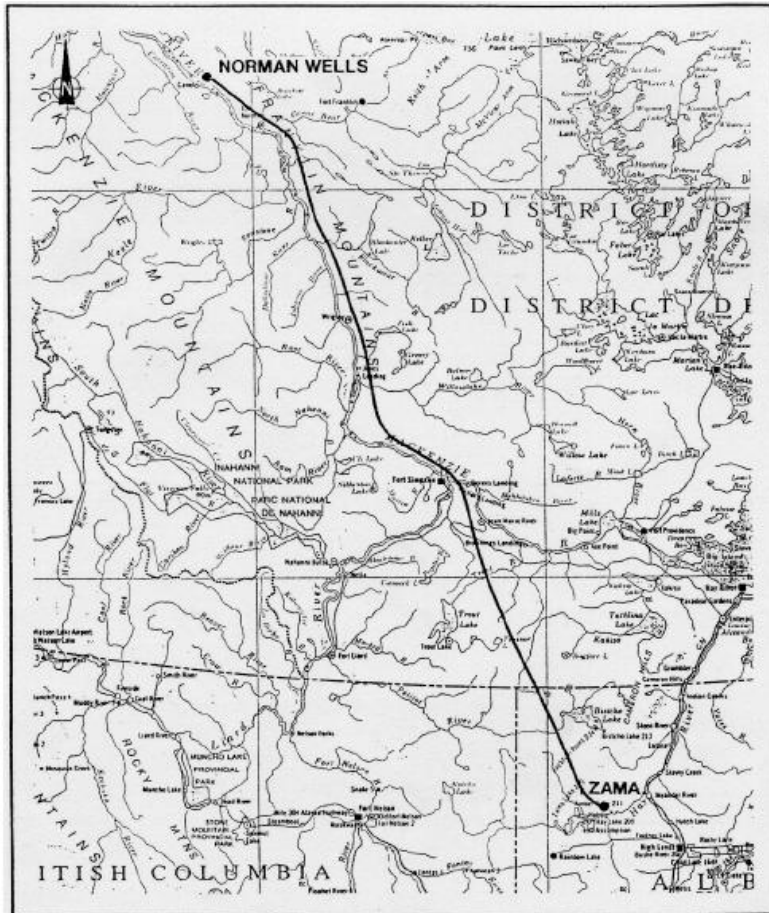
##### **Segment One**

The first leg of Option 2 starts at Fort McMurray, runs south of Wood Buffalo National Park, and ends at Zama City. The pipeline is approximately 680 km long. The following map depicts the proposed pipeline route for the first leg of Option 2.



### **Segment Two**

The Norman Wells - Zama pipeline (869 km) connects oilfields in the Northwest Territories with the North American pipeline grid. Construction began in 1983 and finished in 1985. The pipeline is 12 inches in diameter and carries 39,400 barrels per day (BPD) crude from a processing facility in Norman Wells, Northwest Territories, to Zama, Alberta. The existing pipeline has three pump stations and 20 remote valve sites and was designed to operate at 0°C. The pipeline is not insulated, is buried with about 1 m of soil cover, and passes through areas of discontinuous Arctic permafrost. A map of this line is shown below.



The Norman Wells-Zama pipeline must operate in reverse flow to transport bitumen or may be used in the current flow direction to transport diluent. If this existing Norman-Wells pipeline is used:

- Operating at 0°C limits the volume of bitumen that can be transported to 40%Cv or lower, by requiring a higher percentage of diluent
- Temperature of dilbit must be limited to 0°C to prevent melting of the permafrost
- Directional drilling or secondary containment may be necessary at river crossings.

### **Segment Three**

The third leg of option continues from the existing pipeline at Norman-Wells and ends at Tuktoyaktuk. This pipeline segment would be approximately 847 km long. The following map depicts the proposed route.

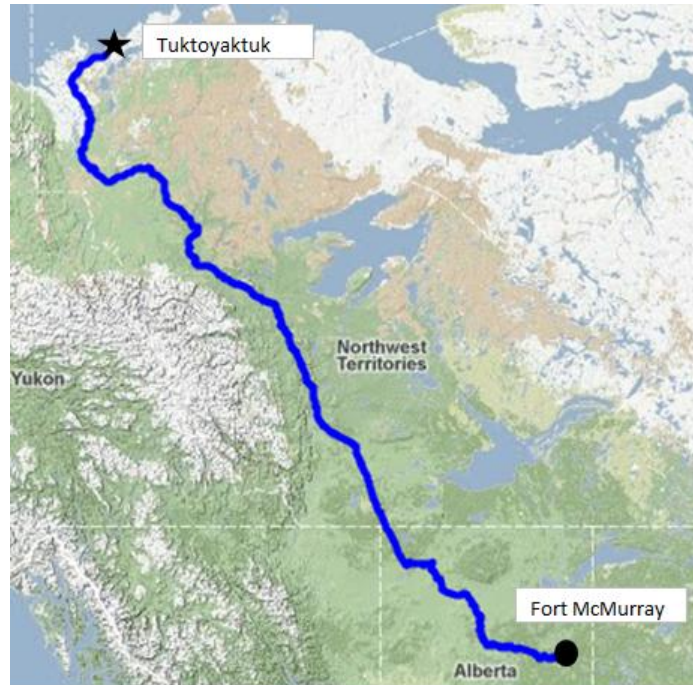




Note that we have chosen Tuktoyaktuk only for illustrative purposes. Following chapters will illustrate some of the other considerations that come into play for site selection of the northern terminal.

#### **4.7.3 Option 3 – New Line for Year Round Export**

This option considers a direct route from Fort McMurray to Tuktoyaktuk. It follows a similar route to that of Option 2, possibly paralleling the existing Norman Wells pipeline. Detailed study of the Norman Wells line location would be required to assess the feasibility of using the existing right of way. This pipeline route would be approximately 2,400 km in length. The following map depicts the proposed route.



Option 3 pipeline route

## 4.8 Implications of Climate Change

As mentioned previously, a leading factor in pipeline operation is maintaining the design temperature. This temperature is greatly affected by the outside temperature along the pipeline route. Overall, the pipeline will be buried below the frost depth and therefore protected from most outside climate changes.

A rise in ambient temperatures related to climate change would affect areas of thaw sensitive permafrost. In these areas the permafrost may thaw in the warm months and freeze during cold months. This cycle of thaw and freeze could potentially damage the pipeline causing it to leak or buckle. In the extreme case, soil that is now permanently frozen could thaw permanently. This could also result in damage to the pipeline.

Bitumen pipeline designs to accommodate rise in ambient temperatures are beyond the scope of this report. However, if the pipeline is buried in thaw sensitive permafrost that is subject to thawing due to massive climate change, there are design techniques available to provide security, such as designing the pipeline and external coating to have neutral buoyancy within the soil so that it will neither tend to sink nor rise in the surrounding soil water medium.

## 4.9 Conclusions

Based on the first level of analysis carried out for this prefeasibility study, all Options were found to be technically feasible.

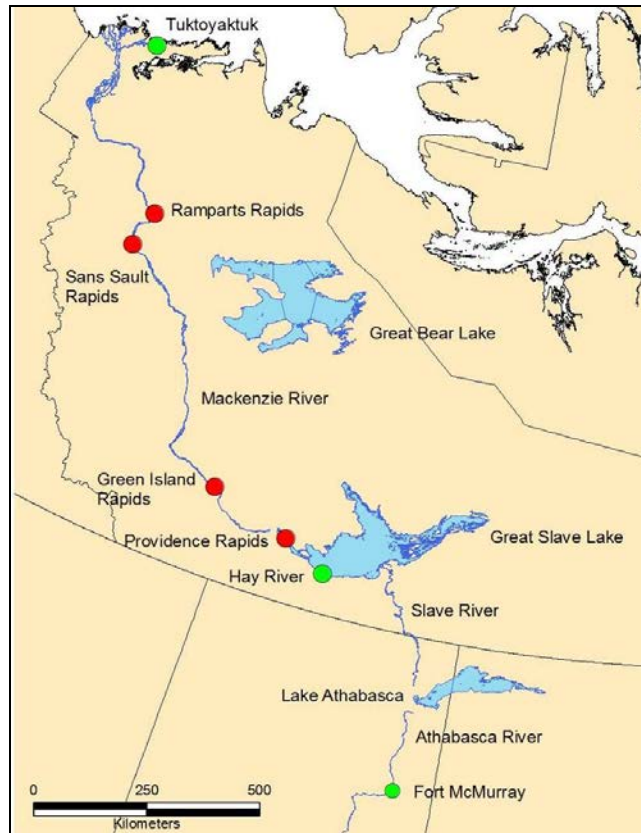
## **5 PIPELINE ALTERNATIVES AND COMPLEMENTS**

In this section a number of transport options are discussed to move bitumen north from Fort McMurray. They are barges, rail, and road. While it is generally agreed these modes are higher cost and less environmentally suitable than pipelines, they have a potential role to accelerate production and revenues while a pipeline is under construction. They are also important infrastructure that will assist the construction of a pipeline and terminal port facilities. In addition, they could be used to transport other petroleum products found along the transport route, supplies to operate the Arctic Energy Gateway, and essential logistics to support other resource development and settlement projects in the Western Arctic.

### **5.1 River**

#### **5.1.1 General Description**

The Mackenzie River system was an essential transportation route in the Western Arctic from before European settlement and continues to be so to this day. It has a vast drainage area equal to 20% of the area of Canada, with the Richardson and Mackenzie Mountains to the west, and the Great Bear and Great Slave Lakes to the east. Within this area there are 34 tributary river systems that feed into the Mackenzie, nine of which could be considered significant in size. The following map shows the principal rivers only, i.e. those which could support barge traffic for an Arctic Energy Gateway.



Because of this huge drainage area, the Mackenzie River flow is very much affected by weather systems, which change its water levels, ice conditions, and bathymetry. On average, the river discharges more than 325 cubic km of water each year into the Arctic Ocean, playing the major role in the local climate because of the huge amounts of warmer fresh water mixing with the colder seawater. For the most part the Mackenzie River is a broad, slow-moving waterway, whose elevation drops just 156 metres from source to mouth over its 1,705 km length from Great Slave Lake to the Beaufort Sea. It is navigable for commercial barge traffic along the whole of this length except for one reach which becomes too shallow for larger barges after mid-summer.

### 5.1.2 Terminals

Although there are river connections, there are currently no barge delivery systems between Fort McMurray and Hay River on a commercial basis, although this fluvial system has been used for intermittent transportation activities in the past.



Alberta tar sands along the Athabasca River (Source Wikipedia)

As the previous map indicates, an extension of the existing commercial transport system starting at Hay River would involve a marine extension along Great Slave Lake towards the mouth of the Slave River, moving south on the Athabasca River towards the junction with the Clearwater River and then towards Fort McMurray, an approximate distance of 500 nautical miles (926 km). This possible extension should be explored to avoid double handling of the product by rail or road. The main challenges are in water depth and rapids on the upper Slave River.

Using current barging systems, product would be moved from the Fort McMurray area via truck or pipeline to a Barge Loading Terminal located on the south shore of Great Slave Lake, probably at or near Hay River. The exact location of this southern Barge Terminal would depend on which mode of transport is selected. Loading could be accomplished by either a wharf/ship complex or some form of an offshore loading system from buoys to ice reinforced terminals. The land facilities would consist of storage tanks with appropriate capacity.

The same kind of infrastructure would exist at the northern Barge Terminal, likely located near Inuvik or Tuktoyaktuk. An exact location can be determined in a later stage depending on the achievable throughputs, storage requirements, and local conditions.

### 5.1.3 Barging

From the southern terminal, product could be loaded into specially constructed double-hulled (OPA 90) barges of approximately 12,000 barrel (bbl) capacity. These barges would be pushed by specifically constructed Shallow Draft Tugs (3) of about 5.5 MW power and 40 to 45 tonnes Bollard pull. Assuming a standard river barge configuration of 6 units (72,000 bbl), this “tow” would take approximately 7 days (2,037 km)) to arrive in an area around Tuktoyaktuk for offloading. A “light tow” return (i.e. south-bound) trip normally takes up to 12 days to Hay River. The following photograph shows a typical barge setup.



Under normal conditions, barging can begin at Hay River around 01 June but, when strong east winds prevail, ice pile-up in the river mouth can delay the start until 10 June. Even though the average potential shipping season is estimated to be 137 days, ice jams at the outlet of Great Slave Lake, weather conditions, and low late season water levels usually result in a shorter actual shipping season. Barge companies generally prepare loading in early May, start loading in mid-May, and start barging in early June. Timing of the shipment is important, since water levels are generally higher at the start of the operating season, allowing greater drafting depth, and thus heavier barge loading.

Draft of the barges is an important factor. A 1500-series barge, the largest used (80 x 20 m) can take over 2,000 tons of cargo on deck or 20 rail cars worth of bulk fuel below deck or a combination of both. At this weight, the draft is five feet (1.5 m) of water but, for the shallower waters of September, crews usually load them to just four feet (1.2 m). Higher water levels allow for greater barge loads, but bring other disadvantages, e.g. debris from spring runoff takes out buoys, clogs propellers, and piles up in front of the barges.

There is reasonable installed capacity for transportation at this time. Barge companies on the Mackenzie River include Horizon North Logistics, who have built 6 new Barges in China; Cooper Barging, who have three shallow-draft tugs from 800 hp to 1450 hp, 9 deck-cargo barges up to 50 m long, 13.7 m wide, and a major landing/storage yard at Fort Simpson; and Northern Transportation Co. Ltd. (NTCL) as the largest company with an extensive fleet (est. +50 Bulk Capable Flat Barges). However, it may be desirable to construct new barges specifically for the purpose of the Arctic Energy Gateway. Barge construction can be done rapidly.

The tows need to get split up at four spots when going down-river to go through rapids. The most significant hazards on the river are the Providence, Green Island, Sans Sault, and Ramparts Rapids. The transit through Providence Rapids has, on average, resulted in the most damage to equipment over the years. It is a narrow, twisty channel for navigation and currents in the channel range from 5 to 9 knots. The towboats are generally limited to relaying just two loaded barges at a time through this section going downstream, and three to four empty barges going upstream. The Sans Sault Rapids consist of boulder shallows with water depths between 1.2 and 2.4 m. The current at Sans Sault is in the order of 3 to 4 knots. The Ramparts includes a drop over a rock ledge that extends over a distance of about 450 m, through which current flows at 5 to 6 knots. The water depth over the ledge is as little as 1.8 to 2.4 m at low water. The Ramparts also represent delay due to the necessity of relaying one or two barges at

a time. The Ramparts become very challenging during a low water year and, on occasion, one of NTCL's best performing river boats will be stationed at the Ramparts just to shuttle barges while the other towboats work the rest of the River. The shallowest depth at Ramparts Rapids falls below the drafting depth of 1.98 m for the latter half of the navigation season and subsequently falls below the drafting depth of 1.22 m in late August. To extend the barging season, dredging of sections like this might be advisable.

#### 5.1.4 Unique Aspects of Bitumen Transport

With existing barges, it would be necessary to dilute the bitumen. The diluent would be carried back to the southern terminal on the return trip. However, the bulk of the cargo carried by barge might be enough to retain much of the heat of the dilbit (diluent and bitumen mix), keeping it at sufficient low viscosity for the trip north, and thereby to allow for lower percentages of diluent to be added than the standard 25 – 55% needed for pipelines. This would allow for better economics, as the barges would be carrying more exportable cargo per load.

If custom-made barges were available, heating and insulating could be built in, thereby allowing for carriage of bitumen, with significantly better economics. This type of analysis can be made in a more detailed feasibility study.

#### 5.1.5 Extensions to the Shipping Season

The standard barge season is set at 140 days based on present equipment. An extension to this season could be made by

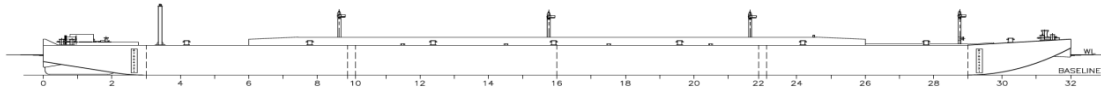
- Using ice-strengthened barges with an adjusted shape
- Increasing the power for the pusher tugs
- Considering deploying icebreakers to assist the fleets through the worst ice areas
- Considering running in convoys to make maximum use of pre-broken channels
- Conducting a small degree of dredging at discrete locations
- Making more effective use of the early break-up and late season closure dates as was done in the Beaufort Sea by the construction spreads in the 1980s.

In comparison with other frozen rivers and lakes, much directly relevant experience has been gained on Russian rivers emptying into the Arctic basin. In addition, two of such shallow draft icebreakers were used by one of the authors (Jolles) in Caspian Sea operations, in support of Kazakhstan offshore drilling programs in ice. Water depth was somewhat greater, however, in various instances ice had grown to the bottom and these shallow draft icebreakers with multiple propellers and equipped with an air bubbler system made operations possible throughout the entire winter.

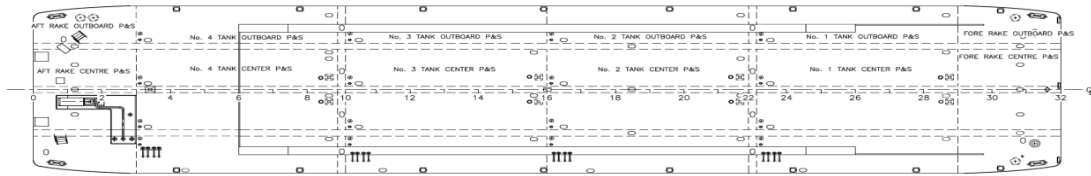
#### 5.1.6 Transport Scenarios

Calculations make use of the NTCL series 1500 barges and IT current barge dimensions as shown in the following illustration and tables.

**NT 1500A SERIES MULTI PRODUCT BARGE**  
OIL/DECK BARGE



**OUTBOARD PROFILE**



**PLAN AT MAIN DECK**



Barge Series	Qty	Type	Length (m)	Breadth (m)	Depth (m)	Light Draft (m)	River Draft (m)	River DWT (tonnes)	Maximum Draft (m)	Maximum DWT (tonnes)
<b>1500</b>	28	Deck/Bulk	76.2	17.1	2.90	0.53	1.52	1,300	2.15	2,190
<b>1050</b>	1	Deck/Bulk	65.9	14.9	3.05	0.56	1.52	960	2.20	1,730
<b>1030</b>	3	Bulk	61.0	14.6	2.95	0.38	1.52	1,010	2.00	1,270
<b>1000</b>	24	Deck/Bulk	61.0	15.2	2.29	0.46	1.52	990	1.80	1,005
<b>820</b>	2	Deck/Bulk	53.4	15.2	2.36	0.36	1.52	885	1.70	1,020
<b>800</b>	11	Deck/Bulk	48.8	14.6	2.95	0.38	1.52	810	1.90	930
<b>750</b>	3	Deck/Bulk	59.24	12.2	2.0	0.37	1.52	825	1.60	849
<b>700</b>	2	24 Man Camp	47.3	13.7	2.16	0.81	1.52	-	1.52	-
<b>600</b>	16	Deck/Bulk	45.7	10.7	2.03	0.36	1.52	560	1.60	607

NTCL 1500 series barge specifications.

**Tank Barges of Island Tug and Barge**

Barge identification	Length	Beam	Capacity
<b>Island Trader</b>	369 ft (112.5 m)	69 ft (21.0 m)	65,000 bbl
<b>ITB 38</b>	270 ft (82.3 m)	60 ft (18.3 m)	38,000 bbl
<b>Empire 45</b>	225 ft (68.6 m)	58 (17.7 m)	23,000 bbl
<b>ITB Pioneer</b>	200 (61.0 m)	50 (15.2 m)	16,000 bbl
<b>ITB Vancouver</b>	252 (76.8 m)	60 (18.3 m)	25,000 bbl



<b>ITB Provider</b>	198 (60.4 m)	54 (16.4 m)	15,000 bbl
<b>ITB 2</b>	170 (51.8 m)	48 (14.6 m)	10,000 bbl

Based on above data of existing barges and the following assumptions, we can calculate approximate throughputs that can be achieved for a transport system from Hay River to Tuktoyaktuk.

**Assumptions for Barge transport scenario:**

Assumptions	Values/Results	Notes
<b>Speed heading north</b>	7 knots	Barges are moved in sets of 6
<b>Standard Barge Capacity</b>	12,000 bbl	Double hulled
<b>Enlarged Barge</b>	15% increased capacity	
<b>Season Duration</b>	140 days	Extended season of 175 days

**Estimated Barge Throughput:**

Barge configuration	Throughput (bbl/day)	Throughput (bbl/year)
<b>Standard barge</b>	990	138,600
<b>6 Barges/Transport</b>	5,930	831,600
<b>6 Enlarged Barges</b>	6,820	1,193,550*

\* 175-day extended season

### 5.1.7 Conclusion

Based on the above conceptual assessment, 7 new spreads of 6 barges each are required for 50,000 bbl/day, which is considered technically feasible for a seasonal operation. In a follow up phase detailed design work will be required to optimize the barges and the pushers and to maximize the possible throughput.

## 5.2 Rail

### 5.2.1 Existing and Proposed Rail Systems

Sass (2011) reported on various new rail acquisitions made by CN in Alberta with investments totalling \$5 million for infrastructure improvements for a leg from Boyle to Fort McMurray, which was the fourth

of such expansions. The company had, in 2006, purchased the Mackenzie Northern and Lakeland & Waterway lines, which run to Hay River from Smith north of Edmonton. These lines have also been upgraded at a total of \$58 million. This line carries agricultural and forest products as well as fuel and supplies transhipped at Hay River to be barged down the Mackenzie River.

Road, rail, and barge transport often work together. Southern Pacific has plans to ship about 12,000 bbl/d of bitumen through a combination of trucks and then rail car to the U.S. Southern Pacific's bitumen volumes will be trucked approximately 60 km from the STP-McKay plant gate to Lynton, Alberta, a CN rail terminal located immediately south of Fort McMurray. From Lynton, volumes will be transferred into rail cars and shipped approximately 4,500 km over CN's network and a short-line rail partner to a terminal in Natchez, Mississippi. The bitumen will then be transferred to barges that will deliver the product as feedstock to refineries on the Gulf Coast. Diluent savings are achieved on two fronts. The amount of process diluent required at the plant site will be significantly lower than what is required to meet pipeline specifications. By transporting bitumen via CN, Southern Pacific will only require process diluent to blend with its bitumen, thus lowering the total diluent requirements by approximately 33 per cent. Secondly, Southern Pacific has the opportunity to backhaul lower priced diluent from the Gulf Coast utilizing its empty return rail cars (CN, 2012).

MEG Energy is also planning to use rail tank cars and barges. Late in 2013, unit trains with up to 118 tank cars are planned to leave Bruderheim, Alberta, daily on either Canadian National or Canadian Pacific tracks, bound for Chicago, where the oil will be transferred into U.S. pipelines or loaded onto river barges (Cooper, 2013). MEG's production should climb to more than 40,000 bbl/d in 2013 and double by 2015 when Christina Lake expansion begins.

The Financial Post, 2012, reported that discussions were underway between Alberta producers, the Port of Churchill (Manitoba), railway companies, and refiners on the East Coast and the Gulf Coast, to collect unrefined oil by rail from fields across Western Canada, get it to the port on the west coast of Hudson Bay and load it on Panamax-class tankers.

Russia is planning to build an 800 km rail line called the Northern Latitude Route to connect oil and gas lines in Siberia to offshore fields and loading points (Barents Nova, 2013).

The Alberta government has indicated it is considering spending \$10-million to study building a new railway to deliver landlocked oil to an Alaska port (BullFAX.COM, 2013).

The EnSys Energy study for the Keystone pipeline (EnSys, 2010) includes many details of pipeline as well as rail, barge, and tanker transport. The authors reported an ability to produce 1,250 bbl/d in the Western Canadian Sedimentary basin. Shipping dilbit via barge or tanker requires no special facilities. Shipping raw oilsands bitumen can be undertaken by effecting limited modifications. Both barges and tankers would need to be fitted with oil heating systems that can maintain the higher temperatures needed to keep raw bitumen liquid. Tank insulation would also generally be undertaken depending on the assessed heat savings. Suitably outfitted barges and tankers would thus be able to ship oilsands bitumen and eliminate the diluent that comprises 25-30% of dilbit. As with rail, the saving is avoided

diluent shipping (and back-haul) costs would more than offset the additional equipment and heat costs on a per barrel of bitumen basis.

At a June 2011 conference, a group named G Seven Generations Ltd (G7G) mapped out a proposal to build a new rail line, potentially from Fort McMurray, cross-border to Alaska to link in to the Trans Alaskan Pipeline System (TAPS) at Delta Junction (see also: Vickers, 2011). The WCSB crude would take advantage of spare capacity on the TAPS pipeline. It would use the lower section of the line down to the port of Valdez (which also has spare capacity) whence the crude would be shipped by tanker. Claimed advantages are that the line would be able to carry oil but also a range of commodities, that the route would eliminate the need for shipping via Kitimat, and that the proposal already has the support of First Nations groups in B.C. and the Yukon; also from Alaskan native groups along the route. Conversely, the project would entail building more than 2,000 km (1,200 miles) of new rail line northwest from Fort McMurray to join the Alaska Pipeline (part of the TAPS, which carries oil to the Valdez oil terminal) at Delta Junction, Alaska. The project's first phase is estimated to cost \$12 billion or more, i.e. approximately double that projected for the Northern Gateway pipeline.



Concept for linking Fort McMurray to Trans-Alaska Pipeline System (after G7G)

### 5.2.2 Advantages and Disadvantages of Rail

An advantage of rail over pipeline transport is that the cost for returning the diluent is very low as the tanker cars carry the diluent back to the source. For short legs such as we envisage, diluent may not be

required and heated rail cars are feasible, likewise for barges. Rail cars can carry between 550 and 680 barrels depending on the product and rail type. Capacity of pure bitumen in an insulated coal car, for example, is 550 barrels. Trains have capacity for about 60,000 barrels of bitumen and do not need to run full. Shippers only pay for what they use when they use it. Five trains can carry the equivalent of a 400,000-barrel-per-day pipeline.

Rail is generally safer than road transport, has much higher throughput, and lower shipping costs. However, roads are cheaper and faster to construct, can be made to have less environmental impact, and are easier to maintain. In conditions of global climate change causing major hydrological effects and permafrost melting, foundation problems in rail transport might end up causing major safety and environmental problems, requiring expensive maintenance and design standards.

A detailed analysis of all technical, economic, social, and environmental factors is required to choose between these different modes. Considering only the transport of bitumen blend, our view is that rail and road would end up being options only for the segment between Fort McMurray and Hay River, where product would be transferred to barges.

### **5.2.3 Conclusion**

We conclude that rail transport is a technically feasible option, for all of our throughput options.

## **5.3 Road**

### **5.3.1 Tanker Trucks**

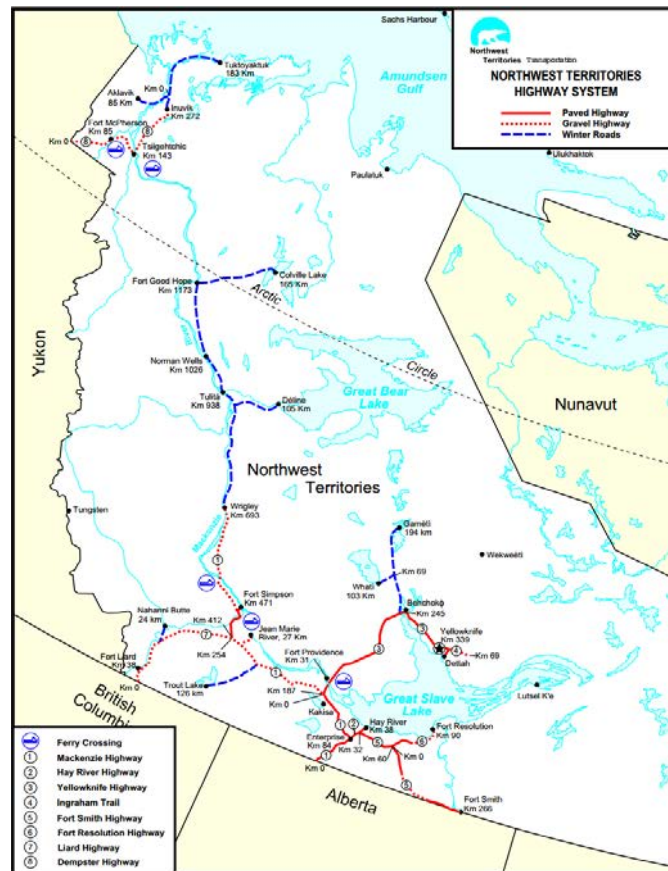
It is technically feasible to transport dilbit by tanker truck. Southern Pacific reported that, on 24 October 2012, the first load of dilbit was hauled by truck to an Alberta market. Since then, approximately 9,000 barrels of dilbit have been hauled to several local markets. Southern Pacific will continue to deliver its dilbit volumes to Alberta markets until such time as its rail marketing arrangement, announced on 27 June 2012, is ready to commence transporting volumes to the U.S. Gulf Coast.

A typical tanker truck carries approximately 200 barrels of product. Special purpose tanker trucks have been built to carry up to 715 barrels. A truck can travel a maximum of about 800 km/day. Considering weather limitations, seasonal road restrictions, darkness limitations and maintenance, about 400 of these large tankers (1,500 standard tankers) would be required to achieve a throughput of 150,000 bbl/d. While entirely feasible from a technical point of view, the much higher cost per barrel-km of trucking, and the much higher safety and environmental risks make this option seem useful only for the Fort McMurray-Hay River segment, for offloading to barges.

On the safety side, the American Petroleum Institute (2011) reported that trucking has a degree of risk of spilling that is 5 times higher than that of pipelines.

### 5.3.2 Road Network

Using tanker trucks will require a seasonal or all-weather road network. This is the other present limitation in considering trucking all the way from Fort McMurray to Tuktoyaktuk; the highway network is not complete in the NWT. From Fort McMurray, there is an all weather road up to Hay Rive and on to Yellowknife, but this does not go further north. Trucks today need to take a much longer route through northern B.C. and the Yukon, but only in the winter can they get to Tuktoyaktuk, using an ice road for the leg from Inuvik. The following map shows existing and planned roads in the NWT. Like road networks everywhere, northern routes are expanding; it is planned that the Inuvik-Tuktoyaktuk extension will begin construction by the decade's end.



### 5.3.3 Conclusion

There is widespread experience in Arctic regions to show it is entirely feasible from a technical point of view to construct an all-weather, all-season road through the Mackenzie Valley and use tanker trucks to transport petroleum products.

## 5.4 Multimodal Considerations

River, road, and rail components are fully feasible from a technical point of view. However, their safety, seasonal, and volumetric limitations mean they are more likely to be considered as low volume, interim alternatives to a dedicated pipeline. More detailed analysis will shed light on what kind of multimodal system shall be preferred, using road, rail, and river for specific segments that would optimize economics and environmental acceptability.

## 6 PORT AND OFFLOADING TERMINAL

### 6.1 Port Facilities for Logistics Support

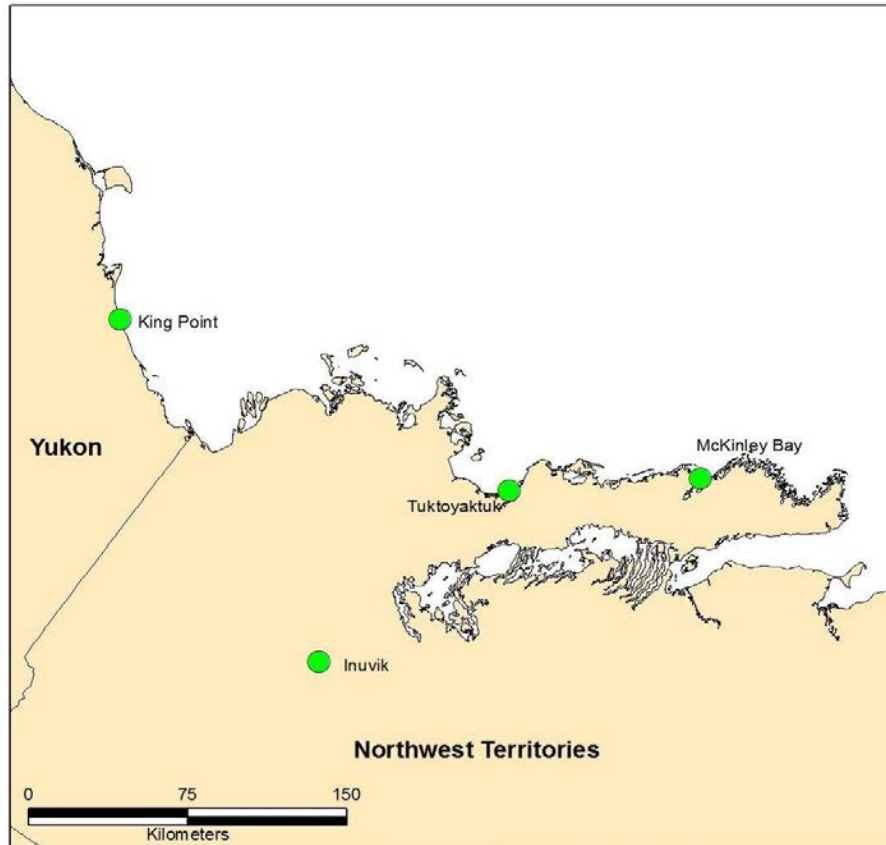
In order to support construction and operations, a port will be required. The photo below shows the Tuktoyaktuk-Base Camp and marine terminal used in the 1980s by Dome Petroleum's CANMAR subsidiary. This port operated fully only in summer and shoulder seasons. However, there are several examples of Arctic ports in Russia that operate year-round, such as Dudinka on the Yenisei, Siberia's biggest river. Many ships transit year-round to ship copper and nickel ores from the Yenisei to the port of Murmansk.



Canadian Marine Drilling Ltd. Tuktoyaktuk base camp

Substantial dredging and port construction has taken place in Russian Arctic waters, the Caspian Sea, and other ice-bound areas. This includes wharves, piers, infrastructure, pipelines, and shore approaches, with ice management as required.

Tuktoyaktuk is a good option, as developed facilities exist. Other possible locations are Inuvik and McKinley Bay. The advantage of Inuvik is that it lies at the end of the all weather, all season Dempster Highway to the south, and is serviced by regular airlines. McKinley Bay is a sheltered anchorage requiring a dredged access channel and mooring basin. It was dredged and used by the offshore petroleum industry in the early 1980s and has good potential for mooring vessels. King Bay in the Yukon Territory is also possible. These sites are located in the following map.



To provide continuity to all transportation and ensure all such movements occur safely and in an environmentally sound way, port facilities must support:

- Reception of river barges
- Storage of dilbit, facilities for separating diluent from bitumen, heating the bitumen and pumping product into the receiving tankers
- Storage of diluent and pumping back into southbound pipeline or barges
- Services to alongside moorage of vessels or a single point loading for the receiving shuttle tankers
- Vessel navigation
- Inspection and maintenance
- Integrated monitoring and forecasting
- Environmental monitoring
- Employment and training.

For the purposes of this study, it is not important to make a choice among these candidate site, since this does not affect technical feasibility. Choice of a port is more affected by political, social, environmental, and economic factors. Given that large, complex logistics and petrochemical treatment



activities will take place, analysis of the best location to carry them out is extremely important, but outside the scope of our initial study. Treatment of dilbit, bitumen, and diluent are all well established procedures that have been worked out in the Fort McMurray area, which operates in a winter temperature regime very similar to that of the Beaufort coast.

## 6.2 Storage

If barging is used instead of a pipeline, then we are assuming a seasonal system which will require large storage facilities at the marine export site. Even with a pipeline, storage will be required in order to have sufficient cargo that can be transferred rapidly to tankers. The size of this storage facility will be determined mostly by the length of the transport season of the most limited component and the daily throughput desired.

### 6.2.1 Marine Storage

Storage in dedicated tankers is used around the world, and the tankers so used are commonly referred to as “Floating Storage and Offloading” (FSO) units. In various areas of Russian offshore production, FSOs are used, although in ice conditions that are substantially less severe than in the Beaufort. The figure below shows one such FSO, the *Belokamenka*.



The *Belokamenka* is stationed at the Varandey Offshore Terminal in Kola Bay, near Murmansk, Russia, on the coast of the Barents Sea near Norway. The *Belokamenka* handles in excess of 4 million tonnes of crude oil per year. The Varandey Terminal's capacity has recently been expanded from 30,000 bbl/d to approximately 150,000 bbl/d. For both the Varandey and Prirazlomnoye fields, Russian shipper Sovcomflot has five Panamax (70,000 DWT) Arctic Class-6 shuttle tankers engaged in the service.

In regard to the feasibility of using floating storage in the Beaufort Sea, we note that it has already been proven in principle. During the active drilling seasons in the mid 1980s, a tanker, the *Skauvan*, was used by Gulf Canada. *Skauvan* stayed in the Beaufort and was anchored in the landfast ice. The vessel

overwintered safely and successfully. Precautions were taken in the early spring to prevent a case of ice early breakout.

Based on this example, one has to conclude that floating storage is technically feasible for the Beaufort region. All depends on the required storage volume. The tanker location will be limited to a water depth in the 10-15 m range, so it will be located in the middle of the normal landfast ice zone. The tanker floating storage can be considered for a seasonal production or a year-round production. Cost comparison with land storage scenarios will be required to verify the most economical and technically feasible concept.

### 6.2.2 Land Storage

On-land petroleum storage in cold climates is used in several locations:

- The De-Kastri terminal in East Russia (see following Section) provides storage and a SPM tanker loading facility that can accommodate year-round crude oil export to world markets. The terminal includes two 100,000 cubic meters (650,000 bbl) capacity storage tanks to hold the Sakhalin-1 crude oil prior to tanker transfer and shipment. Tankers are Aframax with 110,000 DWT capacity.
- Another Russian East Coast example is the on-land storage for crude oil in Aniva Bay (see following Section), the southernmost bay on Sakhalin island. Here, only thin ice is encountered and the tanker loads off a loading tower.
- The Pechora Sea offloading tower is connected to onshore storage units of 325,000 cubic meters and the terminal receives tankers of 70,000 DWT to offload the cargo.

Therefore the conclusion is drawn that on-land storage is feasible when connected to an offshore loading system.

## 6.3 Loading Facilities

Loading of ocean-going, deep-water, tankers will require shore facilities beyond the outlet channels of the Mackenzie River. Tuktoyaktuk is too small and shallow for this and Inuvik is only a very small river port. Shore facilities would be more feasible in a dredged McKinley Bay or as one past study (DIAND, 1986) proposed, King Point in the Yukon Territory.

More likely for the Delta area, an offshore loading terminal will be used to accommodate the greater drafts of the transport tankers. For a typical (CAC 2) tanker of 40,000 DWT that we might envisage (Johansson et al., 1994), the maximum draft would be 16 m, which would put a terminal typically in the middle of the landfast ice zone. Depending on the localized ice conditions, this location may need to be moved to slightly deeper depth to move into the shear zone ice rather than the landfast ice zone. The former may be better for the offloading and accessibility, while the latter could result in lower total ice loads. Both water depths for location of an offloading tower are considered feasible.

A subsea pipeline will be required from the shore to the loading platform. The pipe will be trenched below the seabed to protect from the effects of ice scouring. Sufficient experience has been gained in several areas, such that this aspect can also be labelled feasible. Potentially, the terminal could be connected into the other offshore fields in this region.

The technology for offshore loading facilities in ice is well proven. Examples include Exxon Neftegaz's tanker offshore loading tower at De Kastri on the Russian Pacific coast, the transshipment to Arctic tankers taking oil from the Varandey terminal in the Pechora Sea, and transshipment activities in the Port of Murmansk.

Several loading terminals are shown below, two composed of single loading towers and one loading from a production unit. The loading towers shown are located in relatively light ice conditions compared to a Beaufort Sea location, where the annual maximum ice thickness is greater (1.8 m) and ridges are much more severe. This consideration does not affect our assessment of feasibility; these are well known engineering design considerations involving structure and foundations. Conceptual design of such systems is being undertaken at the present time by several petroleum companies involved with the Amauligak field development in this same region. The following picture shows the installation at Sakhalin-1. As of July 2011, the Sakhalin-1 Consortium had loaded over 400 tankers from the De-Kastri Terminal, operated by Exxon, without a single spill incident. The terminal is designed to handle Aframax tankers of 110,000 DWT.



The next picture shows a very similar installation at Sakhalin-2. The oil export line is a 30 inch (762 mm) x 4.8 km line, running from the oil export terminal (OET) landfall to the tanker loading unit (TLU) rated for 50,000 bbl/d. (Sakhalin Energy, 2012)



The Varandey terminal shown in the next picture (Lukoil, 2012) is piled into the ocean bottom and is able to resist 2 m thick ice. The annual throughput is about 12 million tonnes.



Next, we show another type of loading platform. This is the Sakhalin-2 single buoy mooring unit for connection of the FSU and offloading tanker in ice. In the distance one can see the production platform *Molikpaq* and attending icebreaker.



Finally, in the following sketch, we show the Pechora loading terminal with transshipment in Murmansk to open water tankers. The tanker offloading details include an oil loading hose of 30-inch (762 mm), capable of rates of 63 KBP/hr. The tankers are a Class 1A Super and carry 70,000 DWT (Ship-Technology.com, 2012; Offshore-mag.com, 2012).



In conclusion, offshore loading towers can be regarded as safe and environmentally sound, in conjunction with onshore storage. Aspects like foundation design, offshore loading, and monitoring, as well as maintenance, will need to be fully considered for the safe operation of such systems.

As a next step after this prefeasibility study, one would need to look at water depth, frequency of barges and vessels (production throughput), safe moorage in ice and open water, and the ice impact in order to move ahead on the location and design of a terminal.

## 7 OCEAN TANKERS

### 7.1 Introduction to Ice and Shipping

To understand marine transport routes in the Arctic it is necessary to make a brief presentation on ice types and hazards, and ship classification regulations.

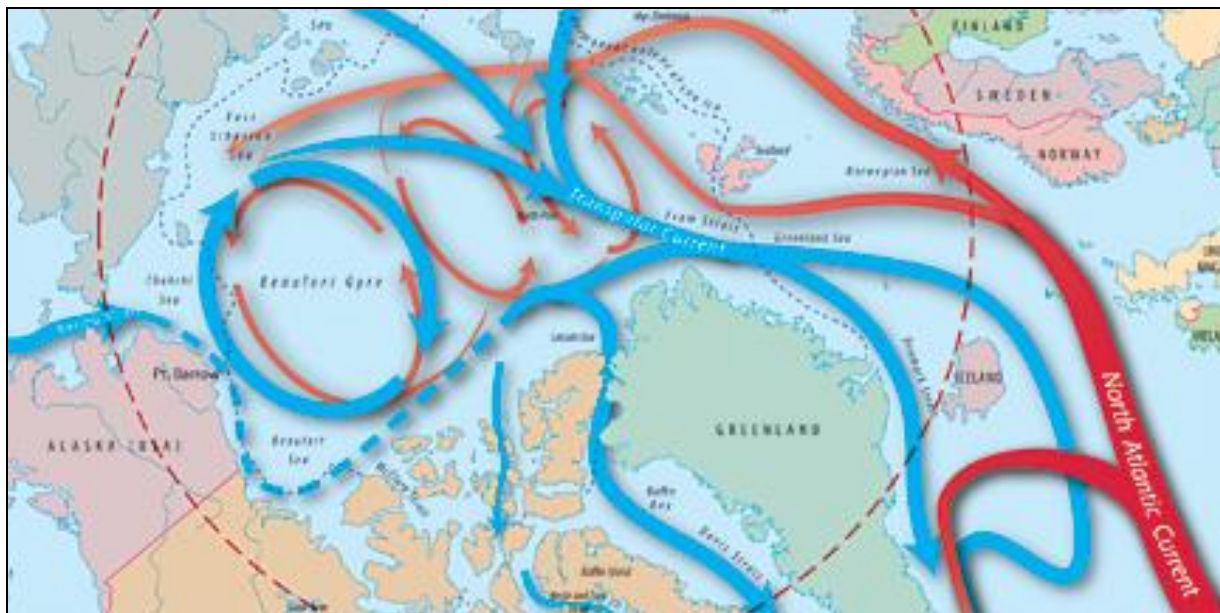
#### 7.1.1 Sea-Ice

There is a great deal of discussion in popular media about thinning of the Arctic ice cover. For port design, loading terminal operation and ship navigational purposes through ice, there are many other properties that must be considered. The main characteristics of sea ice are codified by the World Meteorological Organization (WMO, 1985). For our purposes in this report, we summarize the following, to aid non-specialist readers in understanding this unusual and complex environment.

- **Concentration** – This is a fractional expression (in tenths) of the amount of an area that is covered by ice. At low concentrations, (0- to 2-tenths), most ships can proceed with caution, to avoid impact on isolated ice floes, and reduce speed, especially at night, so that any impact will have minimal effect.
- **Thickness** – Undeformed sea-ice is typically about 1.8 m thick at its maximum thickness. Thickness is, however, highly variable, following the local freeze – thaw trend. The period with the maximum thickness does not last very long and, soon after, melt pools and warming will occur. This in turn will weaken the ice, although the thickness will remain for some time. The thicker the ice, the more difficult it is for ships to break, the slower they progress, the more energy they must expend and the stronger the hull must be, all increasing cost.
- **Age** – ice that has formed in the current year is not only relatively thin, but it is also relatively weak as much of its internal structure is filled with pockets of brine, or concentrated sea water. Ice that survives the summer without melting is significantly lower in brine content, and so is harder. By a third year, this type of ice (by this point called multi-year) is much more consolidated and much harder still, capable of generating very high impact loads on vessels. In this report we will use the term “old” to group both second year and multiyear ice.
- **Ridging** – Ice in the Arctic Ocean is highly mobile, moving around the entire Arctic basin in a multiyear rotation, following the ocean circulation below. As it moves, the ice undergoes extensive ridging, which is caused by different sheets running into each other. Ridges may be many tens of metres deep, entirely impassible by ships. If they survive the summer melt season, they become highly consolidated and even thin ridges of a metre or two represent formidable obstacles for icebreakers.
- **Multi-year hummock fields** – These features are formed by the pressure of ice movement against coastlines. Basically, they are massive fields of multi-year ice ridges, which can be many tens of km in extent. They periodically break free and drift in the general circulation of the Arctic Ocean.

- Pressure fields – Even thin first-year ice, if subject to a strong, continuous, onshore wind, can create conditions where the most powerful icebreakers are beset, due to the intense ice pressures generated against the hull.
- Ice jams - Such pressure fields can cause intense pile-ups of ice in constricted channels, which are then rendered impassible.
- Leads – Wind force and currents can drag ice sheets apart. This is very common in break-up and freeze-up seasons. It means that ice cover can be highly unstable, with open water areas forming within hours and extending for hundreds of km. These features offer extremely important opportunities for ships to make quick progress, if the opening and closing can be accurately forecast.

The Arctic Ocean is characterized by a strong and consistent circulatory pattern, dominated by a single feature called the Beaufort Gyre, which rotates the whole western ocean mass in a general clockwise direction. The Bering Strait is an inflow and water flows out in currents around Iceland. This is generally driven by large-scale, long lived wind patterns; when they do reverse, occasionally, the whole circulation can reverse or take temporarily, very different local forms. On the European/Russian side, the North Atlantic Current (the tail end of the Gulf Stream) brings warm water in to Russia and melt the ice there. Unfortunately for us in Canada, only cold water flows along the Canadian Archipelago coast and sweeps the ice against this shoreline where it jams up and creates the above-mentioned very large, thick, hard, consolidated multi-year ridges and hummock fields that make polar navigation so problematic. This general pattern is shown in the following diagram.



Arctic basin ice circulation (after Woods Hole Oceanographic Institute).

### 7.1.2 Ice Islands

In the Beaufort Sea and channels of the Arctic Archipelago, there are occasional incursions of ice islands. These are formed by the break-off of ice from the ice shelves of Ellesmere Island and, to a lesser extent, Greenland. These shelves are thought to be very old, up to 3,000 or 4,000 years, but in the past century have undergone dramatic reduction in size. In recent decades, there has been a significant acceleration of this type of ice shelf break-up, liberating annually hundreds of features of many tens of km in dimension. They are fresh water ice, and thus extremely hard, and can be up to more than 100 m thick. Ice Islands represent a major hazard for fixed offshore petroleum installations, but since they are relatively few in number and easy to track, they are not a major hazard for shipping.

### 7.1.3 Glacial Ice

The distinctive ice feature of this region is icebergs, formed by calving off glaciers. Glacial ice is quite different than sea-ice in its location, formation, and impact on shipping. The glaciers are both on the Canadian and the Greenland side of Baffin Bay/Davis Strait. The glaciers in this region are all fed from massive ice fields flowing out to the ocean. Greenland is almost entirely covered by an enormously thick ice cap, second in volume only to the entire continent of Antarctica. The ice fields feeding the glaciers in Greenland are more than 10 times larger by volume than those on the Canadian side, in the Queen Elizabeth Islands, but it is still important to consider the Canadian glaciers for shipping hazards, because they are liberated just north of where the Northwest Passage lies.

Icebergs are highly concentrated in a narrow band of water from shore to about 15 km offshore, by the current system and because they are calved from coastal glaciers. The following photo shows this narrow but intense “iceberg highway,” with a glacier in the background, calving more icebergs.



Once this narrow band is passed, the concentration of glaciers drops by perhaps 100 times towards the middle of Baffin Bay (Canatec field observations and Valeur et al., 1997).

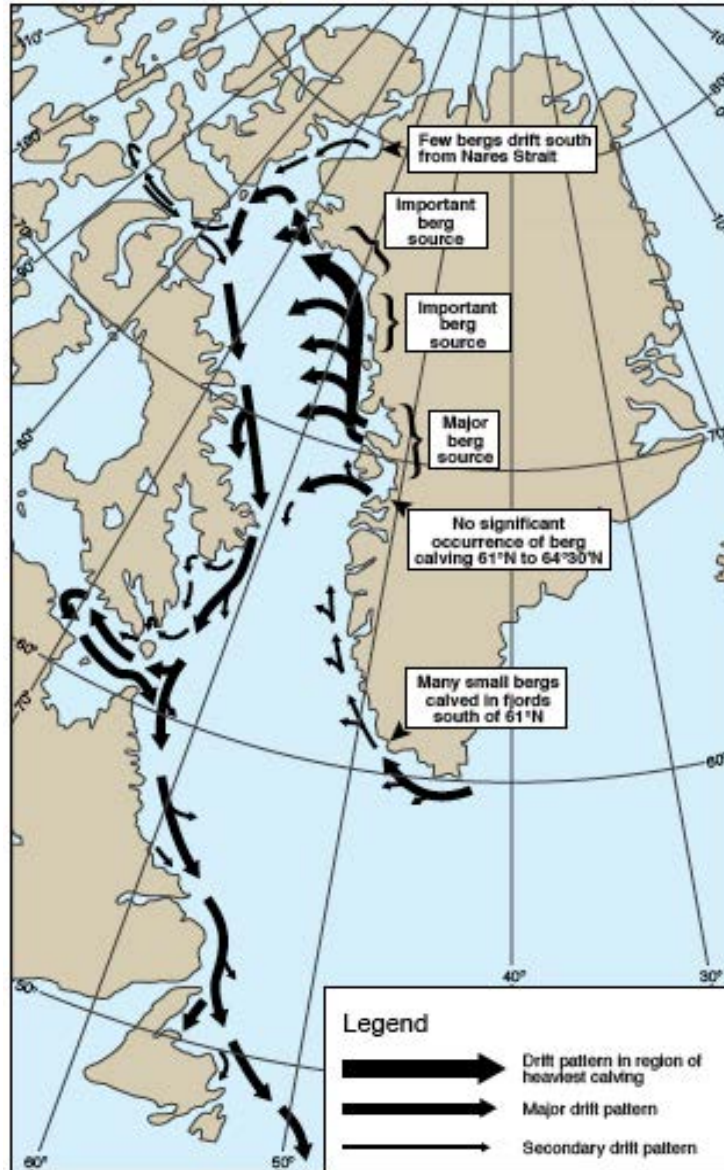
During the summer and autumn, after calving, the iceberg is carried seawards from the fjord. Icebergs drift all year, however are slowed in winter due to pack ice forming in Baffin Bay. When this sea ice deteriorates, icebergs will move more freely. Rates of motion along the Greenland coast are 3-5 nautical miles per day so that total drift before freeze-up will vary from 200 to about 600 nautical miles (Valeur



et al. 1997). Survival rates during the open water season are low; only about 1 in 5 of all bergs survives long enough to pass Kap York; naturally the large bergs are the survivors (Valeur et al. 1997). Taking water temperatures and drift rates into account, it becomes apparent that most of the survivors reaching Canadian waters south of Baffin Bay will come from more southerly Greenland glaciers between Kap York and Upernavik, and in general, only the very large bergs from Disko Bay reach Canadian waters in Davis Strait unless they are diverted directly westward from Greenland's coast.

The sea ice and iceberg environment of Baffin Bay is conditioned by the ocean circulatory patterns of this basin, which is completely different than the Arctic Ocean. It is connected to the Arctic Ocean only by a few narrow channels to the north and west, while it is fully open in the south to the Atlantic Ocean. The currents are strong and stable, coming in from the southern tip of Greenland and hugging the Greenland west coast all the way up to the top of Davis Strait and Baffin Bay, then going down the Canadian side all the way to Labrador and Newfoundland. The current coming in is warm, the current going out is cold.

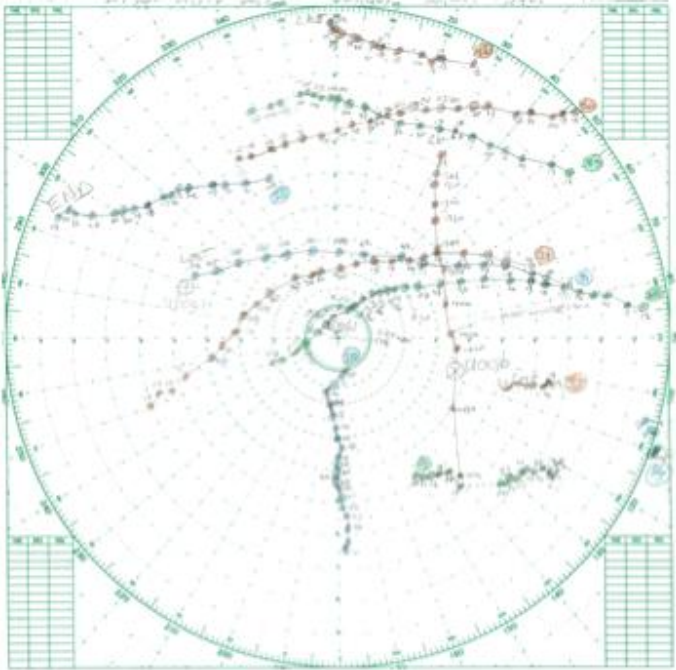
The glaciers that flow to the sea in Greenland are annually the source of hundreds of thousands of icebergs. These icebergs follow the currents from south to north up to the top of Baffin Bay and then start moving south along the Canadian coast. The following map displays this general circulation of icebergs.



Near the coast, they drift at about 1.3 knots with the current; out of this current, they meander, and do so at much lower speeds (0.3 knot). Data are very limited on icebergs this far north, but studies suggest that there may be 25,000 to 40,000 icebergs per year passing through; by the time they get to the northern part of Newfoundland, there are only from 4,000 to 8,000 per year. There is continuous attrition along this southern voyage. As the icebergs drift, they melt in summer and undergo continuous fracturing, which reduces their size and number. Many ground in fjords along the coast.

Icebergs average about one million tonnes in size in the northern region. However, as they decay, they produce swarms of smaller features. Smaller icebergs are known as *berg bits*; the smallest features (about the size of a car) are known as *growlers*. The smaller these features become, the more rapidly

they melt. However, they can be hazardous to shipping right down to the growler size, especially in heavy seas with limited visibility where wave motion not only obscures them but adds to their peak velocities on impact. Growlers are influenced by wind-driven currents, while icebergs, being much deeper in draft, are influenced by the general oceanographic current movement. This means they behave in very different ways as the following plot shows. In it we see a set of tracks for icebergs moving east to west in a uniform manner, but crossing them, is a growler track, from north to south, completely perpendicular in movement.



The following photograph shows a typical growler field.



Despite their reputation and appearance, icebergs are not technically difficult to deal with. Even with these high numbers, they represent only a tiny fraction of the sea surface and, as indicated above, they are concentrated in a relatively narrow band along the coastline. They can be tracked by marine radar, satellite, and aircraft quite accurately and the larger ones can be continuously identified. Since they move slowly and their drift can be predicted fairly well up to half a day in advance, ships with the right radars and exercising proper caution can navigate at reasonable speed and with acceptable safety margins in iceberg fields. Good experience has been gained over the last few years with special ice marine radars, used by many ships off the Greenland coast and other areas as well.

Commercial shipping has plied this region for over 25 years without a single iceberg incident. For this reason, icebergs do not enter into the regulatory classification systems that control ship design and operations in Arctic areas – only sea-ice is involved, as explained in the following section.

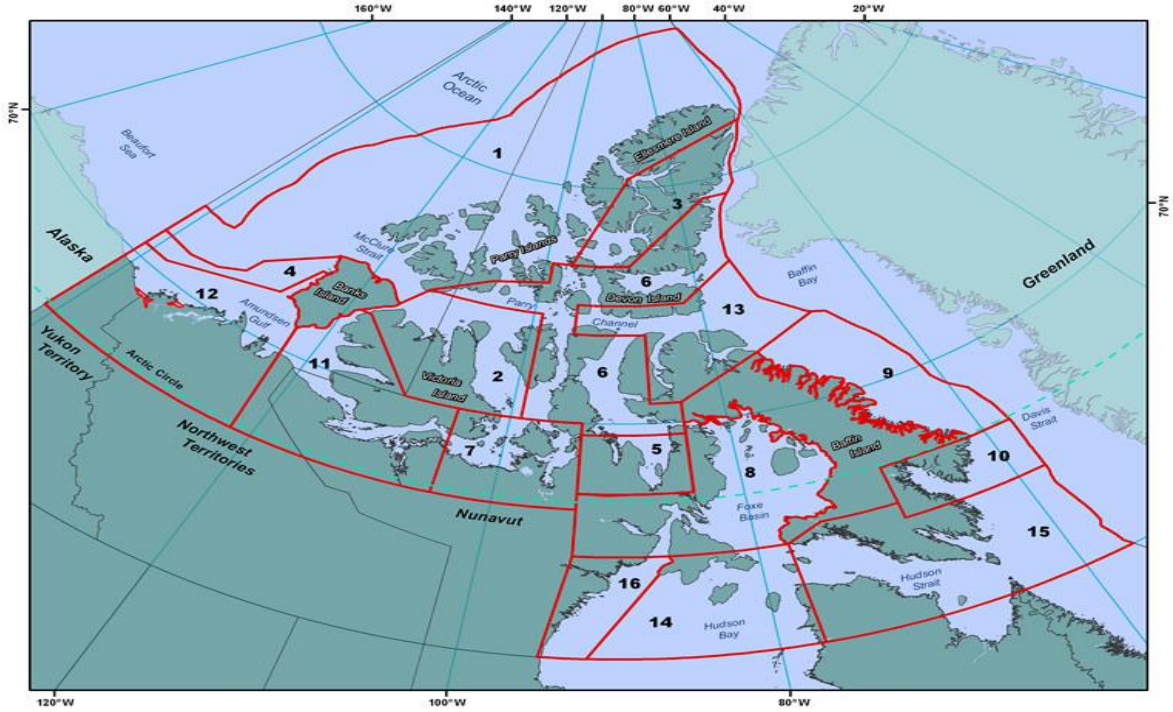
#### **7.1.4 Classification Systems for Ships Operating in Arctic Ice**

To ensure safe shipping, the entire Arctic is regulated by national and international codes of ship classification in terms of the hull's ability to withstand ice impact forces and the machinery to drive and control the vessel. There are different systems for each national jurisdiction and by different ship classification societies. There is only limited correspondence among these different classification systems at the moment; they reflect different national or commercial priorities. For example, Finnish criteria are driven by the need for maintenance of ship speed in ice with an underlying objective of maintenance of continuity of trade during the winter season in the Baltic. The Canadian criteria are driven by a need to limit the potential risks of hull and machinery system damage with an underlying philosophy/objective of prevention of pollution due to ship damage. As the potential for more intense Arctic shipping becomes more recognized, agencies are beginning to promote the development of a unified scheme, but at present, this is in evolution only.

For the purposes of this study, we will focus on the Canadian system. First, we explain the ice classification system, which is built from two distinct parts:

- The Zone-Date system (ASPPR)
- The Arctic Ice Regime Shipping System (AIRSS).

The ice Zone-Date classification scheme is based on the type of ice parameters indicated above. It is called ASPPR, or Arctic Shipping Pollution and Prevention Regulations (Transport Canada<sup>a</sup>, 2010), and is enshrined in law. For each zone, shipping seasons and ship entry and exit dates are prescribed, for different classes of vessels. The zone map is shown below, followed by the table indicating dates of entry for different types of ships. Zones are numbered 1 through 16, with severity of ice decreasing with higher zone numbers.



Arctic Shipping Pollution Prevention Regulation ice zones

Item	Col. I	Col. II	Col. III	Col. IV	Col. V	Col. VI	Col. VII	Col. VIII	Col. IX	Col. X	Col. XI	Col. XII	Col. XIII	Col. XIV	Col. XV	Col. XVI	Col. XVII
Category	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Zone 11	Zone 12	Zone 13	Zone 14	Zone 15	Zone 16	
1. Arctic Class 10	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year
2. Arctic Class 8	July 1 to Oct. 15	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year
3. Arctic Class 7	Aug. 1 to Sept. 30	Aug. 1 to Nov. 30	July 1 to Dec. 31	July 1 to Dec. 15	July 1 to Dec. 15	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year
4. Arctic Class 6	Aug. 15 to Sept. 15	Aug. 1 to Oct. 31	July 15 to Nov. 30	July 15 to Nov. 30	Aug. 1 to Oct. 15	July 15 to Feb. 28	July 1 to Mar. 31	July 1 to Mar. 31	All Year	All Year	July 1 to Mar. 31	All Year	All Year	All Year	All Year	All Year	All Year
5. Arctic Class 4	Aug. 15 to Sept. 15	Aug. 15 to Oct. 15	July 15 to Oct. 31	July 15 to Nov. 15	Aug. 15 to Sept. 30	July 20 to Dec. 31	July 15 to Jan. 15	July 15 to Jan. 15	July 10 to Mar. 31	July 10 to Feb. 28	July 5 to Jan. 15	June 1 to Jan. 31	June 1 to Feb. 15	June 15 to Feb. 15	June 15 to Mar. 15	June 15 to Feb. 15	June 1 to Feb. 15
6. Arctic Class 5	Aug. 20 to Sept. 15	Aug. 20 to Sept. 30	July 25 to Oct. 15	July 20 to Nov. 5	Aug. 20 to Sept. 25	Aug. 1 to Nov. 30	July 20 to Dec. 15	July 20 to Dec. 31	July 20 to Jan. 20	July 20 to Jan. 25	July 15 to Dec. 15	July 5 to Dec. 31	June 10 to Dec. 31	June 10 to Jan. 10	June 20 to Jan. 31	June 20 to Jan. 10	June 5 to Jan. 10
7. Arctic Class 2	No Entry	No Entry	Aug. 15 to Sept. 30	Aug. 1 to Oct. 31	No Entry	Aug. 15 to Nov. 20	Aug. 1 to Nov. 20	Aug. 1 to Nov. 30	Aug. 1 to Dec. 20	Aug. 1 to Dec. 20	July 25 to Dec. 20	July 10 to Nov. 20	June 15 to Dec. 5	June 25 to Nov. 22	June 25 to Dec. 10	June 25 to Dec. 20	June 10 to Dec. 10
8. Arctic Class 1A	No Entry	No Entry	Aug. 20 to Sept. 15	Aug. 20 to Sept. 30	No Entry	Aug. 25 to Oct. 31	Aug. 10 to Nov. 5	Aug. 10 to Nov. 20	Aug. 10 to Dec. 10	Aug. 1 to Dec. 10	July 15 to Nov. 10	July 1 to Nov. 10	July 15 to Oct. 31	July 1 to Nov. 30	July 1 to Dec. 10	July 1 to Dec. 10	June 20 to Nov. 30
9. Arctic Class 1	No Entry	No Entry	No Entry	No Entry	No Entry	Aug. 25 to Sept. 30	Aug. 10 to Oct. 15	Aug. 10 to Oct. 31	Aug. 10 to Oct. 31	Aug. 1 to Oct. 31	July 15 to Oct. 20	July 1 to Oct. 31	July 15 to Oct. 15	July 1 to Nov. 30	July 1 to Nov. 30	July 1 to Nov. 30	June 20 to Nov. 15
10. Type A	No Entry	No Entry	Aug. 20 to Sept. 10	Aug. 20 to Sept. 20	No Entry	Aug. 15 to Oct. 15	Aug. 1 to Oct. 25	Aug. 1 to Nov. 10	Aug. 1 to Nov. 20	Aug. 1 to Nov. 20	July 25 to Nov. 20	July 10 to Oct. 31	June 15 to Nov. 10	June 25 to Oct. 22	June 25 to Nov. 30	June 25 to Dec. 5	June 20 to Nov. 20
11. Type B	No Entry	No Entry	Aug. 20 to Sept. 5	Aug. 20 to Sept. 15	No Entry	Aug. 25 to Sept. 30	Aug. 10 to Oct. 15	Aug. 10 to Oct. 31	Aug. 10 to Oct. 31	Aug. 1 to Oct. 31	July 15 to Oct. 20	July 1 to Oct. 25	July 15 to Oct. 15	July 1 to Nov. 30	July 1 to Nov. 30	July 1 to Nov. 30	June 20 to Nov. 10
12. Type C	No Entry	No Entry	No Entry	No Entry	No Entry	Aug. 25 to Sept. 25	Aug. 10 to Oct. 10	Aug. 10 to Oct. 25	Aug. 10 to Oct. 25	Aug. 1 to Oct. 25	July 15 to Oct. 15	July 1 to Oct. 25	July 15 to Oct. 10	July 1 to Nov. 25	July 1 to Nov. 25	July 1 to Nov. 25	June 20 to Nov. 10
13. Type D	No Entry	No Entry	No Entry	No Entry	No Entry	No Entry	Aug. 10 to Oct. 5	Aug. 15 to Oct. 20	Aug. 15 to Oct. 20	Aug. 5 to Oct. 20	July 15 to Oct. 10	July 1 to Oct. 20	July 30 to Sept. 30	July 10 to Nov. 10	July 5 to Nov. 10	July 1 to Nov. 10	July 1 to Oct. 31
14. Type E	No Entry	No Entry	No Entry	No Entry	No Entry	No Entry	Aug. 10 to Sept. 30	Aug. 20 to Oct. 20	Aug. 20 to Oct. 15	Aug. 10 to Oct. 20	Aug. 10 to Sept. 30	July 15 to Oct. 20	July 1 to Oct. 20	Aug. 15 to Sept. 20	July 20 to Oct. 31	July 20 to Nov. 5	July 1 to Oct. 31

Table of entry criteria for ASPPR ice zones.

The Zone-Date System has been shown to be too simplistic and restrictive, so it is being augmented by the second system mentioned, the Arctic Ice Regime Shipping System (AIRSS) (Transport Canada<sup>b</sup>, 2010), where a vessel's access to a given zone is determined by the **actual** ice conditions at the time of transit. Use is made of ice charts provided by the Canadian Ice Service and points are given to each of the ice types found en route based on the ice class of the vessel. The total mark for all ice conditions met in each of the areas is used to calculate dates for access. Icebreaker support can be added as well. By using actual conditions and more detail, it is more realistic, less restrictive and safer.

Note in the table above that the ASPPR zones are keyed to a vessel Class classification scheme which uses 14 different classes of vessels based on power and strength. In this table, we see two different classification systems for ships being used. These are the Type system, from A to E, and the Arctic Class, from 1 to 10. Like the ice zone system, these are being replaced, by the Canadian Arctic Class (CAC) System, which has only 4 levels.

In the following sections, the report will refer to ships in terms of how they fit these ice classes by the two systems most currently in use: Type (A through D) and CAC (1-4).

For completeness and for comparison only with ships in service in other ice covered waters, reference is made in the below Table to Polar Class and other regulations.

Ice Type	Typical ice thickness	Classes used in this report
Year round operation in all polar waters	>3 m	CAC 1
Year round operation in moderate multiyear ice conditions	3 m	CAC 2
Year round operation in second year ice with old year ice incursions	2.5 m	CAC 3
Year round operation in thick first year ice which may contain old year ice incursions	>1.2 m	CAC 4
Year round operation in medium first year ice with old year ice inclusions	1.2 - .7 m	Type A
Summer/autumn operation in thin first year ice with old ice inclusions	.7 m	Type B
First year ice	.5 m	Type C
First year ice	.4 m	Type D

## 7.2 Vessels in Arctic Service

This chapter refers to vessel size in DWT, or deadweight tonnes, which measures the total carrying capacity. There are many different classes of ships that carry petroleum. To convert to barrels of petroleum carried, we present the following table with the different classes referred to in this chapter. Since barrels is a volumetric measurement and petroleum comes in a variety of densities (which vary by temperature), there is a significant variation in this correspondence: we have chosen approximate figures for illustrative purposes of 1 tonne equaling about 7 barrels.

Ship Class	Typical/Average DWT	Average bbl equivalent
Handysize	25,000	175,000
Handymax	45,000	315,000
Panamax	80,000	560,000
Aframax	100,000	700,000
Suezmax	150,000	1,050,000
VLCC	250,000	1,750,000
ULCC	>300,000	2,100,000

### 7.2.1 Canadian Icebreakers

With a focus on the Great Lakes and the St. Lawrence/East Coast shipping zones, the Canadian Coast Guard (CCG) has only minor resources to spare for the Eastern Arctic and for the Western Arctic. There is only one Light Duty vessel, the CCGS *Sir Wilfrid Laurier*. She is only available for summer Arctic operations from early July to mid-October (109 day season). The icebreakers CCGS *Louis S. St-Laurent* and the CCGS *Terry Fox* are scheduled for decommissioning in 2017 and 2020 respectively, and there is only slow advance in the government's plans to build replacements. Therefore charters of foreign (Russian and Swedish) icebreakers for Canadian Arctic projects are now, and will continue to be in the foreseeable future, required. The following photograph shows a Swedish icebreaker in use off Greenland, supporting offshore petroleum activities.





## 7.2.2 Commercial Vessels Operating in the Arctic

There are many vessels operating in the Arctic. Here are some highlights of new vessels that are relevant to an Arctic Energy Gateway:

- The Motor Tankers *Mastera* and the *Tempera* are 106,200 dwt Aframax crude oil tankers operated by Neste Shipping, and are the first ships to utilize a sophisticated double acting tanker (DAT) concept, developed by Aker Arctic, for icebreaking operation. The two icebreaking tankers are used to transport crude oil year round from the Russian oil terminal in Primorsk to Neste Oil refineries in Finland.
- Russian mining company Norilsk Nickel operates four new series of ships that are the world's first container ships built to Arc7 class standards. The new double-acting hull form and Arctic container vessels will be used to transport metallurgical products from Dudinka on the Yenisei River, in Siberia, to Murmansk, in European Russia. These vessels are propelled by a single 13 MW Azipod unit, and are 169 m in length and 23.1 m wide. They have a draught of 9 m for winter deployment under heavy ice conditions, and a deadweight of 14,500 dwt. In summer, the draught is 10 m and 18,000 dwt. The gross tonnage is 16,486 t.
- The 70,000 ton tanker *Vasily Dinkov*, of the Russian tanker operator Sovcomflot, was built in South Korea and operates as a shuttle tanker, moving oil from the Varandey Arctic terminal, on the Pechora Sea coast, to Murmansk, where the cargoes are forwarded into more traditional tankers. The diesel electric vessel is powered by two 11,200 kW and one 4,200 kW generators distributed to two azipod drives, enabling her to break up to 1.5 m of ice at a speed of 3 knots either forward or astern, and carry 85,300 m<sup>3</sup> of cargo.



Year round mining in Northern Labrador is supported by the Fednav-operated ore carrier *Umiak*, shown below. She carries 31,992 DWT and sails to Voisey's Bay to the INCO mines.

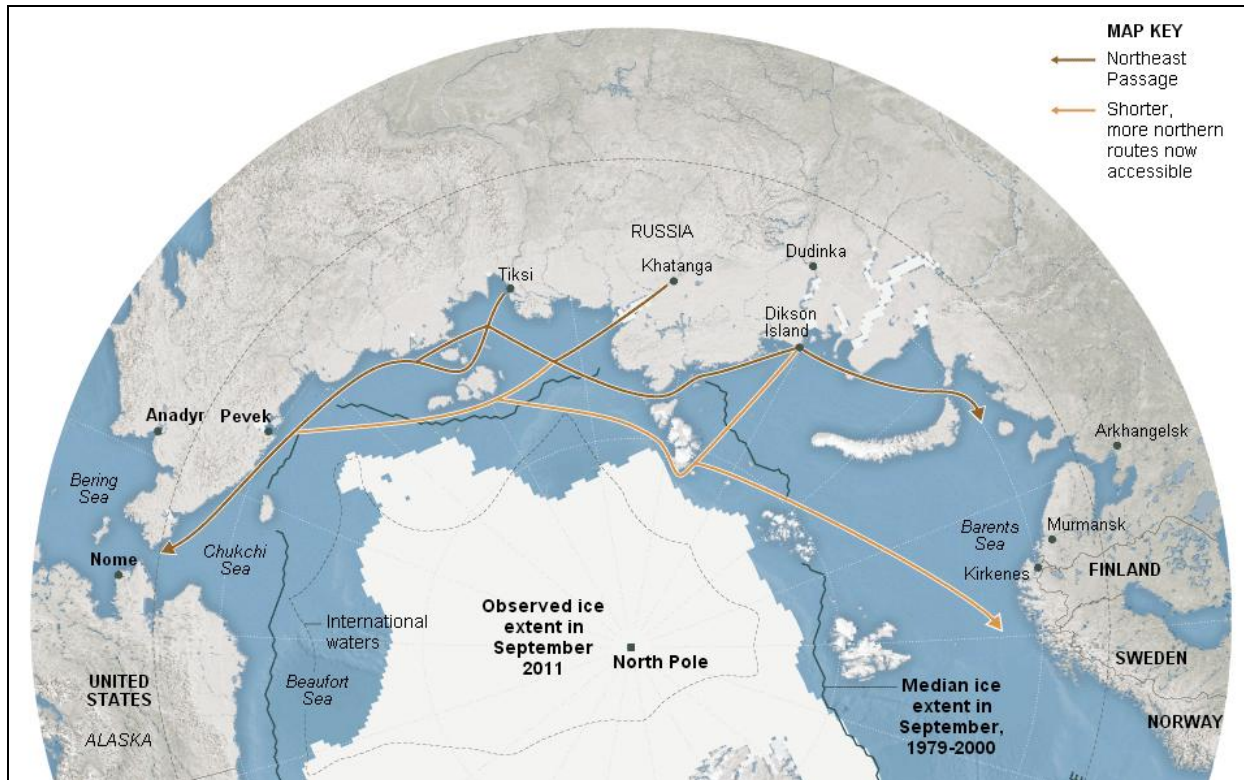


In 2013 a new icebreaking bulk carrier will join the *Umiak*, to ship products directly from a mine in northern Quebec, in the Nunavik region from the Raglan complex to Europe (Bryant, 2013).

### 7.3 Current Shipping Routes in the Arctic

Navigating the Arctic has been technically feasible, at least in summer months, for almost a century.

The Northern Sea Route (NSR) over Russia has much less severe ice conditions than the Northwest Passage (NWP), through the Canadian Arctic Archipelago, and it is already open to commercial traffic, on a limited scale. Russian routes are now well established as the following map indicates.



<http://www.nytimes.com/interactive/2011/10/18/business/the-northeast-passage-opens-up.html>

In 2011, traffic along the NSR doubled over that of 2010. The 160,000 ton Suezmax-class super tanker *Vladimir Tikhonov* conducted its summer 2011 transit at a speed of 14 knots, which is the highest yet seen. The *Ob River* liquefied natural gas (LNG) carrier shown below chartered by Gazprom Group completed the world's first LNG supply via the NSR in November 2012 (Gazprom, 2012).

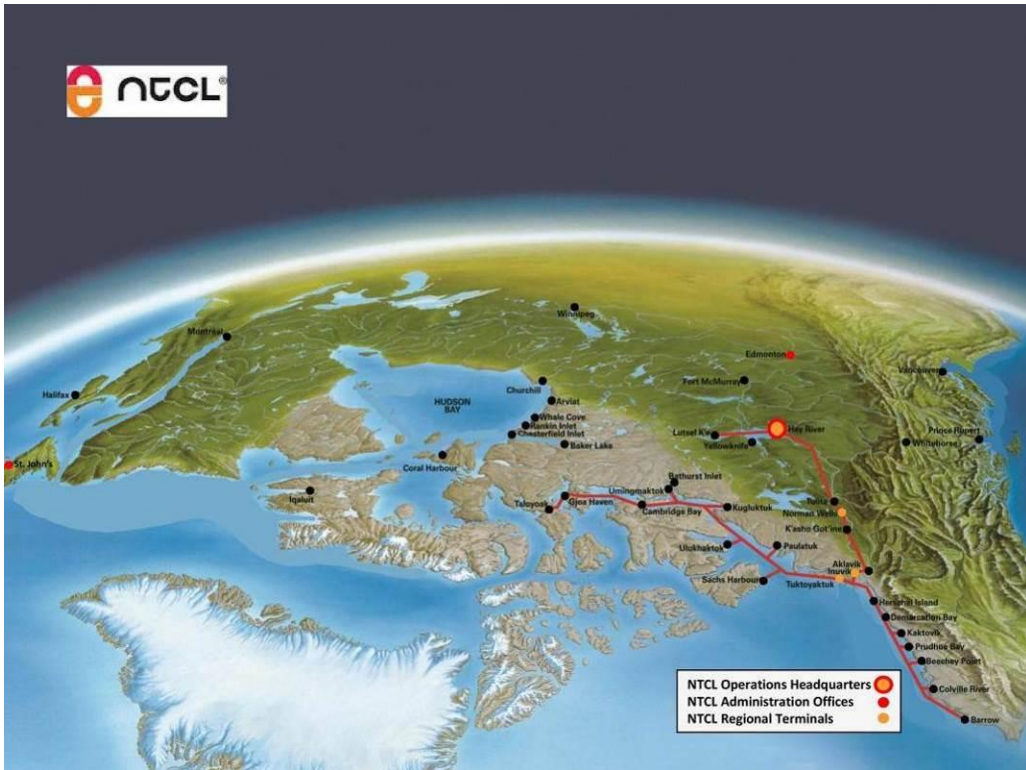


Ob River LNG carrier

Ice conditions are gradually lessening so that ships are venturing farther offshore along this route, to save distance. In 2012, the icebreaker *Xue Long* sailed along the Northern Sea Route into the Barents Sea, but on the return, sailed a straight line from Iceland to the Bering Strait via the North Pole. The Barents Observer reported, in 2012, that 46 vessels had sailed the Northern Sea Route, compared to 34 in 2011 and only 4 in 2010. The total cargo transported on the NSR in 2012 was 1,261,545 tons – a 53 percent increase from 2011, when 820,789 tons were shipped on the route. The figure below shows the *Xue Long*.



The Canadian Arctic has shipping routes, but they are less developed in terms of traffic, harbours, navigational aids and charts. The Western Arctic is open for summer shipping as can be seen in the following figure, which also illustrates that the shipping company NTCL operates a multimodal system along the Mackenzie River.

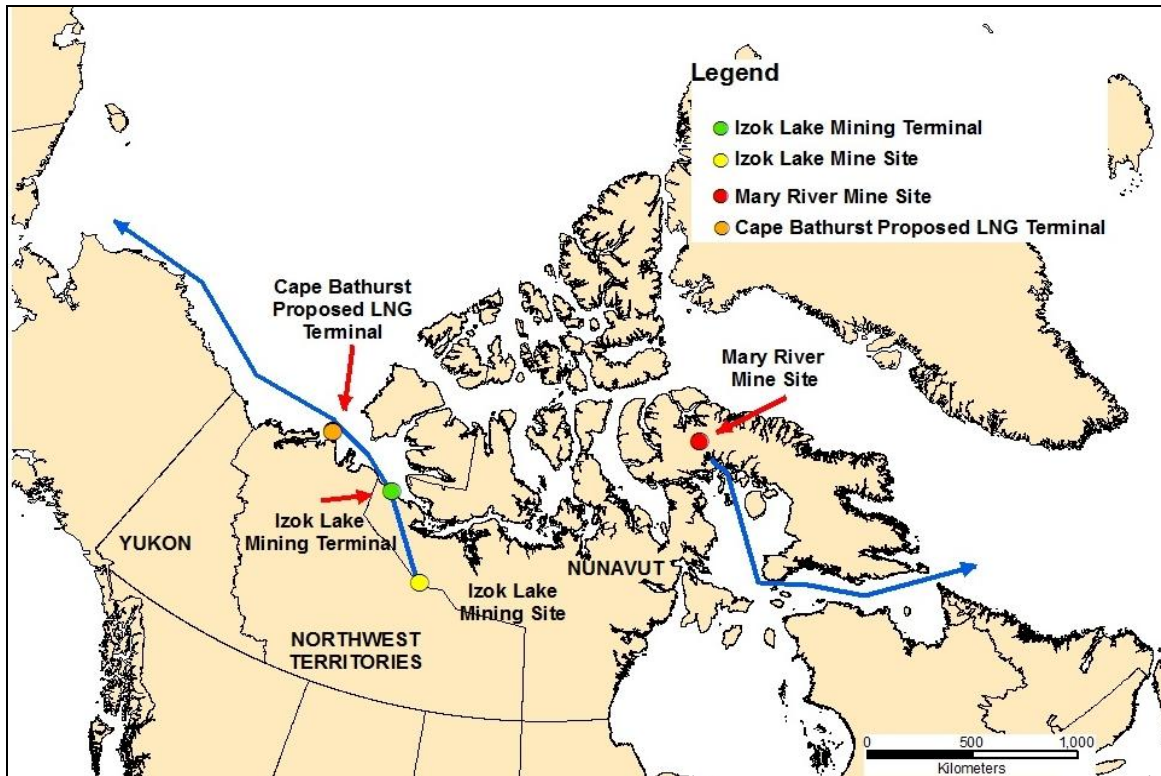


NTCL Shipping Routes Map

The following map, from Transport Canada (Transport Canada<sup>c</sup>, 2010) summarizes the ports and routes throughout the Canadian arctic.



There are individual transits of vessels for specific infrastructure projects from time to time making transits of the Northwest Passage. In 2011, the Korean Gas Corp. visited Inuvik to consider the possibility of building an offshore export LNG terminal in Cape Bathurst, located northeast of the Umiak SDL 131 gas field in the Mackenzie River Delta. Mining projects, such as Mary River, in Baffin Bay, require seasonal to year-round shipping, as shown in the following map. In the Western Arctic, the Izok Lake project will require shipping of ore out to the west.

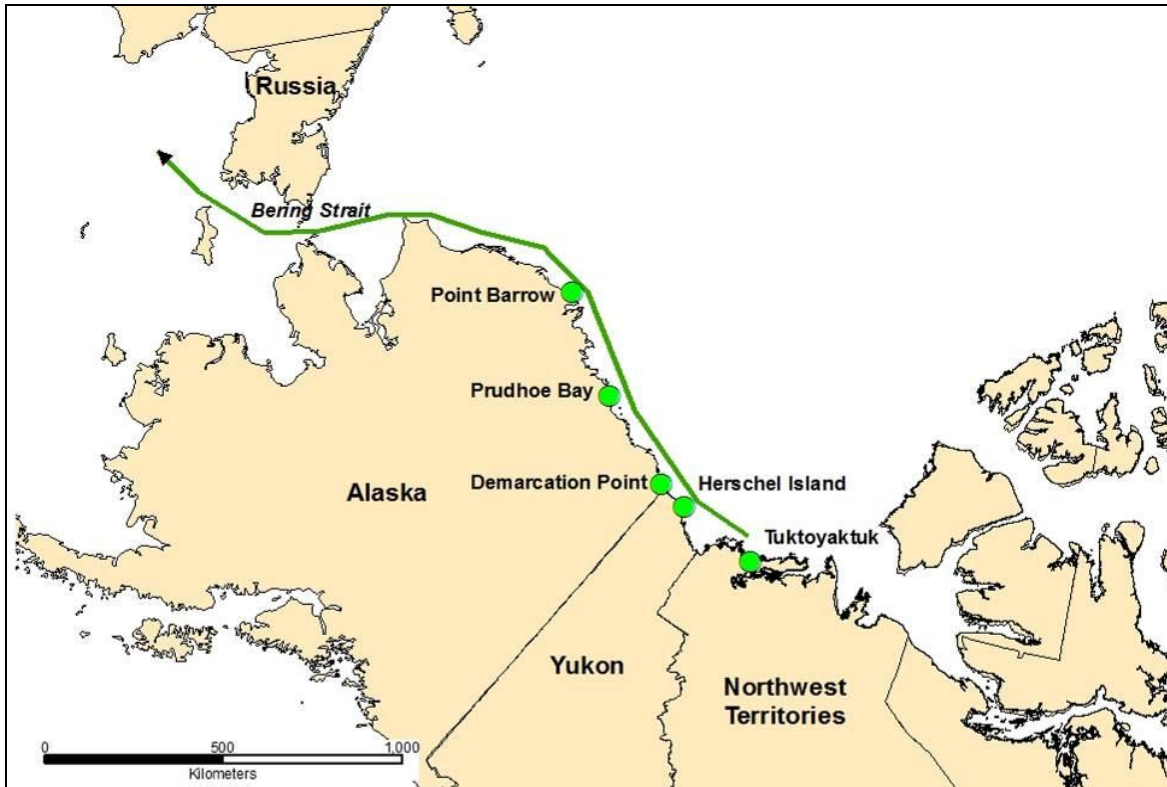


## 7.4 Arctic Energy Gateway Shipping Routes

Choosing a shipping route generally begins by minimizing distance, and then making modifications to take into account hazards, national jurisdictions, and safe havens for storms and repair/supply facilities. In this report, we will describe the approximate routes that tankering of petroleum products in an Arctic Energy Gateway could utilize. Further study will be required to optimize them. During transits, routing will need to be flexible to avoid ice hazards and storms, so alternate routes will always be required.

### 7.4.1 Western Route to Asia-Pacific

The Western Route is from the Tuktoyaktuk Sea Buoy, past Herschel Island and Demarcation Point (141° W & 178nm) which is Area 12 governed by ASPPR. From Demarcation Point, and entering United States coastal waters, the route follows the 20 to 30 m depth contour until reaching Point Barrow, Alaska, a distance of 318 n.mi. (590 km). The western section of this leg is where a vessel will encounter the heaviest ice conditions, especially at the beginning (mid- to late July) and end (mid-October) of the regular shipping season. Sea ice usually covers the northern Bering and Chukchi Seas from late autumn through early spring. The ice edge reaches its maximum southern position during late March.



Prior to recent changes in the ice environment, year-round shipping out of the Beaufort Sea going west required extremely ice-capable (ice breaking) cargo ships capable of sustained operations in polar ice (multi-year, 4 m thick). No such vessels were ever built. However, in the current winter ice environment of first-year ice along the Alaskan coast, first-year ice capable cargo vessels could make the voyage, do currently exist, and are presently operating regularly in Russian waters.

#### Early Season Voyages

Navigating into (or out of) Tuktoyaktuk in an early season voyage (01 June to 15 July) would bring a vessel into much more benign conditions than existed in past years. A principal barrier to early season voyages historically has been the extension of the Polar Pack down to the Alaska coast. This condition caused vessels to face from tens to hundreds of miles of active ice breaking in multi-year ice, which is typically 3 to 4 m thick, and is generally heavily ridged. Studies of ice conditions along the Alaska coast in the early season have reported many cases of encountering impenetrable multi-year ice features with ridges reaching 10 m height. In the current ice environment a vessel transiting in the early season would traverse a mostly first-year ice (1 to 1.5 m thick) with some multi-year ice incursions. In addition, when transiting areas of high ice concentrations adjacent to a coast (like the Alaska coast) multi-year ice always has the ability, in an on-shore wind event, to carry a vessel inshore to the point of grounding, whereas, with latter day predominance of first-year ice, most icebreaking classes of vessels would be able to break the 1.5 m ice and move further offshore.



### Mid-Season Voyages

Mid-season voyages (15 July to 15 Sept.) are typically characterized by navigation through mixed pack ice conditions of various concentrations. As discussed earlier, the infrequency of multi-year ice in the current ice environment makes a given journey much safer than before as there are fewer 10 m thick (multi-year) ice features to impact during periods of the inevitable fog. An additional change in ice hazards is the reduction in floebergs. Floebergs are areas of ice that have been ridged and piled up (usually from being forced against the coast) to the point that they sink to the bottom and become grounded along the coastline. In previous years when the polar pack would come down and press against the coast, extensive floebergs were created, and these would then subsequently float into navigation channels later in the season when surface melt would re-float these features and set them adrift. These features are essentially like icebergs, and all but the most extreme of icebreakers would sustain damage upon impact. In the current ice environment, floebergs are relatively uncommon, and their size (being formed of only first-year ice) is also much reduced.

The principal difference for mid-season voyages compared to past years is the extensive area of open water that now forms along the Alaska coast. This wide area of open water (now typically greater than 100 km wide) makes for much easier transits from an ice perspective. In the face of a north wind, this area now has the fetch to set up significant waves, which wasn't really a problem in the past. In addition, when significant storm events do occur, there are very few harbours with adequate depths to provide refuge to any but the smallest of ships.

### Late Season Voyages

In past years, late season voyages (15 Sept. to 01 Nov.) were primarily dealing with incursions of the polar pack into the shipping channels. In the late season, when northwesterly winds predominate, the resulting southward ice drift would bring anywhere from strips and patches to 9-tenths of multi-year ice into the shipping route along the Alaska coast. Since 2006 multi-year ice has not blocked the ship route west in the late season.

In recent years the extensive areas of Open Water in summer have resulted in increased water temperatures, and a delayed on-set of freeze-up. This extends the season for light-ice class vessels, and reduces ice thicknesses throughout the season.

The current ice environment, where the "dangerous" ice (polar pack) typically lies far offshore of Alaska, has a significant impact on trip planning and risk assessment in the fall. In previous years, when there was a relatively narrow area of navigable ice conditions along the Alaska coast, regardless of ice or weather forecasts, most ship transits were avoided if at all possible. The risk of getting caught between the polar pack and shallow waters along the Alaska coast was a real and unacceptable risk to many operations. Late season voyages are now much less prone to the risk of being pushed against the Alaska coast by 4 m thick multi-year ice.

## Winter Navigation

Winter navigation in the Beaufort Sea, in the current ice environment, would be much more feasible than it was pre-2006. Although many vessels have been constructed and are in operation that can routinely operate in 1.5 m thick first-year ice, none regularly operate in multi-year ice. In the years prior to 2006, any vessel operating regularly out of Tuktoyaktuk would eventually have needed to conduct active icebreaking in polar ice. Although some cargo vessels do have the capability for limited icebreaking in polar ice these same vessels, when encountering high ice concentrations or pressured ice conditions, would become beset and require escort by Polar class ice breakers.

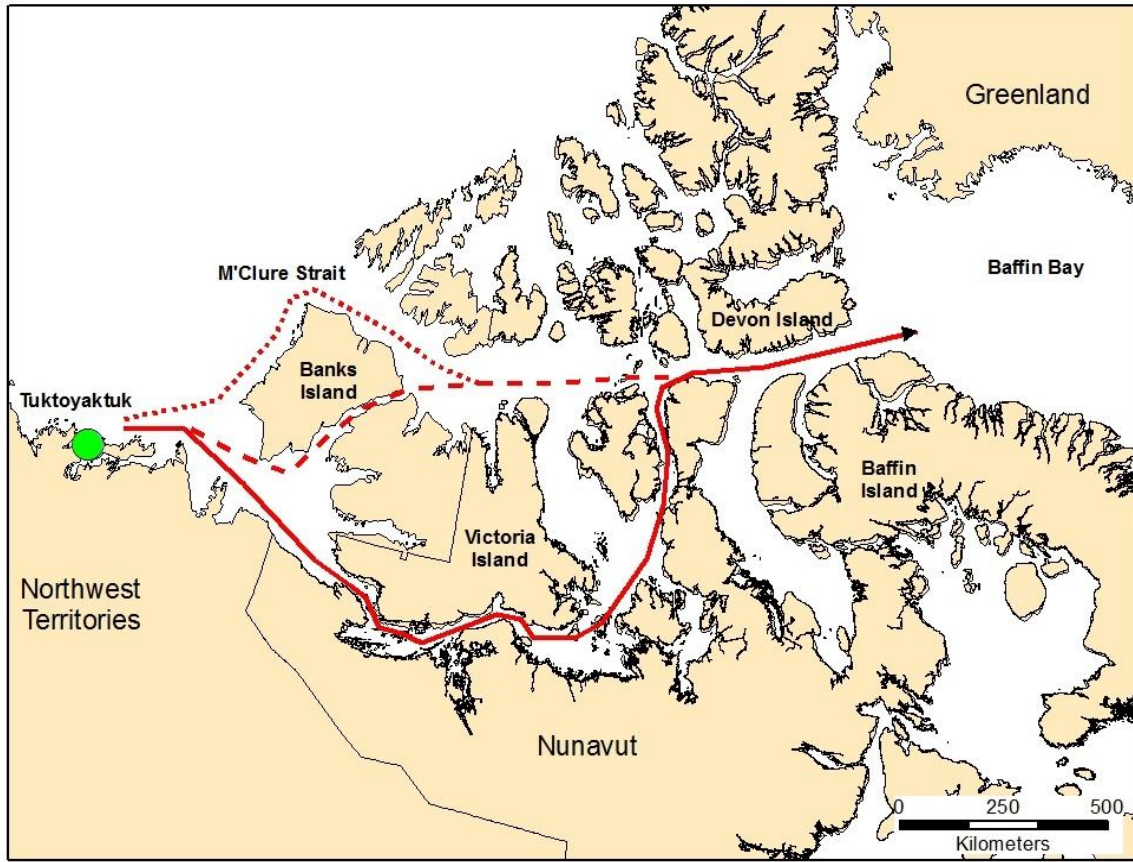
In the current ice environment, it would be possible for a CAC 4 ice capable vessel to operate regularly during the winter out of Tuktoyaktuk while keeping a good watch for incursions of older ice and using prudence and a safe ship speed. This was not possible in the past due to the continuous close proximity of multi-year ice to the Alaska coast. Icebreaker escort may be required in mid-winter conditions. A more robust scenario is to use a CAC 2 vessel which could operate year-round in thick first-year ice which may contain old ice inclusions.

## Summary

The navigation season for the western route could be year-round for a CAC 2 ship without icebreaker escort. Shorter seasons will apply to lower ice class vessels. Attempting to extend navigation into the shoulder seasons with these lower class hulls is technically feasible, but will require CAC 4 and possibly Class 1 vessels, both with icebreaker support. Vessels capable of year-round operations are feasible, but will be much more expensive.

### **7.4.2 Archipelago Section of Eastern Route**

The following map shows the classic Northwest Passage. It has several alternative segments. The primary segment is to the south of Victoria Island, which is almost always fully open in summer. We have also indicated the passage through the Prince of Wales Strait, between Banks and Victoria Islands. This route can become quite clogged with ice jams, but just as easily be ice free; it is much shorter and has fewer depth restrictions. The third alternative segment, with the best bathymetry, is M'Clure Strait to the north and west of Banks Island. This alternative is not currently feasible as very heavy ice conditions prevail every year at its entrance to the Beaufort Sea. However, as we show in the next chapter, this route will become more practicable in the future. Following is a brief discussion of transits of the NWP.



### Summer Voyages

Historically, transits of the Northwest Passage were only undertaken in late summer when the multi-year ice was at its weakest and thinnest after a summer of melt. In the current ice regime, however, the first-year ice that now covers the route is significantly weakened by mid-June. Vessels transiting the Northwest Passage in summer under present day conditions will experience significantly reduced ice strengths (and ice thicknesses) much earlier in the season. The shipping season is a function of the ice class and assisting icebreakers if and when required. The MV *Arctic* is a CAC 2 equivalent vessel and this vessel could be readily used. She has made numerous transits unescorted.

### Extended Season Voyages

Use can be made of the experience gained along the Russian Northern Sea Route and apply that experience to the NWP transits. In the Russian Arctic ore carriers (to the Norilsk Mines) operate unescorted between Murmansk and Dudinka. In thick ice they transit backwards, utilizing the Azipod propulsion system. Their ice class is LU7 (Russian Register), which means they are capable of transiting second-year ice in the summer (up to 3.2 m) and first-year ice in the winter (up to 2.0 m). This is roughly equivalent to Canadian Class CAC 3. Such vessels could be used along the NWP with icebreaker escort

for a period of up to 3 months. With a CAC 2 classification, they might be able to operate for perhaps up to 5-6 months. The photo below is of a Norilsk icebreaking ore carrier.



### Winter Voyages

Navigating into (or out of) Tuktoyaktuk in winter, following the deep-water route shown above has never been done. Historically, transits of this route in winter entailed active ice-breaking in multi-year ice for as much as 70 percent of the route, or as little as a few tens of miles, but never zero. No cargo/tanker vessels are currently in service that can operate effectively in high concentrations of multi-year ice without the assistance of CAC 1 icebreakers.

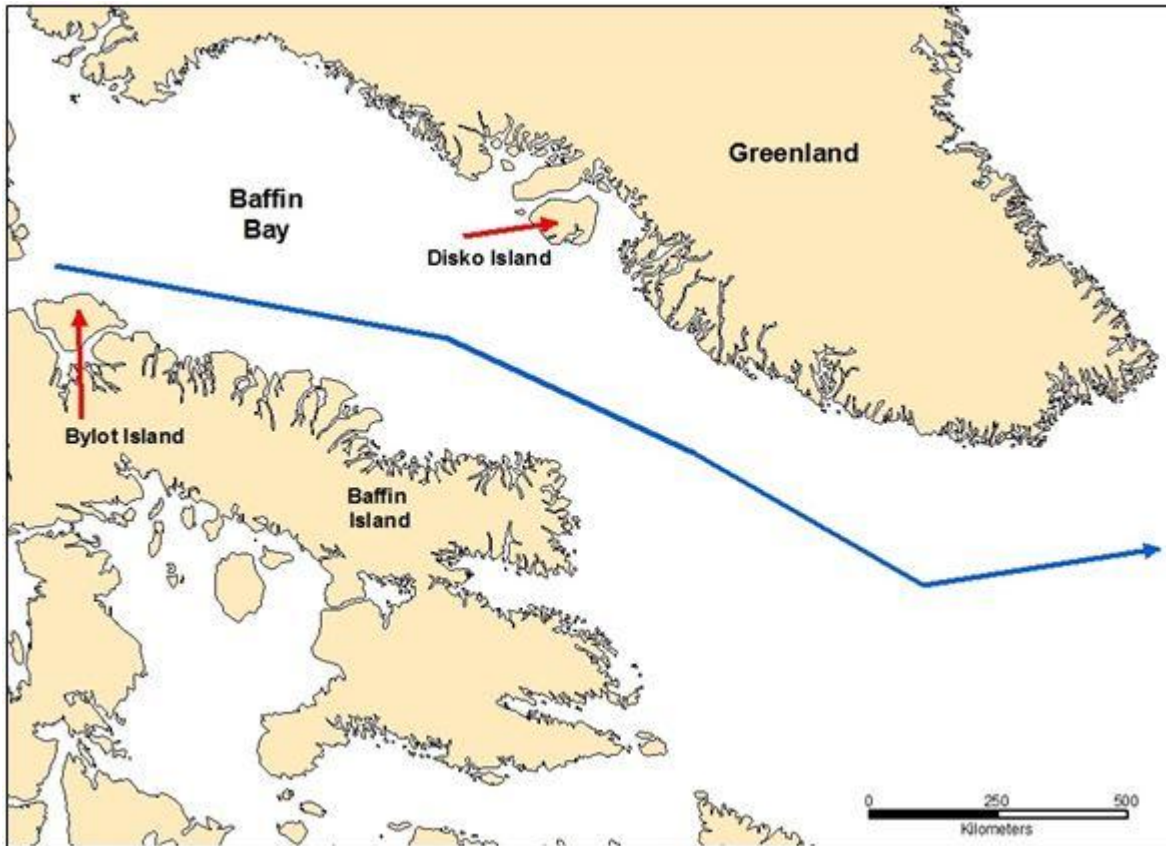
### Summary

The deep-water route of the Northwest Passage has historically not been considered a viable commercial route due to the requirement to transit areas of 3-4 m thick multi-year ice. Less multiyear ice now blocks the passage and this introduces the opportunity for first-year ice capable ships (CAC 3) to transit this route during a portion of the year and, where needed, with escort and due consideration and deployment of safe speeds in hazardous conditions. However those ships must be capable to resist some ice impacts with older ice along the route at reduced speeds. A more secure system would require CAC 2 with icebreaker escort in critical locations or even CAC 1 for unescorted operations.

It is considered feasible to deploy existing tankering like the MV *Arctic* for a summer and extended summer operation to the Beaufort Sea and along the Northwest Passage for delivery of the product to the Canadian East Coast or to transship the cargo for European destinations. The expected season length will need to be defined in detail at a later date, but, based on past projects, four months should be feasible.

### 7.4.3 Baffin Bay Section of Eastern Route

The distinctive feature of this region, icebergs, has been described in Section 7.1.2. Sea ice, however, is far less a problem than in the other routes. Baffin Bay has always been a predominantly first-year ice regime. Although the ice tends to accumulate with more thickness and pressure against the Canadian coast, and last longer, it always melts out almost entirely in summer.

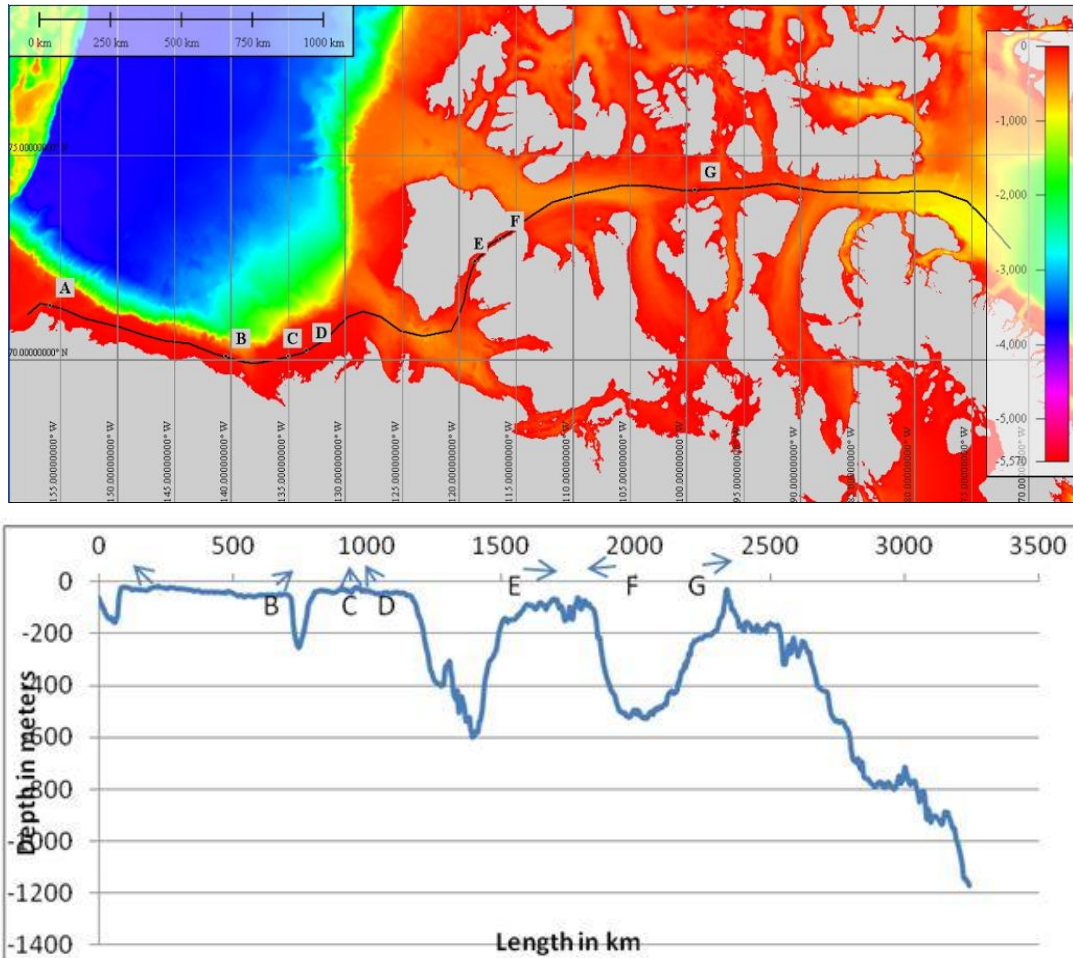


With these considerations in mind, we indicate in the following map, the approximate shipping route out through Baffin Bay from the Northwest Passage entrance. This route would have the freedom to vary widely to find the most favourable ice and iceberg conditions. Once around the southern tip of Greenland, it would then be in iceberg-free waters.

### 7.4.4 Bathymetric Considerations of NWP Route

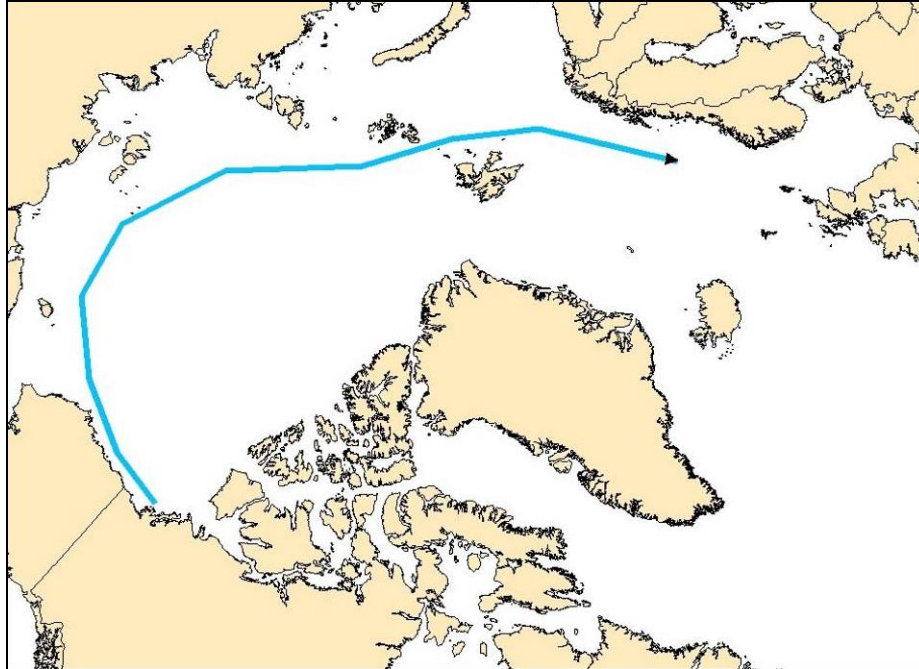
Bathymetry is an important design factor, affecting the terminal/port, the loading tower and the transiting tankers. The figure below shows this bathymetry along one of the routes. M'Clure Strait is completely free of any bathymetric obstructions. Prince of Wales Strait is clear except for one spot. Ice conditions will tend to get more severe in those areas. The southern route along Victoria Island is the most problematic, with numerous shoals and obstructions. In general, all these passages are poorly

charted. Before regular tankerage can occur, major bathymetric charting will need to be carried out. Such charting is carried out by the Canadian Hydrographic Service. The following diagrams show bathymetry along our preferred NWP route, keyed to a depth chart next, highlighting potential restrictive locations.



#### 7.4.5 Russian Route to Europe

As has been shown in the previous section, the Russian route is already in use for routine commercial shipping. It therefore offers Alberta a realistic alternative of exporting to Europe on a seasonal basis. Navigating as close as possible to the polar pack edge with a single icebreaker support in a convoy is the best case scenario and is only about four percent longer in distance than Northwest Passage route going north of Great Britain to Rotterdam. In severe conditions, the voyage would have to go closer to the Russian coast, adding perhaps another 15 percent to the distance. The map below shows the shortest route, navigating very close to the polar pack edge.



The average ice conditions along the NSR are shown in the following table which shows average percentages of regions ice free area. One can see that no area is totally ice free but conditions are light enough to allow cargo transits. Conditions are also tending to become less severe, just as in North American waters.

Average percent of Russian seas that develop ice-free areas.

End of month	Region						
	South-western Kara Sea	North-eastern Kara Sea	Western Laptev Sea	Eastern Laptev Sea	Western East Siberian Sea	Eastern East Siberian Sea	South-western Chukchi Sea
June	17	0	10	10	0	0	27
July	40	18	24	33	10	6	57
August	85	41	45	69	31	17	75
September	95	53	51	80	49	27	85

Large scale year-round transport is not expected soon, since ice conditions will have to improve further. Seasonal transport may, however, increase and be possible for several months (2-4).

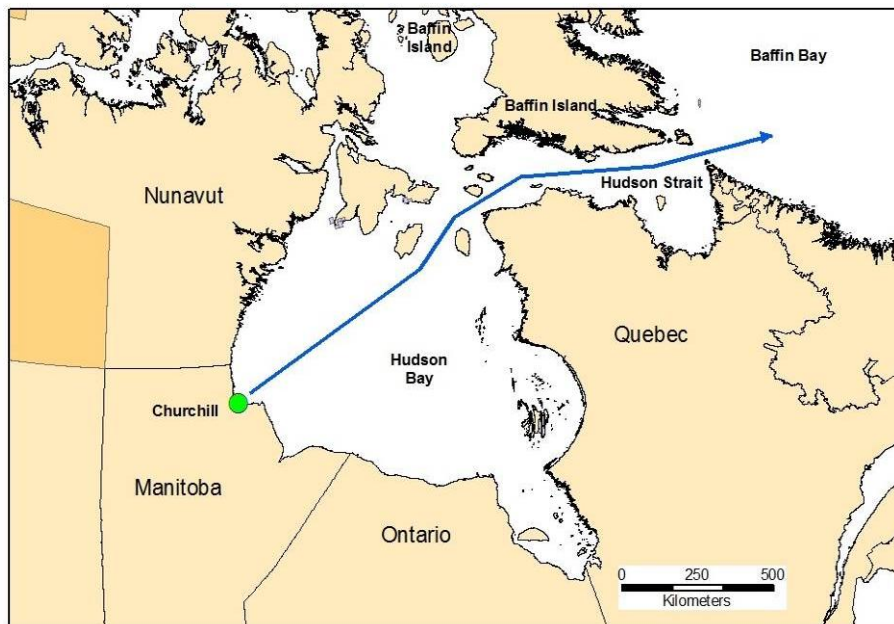
The table below shows the minimum ship class (Canadian classification, AIRSS) required to transit the Russian route, under the toughest ice conditions (end of March), for the last ten years.

Ship Class (AIRSS)	Date
CAC 4	March 31, 2003

CAC 4	March 29, 2004
CAC 4	March 28, 2005
CAC 4	March 27, 2006
CAC4 (possibly Type A)	March 26, 2007
CAC 4	March 24, 2008
CAC 4	March 30, 2009
Type A	March 15, 2010
Type A	March 28, 2011
Type A	March 26, 2012

#### 7.4.6 Hudson Bay Route to Europe

An additional aspect of the Arctic Energy Gateway may include shipping through the developed port infrastructure at Churchill, Manitoba and out via Hudson Bay. Although outside the terms of reference of our study, a brief mention should be made here in order that all reasonable alternatives are put forth for future consideration. The marine transport route from Churchill to open ocean is shown in the following map.



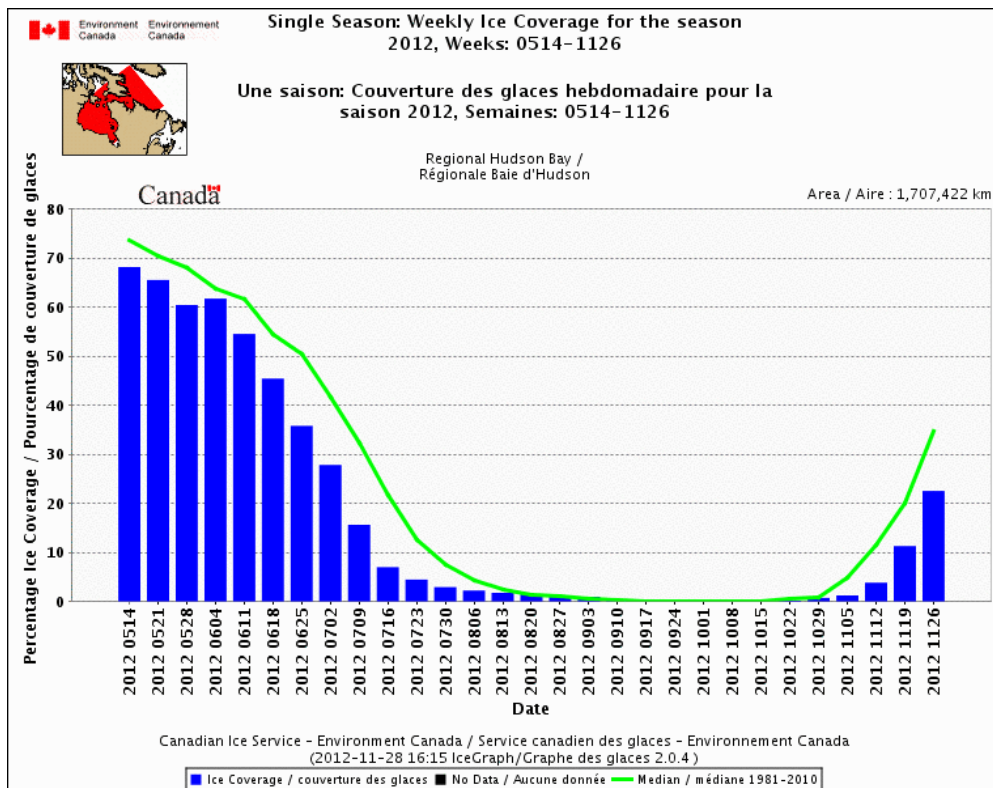
The Port of Churchill has been operating since 1929 with the overwhelming bulk of export traffic being cereal grains produced in Manitoba and Saskatchewan. The conventional advantage of shipping



through Churchill has been more favourable access to ports along the northern European seacoast by comparison with originating ports at Thunder Bay and the east coast of Canada, which require long train journeys. About a dozen or so ships visit this port during the summer season, and no traffic occurs during ice season.

Transport of Athabasca bitumen to Churchill for export could follow the scenarios that have been put forth for the Mackenzie Valley outlet. Rail, road, and pipeline multi-modal systems could serve to move bitumen via the established infrastructure and rights of way in the southern parts of the Prairie Provinces, leading to the Hudson Bay railway from The Pas to Churchill. Like the Mackenzie Valley scenario, bitumen export could benefit from synergies with other established and developing export interests focusing on Churchill; these include the ongoing grain trade and export of conventional petroleum from Saskatchewan and Manitoba. Again, similar to the Mackenzie Valley scenario, a Churchill option would require coordination of interests of several jurisdictions. (NWT and First Nations in the Mackenzie Valley; two additional provincial governments in the Hudson Bay option). Arnason (2013) reports that OmniTRAX Canada, which owns the port and rail line at Churchill, and the Hudson Bay Route Association have been studying this route and promoting it to petroleum companies for a year. They have also proposed exporting petroleum from northern parts of the US via this route.

The defining obstacle to shipping from Churchill is the seasonal ice cover of Hudson Bay, from November to mid-July, as shown in the following figure. According to the Zone Date system, Zones 14 and 15 need the same ice class as the southern Beaufort, which is Zone 12. While we have not done a detailed review of ice conditions for this route, as it was outside our terms of reference, it would seem highly likely that any conclusions we arrive at for the Alaskan route would hold for this region as well, especially since open water season is quite a bit longer than in the Beaufort (Canadian Ice Service, 2013).



During the existing three-month shipping season, open water conditions permit conventional (non-ice-strengthened) vessels to traverse the sea route in and out of the port.

However, unlike all routes in the Arctic Ocean, the Hudson Bay route is, at no point, encumbered by multi-year ice drifting into the region or forming there in situ. Therefore, cargo vessels and icebreaker escort to extend the shipping season from Churchill need much lower ice strengthening and hence can operate at lower cost.

As with the Russian route, the table below shows the minimum ship class required to transit the Hudson Bay route at the time of the worst ice conditions, over the past 10 years.

Ship Class (AIRSS)	Date
Type A	March 29, 2003
Type A	March 29, 2004
Type A	March 28, 2005
Type A	March 27, 2006
Type A (possibly Type B)	March 29, 2007
CAC 4	March 22, 2008
CAC4	March 29, 2009
Type A	March 29, 2010
Type A	March 29, 2011
Type A	March 19, 2012

#### 7.4.7 Ports for Supply and Refuge

The tanker traffic we envisage does not require landing at any port other than the final delivery site. Harbours along the route are useful for provisioning of navigational assistance, rescue services, and spill response and so are an important component of a marine transport system and need to be investigated in follow up studies. In addition, these ports are important supply points for northern communities and will benefit greatly from the presence of the main Arctic Energy Gateway terminal at or near Tuktoyaktuk.

The map shown previously from NTCL shows ports in the Western Arctic. Nearly all of them are unsuitable for use or even approach by large tankers.

### 7.5 Summary: Options for the Arctic Energy Gateway Marine Fleet

For the marine transport of petroleum product the following alternatives are all technically feasible:

- Non ice-strengthened ships operating only in summer months, going to Asian markets; through the Northwest Passage on an opportunity basis for several weeks in summer to European markets; and through Hudson Bay to European markets in summer months.
- Ice-strengthened tankers to significantly extend the operating season in the spring and fall of the Alaskan and Russian routes, to open the possibility for transit through the Northwest Passage on a longer and more regular basis, and to open the possibility of all year round transit of Hudson Bay from Churchill.
- The use of existing icebreakers to extend the season even farther with these ships and make their transit time faster. As Jolles (1984 and 1989) has pointed out, experience in their operations will over a few years allow for significant incremental extensions to seasons and shortening of transit times.
- The use of specially designed and dedicated icebreakers, and high ice-class tankers to achieve year-round operations. This would first be achieved in the Alaskan route then the Russian, and only some years later through the Northwest Passage.

The following conceptual systems can be considered which all need further design work and which could be regarded as starting points for further studies of full feasibility and economic viability.

#### Low Ice Class Tankers (open water) with Minimal or No Escort

Route	Class	Season (months)
<b>Alaska</b>	A, B (D),	2-3
	1A	3-4 with partial escort
<b>Russia</b>	A, B (D)	2-3 needs partial escort
<b>Northwest Passage</b>	A, B (D)	2-3 needs partial escort

#### Ice Class Tankers, Unescorted

Route	Class	Season (months)
<b>Alaska</b>	CAC 2	12
<b>Russia</b>	CAC 3	6-8
<b>Northwest Passage</b>	CAC 4	
	CAC 2	6-8

Ice Class Tankers, Escorted by icebreakers:

Route	Class	Season (months)
<b>Alaska</b>	CAC 4	5-6
	CAC 3	6-8
	CAC 2	12
<b>Russia</b>	CAC 3	6-8
<b>Northwest Passage</b>	CAC 2	10-12
	CAC 4	2-3

Throughputs achievable by these vessels will be a function of:

- Vessel size
- Loading rates and turnaround time
- Number of vessels in service
- Operating season.

Johansson (1994) provided a preliminary design of a 42,000 DWT tanker with an ice class of CAC 2, which could be used as a starting point for further studies. It is not possible at this time to come with estimates of throughputs, which should be done in a follow up phase, looking at the above variables in concert.

## 8 IMPLICATIONS OF THE CHANGING ICE ENVIRONMENT

The previous chapter has presented the situation for marine tankering now, under current ice conditions. This is the initial basis and the more secure one, for determining technical feasibility.

However, as is well known, the Arctic ice environment is changing, and rapidly. How does global climate change affect the system described in previous chapters?

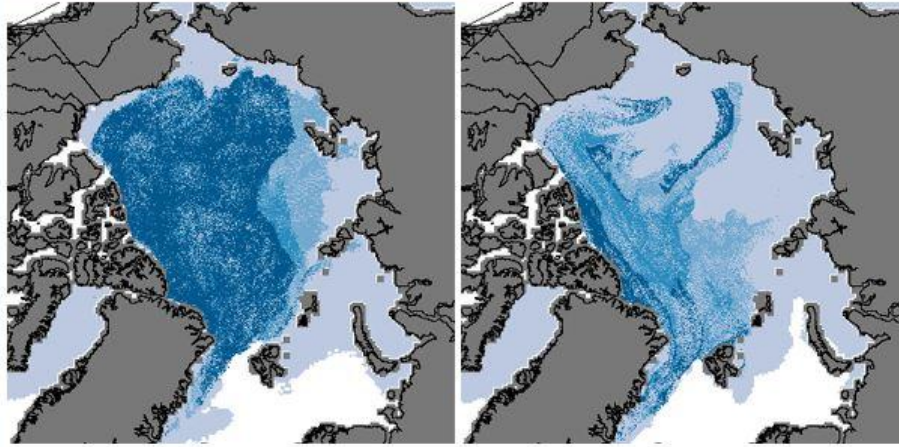
In the case of river systems, global climate change impacts the water levels and ice season along the Mackenzie River. The obvious positive implication is that the ice season will be shorter, but local patterns of ice accumulations could change as well as currents and high and low water levels, with negative consequences. In the case of pipelines, roads and railways, warming of the Arctic affects foundation design. While hydrological changes are not sudden and can be fairly easily dealt with through design and maintenance, rapid permafrost melting and consequent slumping of terrain is more significant.

However, by far the most dramatic and uncertain impact from global climate change will be on sea and glacial ice along the ocean transport route. The following sections describe the present and forecast conditions and their impact on the feasibility of shipping petroleum. We begin with the situation at the level of the whole Arctic Ocean Basin, then look at each of the route areas in turn, as it is well known that there are substantial differences in dynamics across this vast region.

### 8.1 Basin-wide Historical Trends for Sea Ice

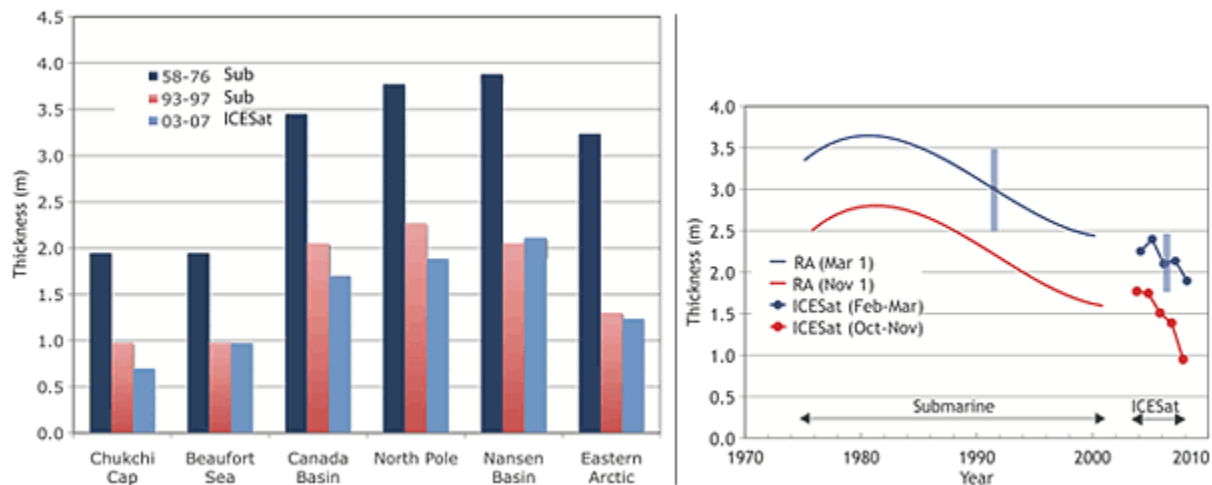
The average sea-ice environment (thickness, duration) in the Arctic Ocean is now much reduced from 30 years ago. In addition to the overall decrease in ice concentrations, the age, and therefore the thickness and hardness of Arctic ice have also decreased. The inset below from NSIDC (*National Snow and Ice Data Centre*) illustrates the decreased age (thickness) of ice in the Arctic Ocean.

A study published in 2007 found a dramatic change in the age of sea ice in the central Arctic Basin since the mid-1980s. In 1987, 57 percent of the ice pack was at least 5 years old, and a quarter of that ice was at least 9 years old. By 2007, only 7 percent of the ice pack was at least 5 years old, and virtually none of the ice was at least 9 years old (Maslanik et al. 2007).



Old v. new ice in Arctic, March 1985 and 2011: These maps show the median age of March sea ice in 1985 (left) and 2011 (right). Overall, the proportion of young ice has increased. By March 2011, ice more than four years old accounts for less than 10 percent of the Arctic ice cover. Image by National Snow and Ice Data Center, University of Colorado, Boulder.

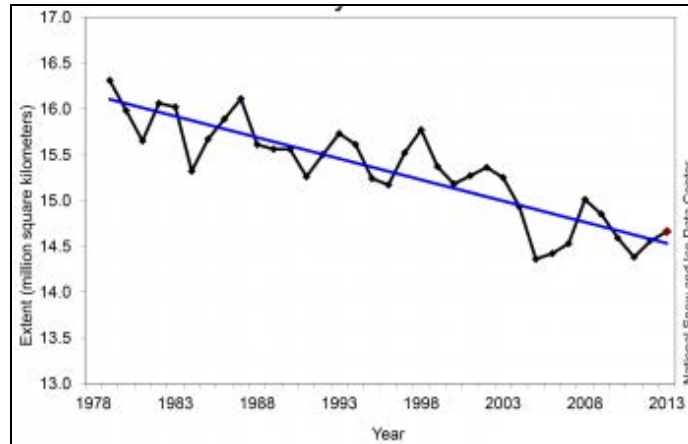
A recent study (Kwok and Rothrock, 2009) examined sea-ice thickness records from submarines and ICESat observations from 1958 to 2008. Examining 42 years of submarine records (1958 to 2000), and five years of ICESat records (2003 to 2008), the authors determined that mean Arctic sea-ice thickness declined from 3.64 m in 1980 to 1.89 m in 2008—a decline of 1.75 m.



These graphs from Kwok and Rothrock (2009) compare sea-ice thickness observations from submarine records and ICESat observations over time. The bar chart (left) compares sea-ice thickness for six Arctic regions. The time series (right) shows submarine sonar measurements compiled in studies published in

2008 and 2009 (designated as RA), and ICESat observations. Error bars on the February-March measurements appear as vertical blue bars.

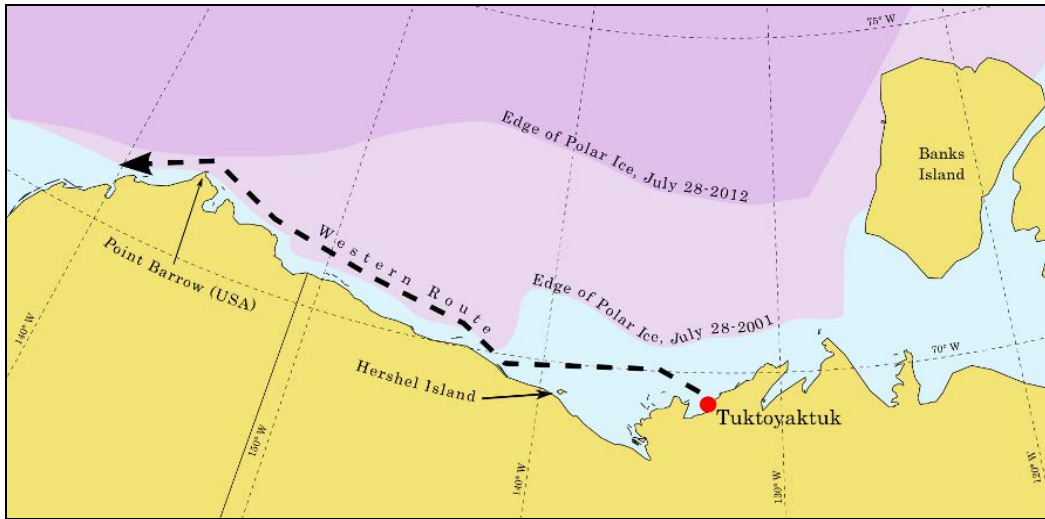
The ice season of 2012 was recorded by the *NSIDC* as having the smallest area of ice in the Arctic Ocean since records have been kept. This trend continues into 2013, as shown by the graph below:



Average monthly Arctic sea-ice extent in February, 1979-2013

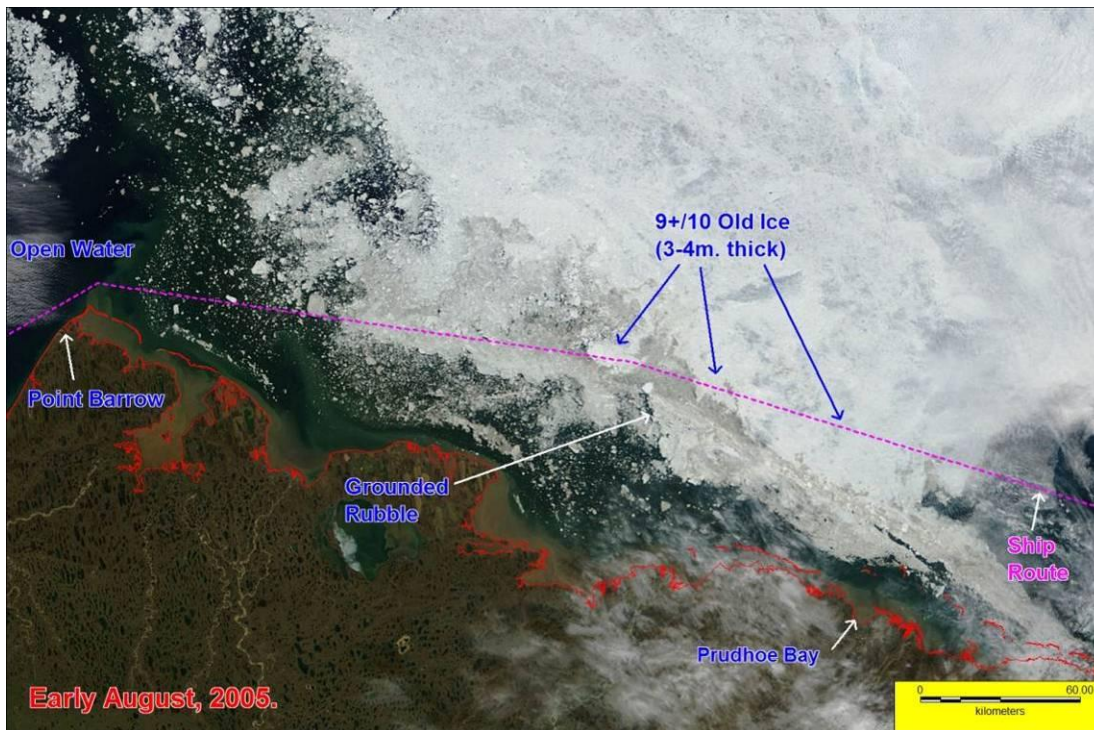
## 8.2 Sea Ice Condition Changes West to the Bering Strait

Prior to 2005, this route (in summer) was typically composed of a relatively narrow lead of open water (a few km) between the Alaska coast and the polar pack ice. In many years no lead was present, and icebreaking was required to support navigation in the area. In the present ice environment (since 2005), the width of the typical shore lead of open water has increased to well over a 100 nautical miles (185 km) on average, and summer transits do not require icebreaker support. Although the Beaufort Sea still becomes solidly ice covered during the winter, the beginning of freeze-up is now 3 weeks later, and the onset of melt is a month earlier than was the case in the 1980s. This has greatly increased the shipping season length for low ice class vessels. In regard to the possibility of year-round shipping, since 2005 the principal ice type along the Beaufort Sea coast has been first-year ice - ice that formed in the current season and is generally 1 to 2 m in thickness. Prior to 2005, the polar pack ice generally extended right down to the Alaska coast in winter, which would then require a vessel to transit polar ice which is typically 4 m in thickness. These dramatic changes are shown in the following map.



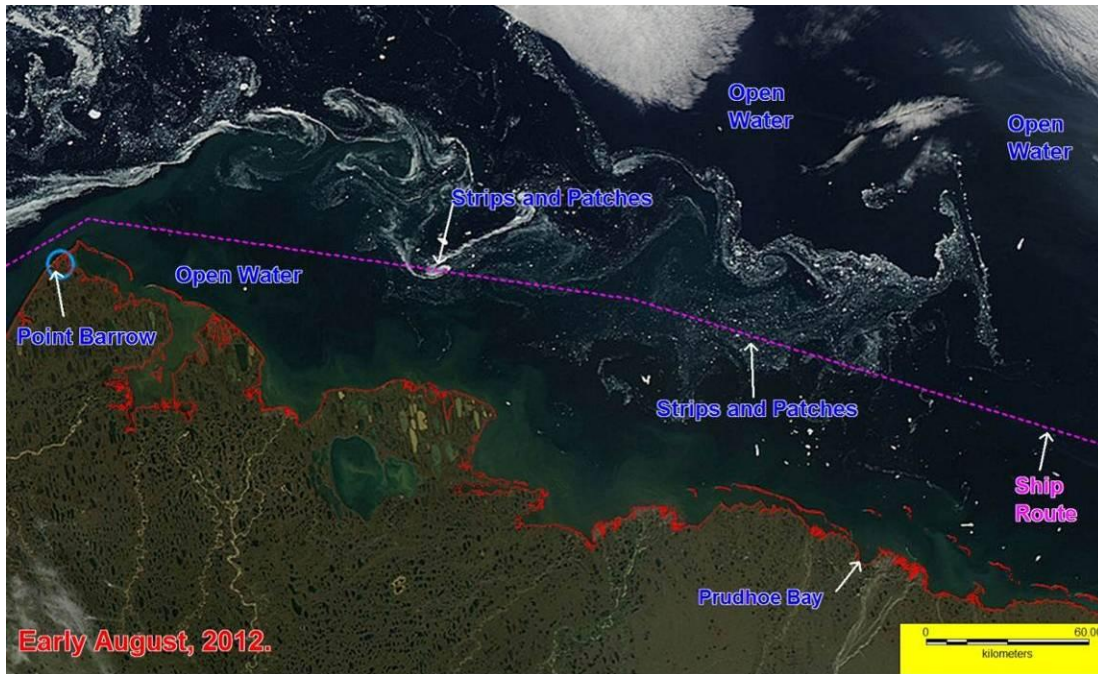
Variation in polar pack ice limit in the Beaufort Sea, 2001 and 2012.

These changes are obvious even to the untrained observer looking at satellite images as the following pictures show.



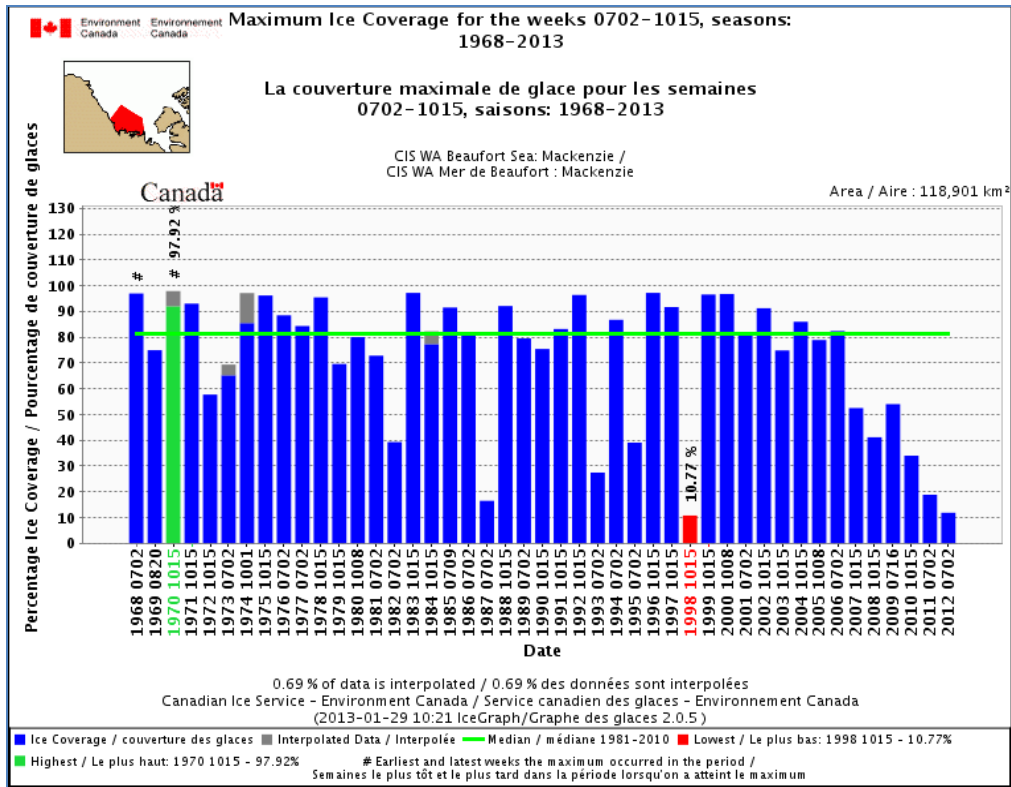
MODIS satellite sensor image of the Beaufort Sea, August 2005





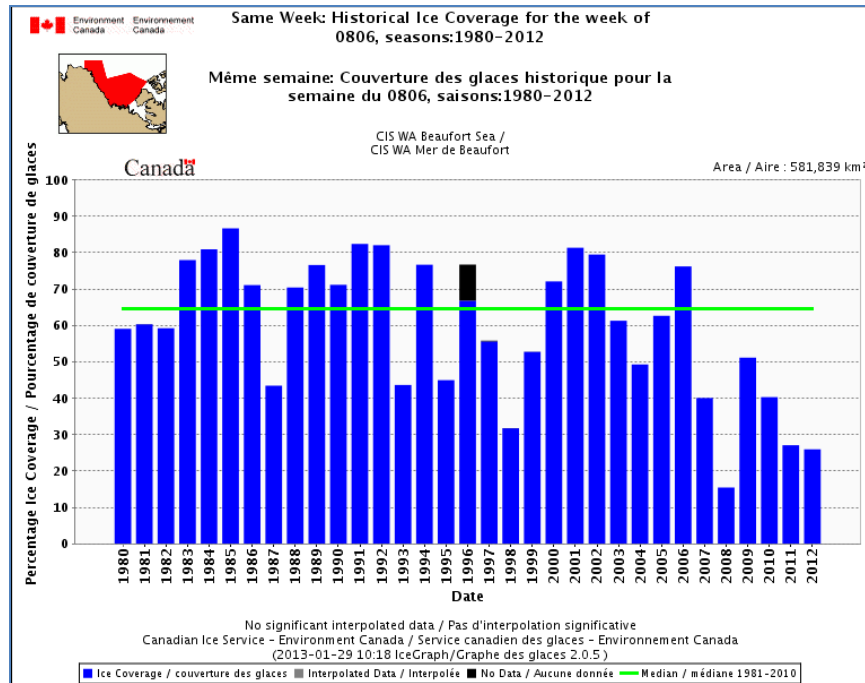
MODIS satellite sensor image of the Beaufort Sea, August 2012

Ice conditions in the Canadian Arctic are monitored regularly by Environment Canada, and have been since 1968. Shown below is a histogram that summarizes the maximum ice coverage for each summer shipping season from 1968 to 2013, extracted from the Environment Canada ice database. In recent years, the summer shipping season has been primarily Open Water.



Maximum weekly ice cover in the Western Arctic, 1968-2013

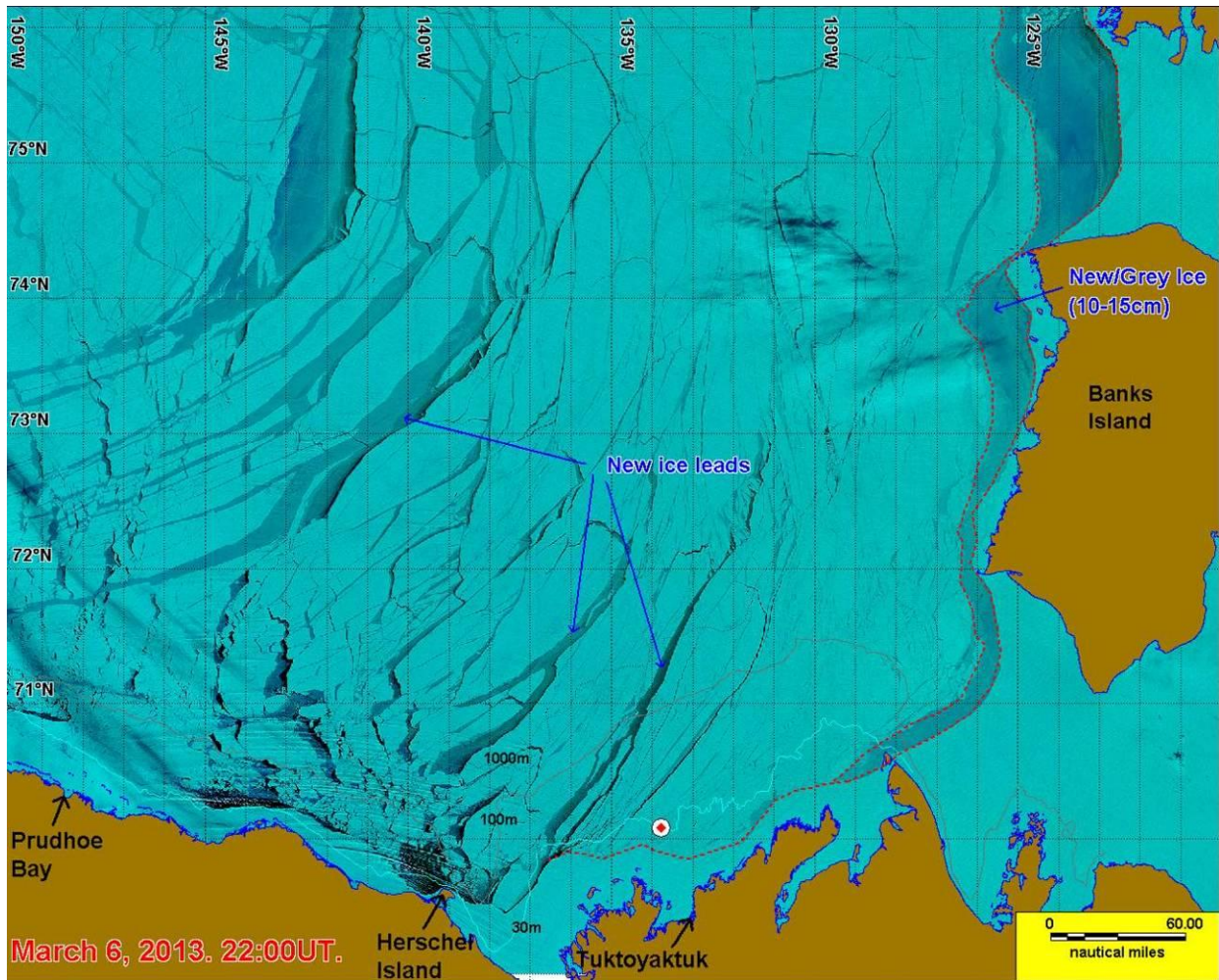
This change to lower concentrations and more open water in summer is prevalent across the Western Arctic. In the following figure, ice coverage for the week of 06 August for the entire ship route from the Beaufort Sea to the Bering Sea is shown.



Actual ice cover of the Beaufort Sea in the week of 06 August, 1980-2012

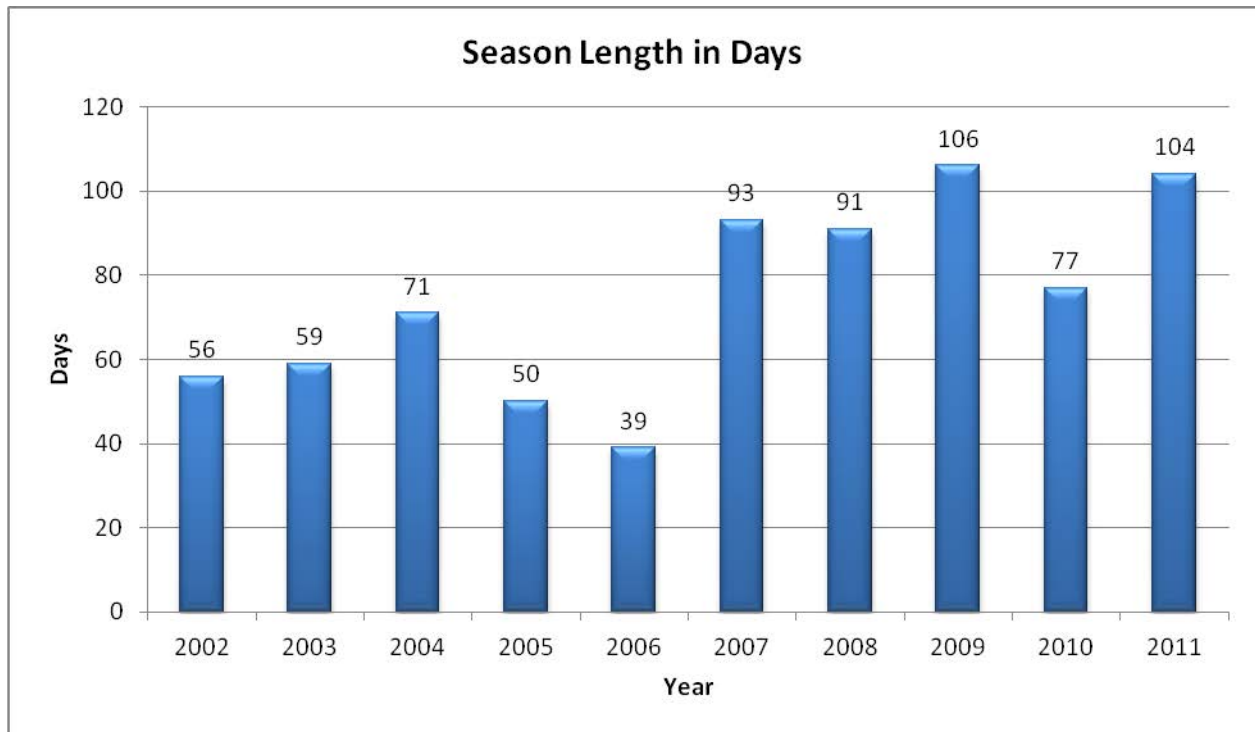
Note in the above graphs that average ice concentration (amount) has been decreasing since 2006, but there can be very large variability from year to year, which makes exact forecasting impossible for the longer range.

The trend to reduced ice conditions in the Beaufort Sea continues in the winter of 2013. Following is a satellite image from 06 March 2013, and the amount of fracturing and new ice (<10 cm thickness) in the Beaufort Sea at this time resembles what was seen historically in May. Historically, March is a month where the ice cover is a semi-consolidated layer of thick first-year ice (120 to 180 cm). However, as seen below, in 2013 there were extensive areas of fracturing and thin ice. This thin ice will melt out quickly as temperatures rise, and the resulting areas of open water act as solar collectors and accelerate ice melt versus areas where the thick ice cover is 100 percent.



Extensive fracturing in the winter of 2013.

As a consequence of milder ice conditions, shipping season lengths have been increasing since 2006. In the following table, season lengths are graphed for the past ten years. Below the graphs is the start and end date of the shipping season in each year.



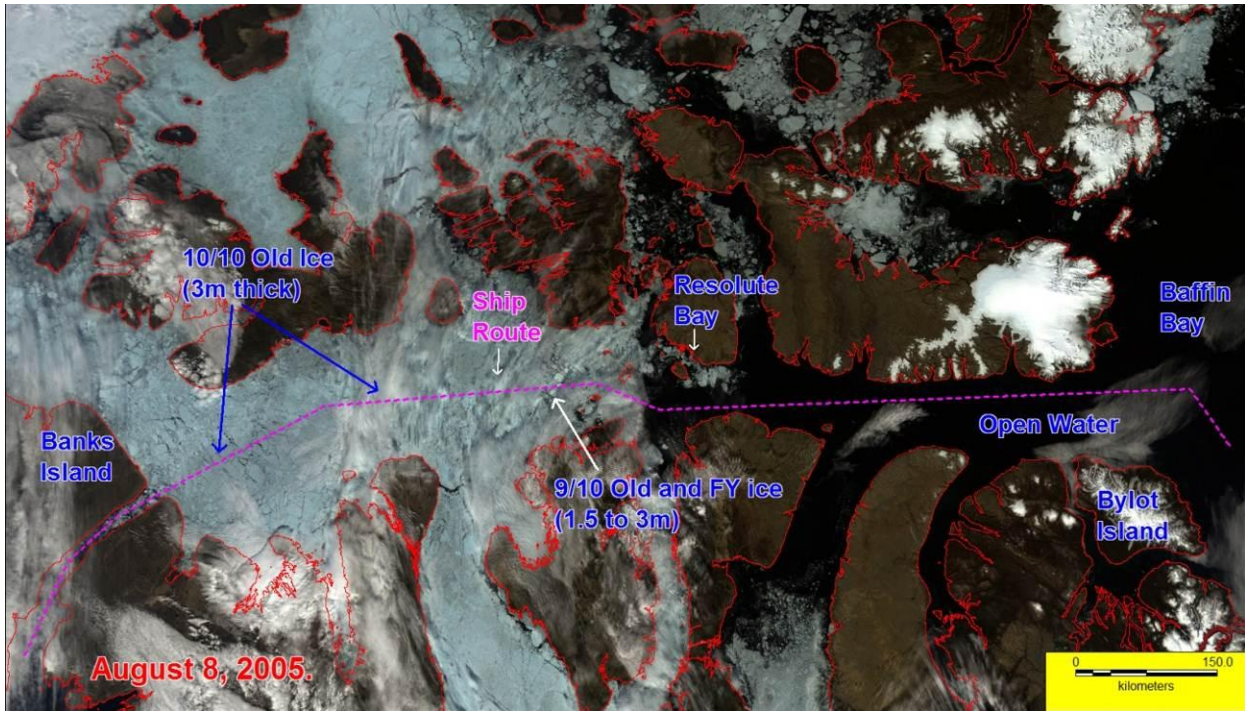
Shipping Season Length (days) 2002 – 2011.

For this analysis, the shipping season is defined as the period when total concentration of ice >10 cm thick is 3-tenths or less. Note in the above graph how the most favourable year pre-2006 (2004) had a shorter season than the most severe year post-2006. In this route analysis the shipping route included all areas deeper than 30 m, and 12 n.mi. (22 km) or more off of the Alaska coast.

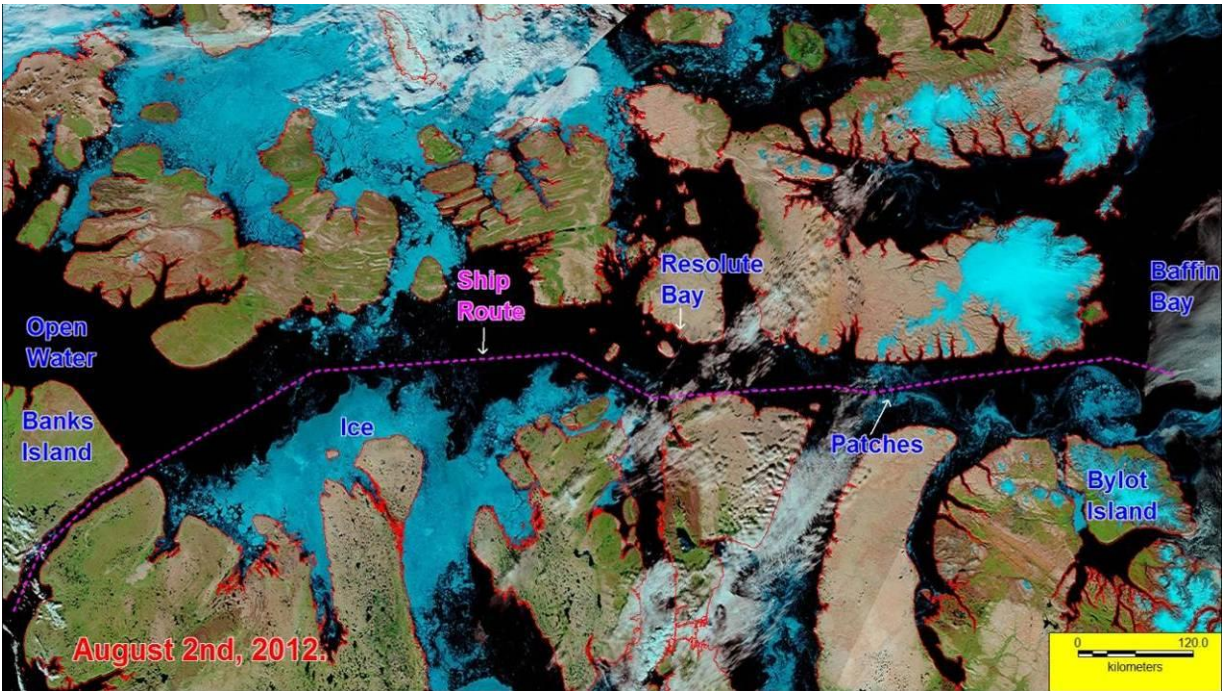
### 8.3 Sea Ice Condition Changes East through the Northwest Passage

Similar to the Alaska coast, significant portions of this route were (prior to 2005) typically covered for most or all of the year by polar ice (4 m thick). In recent years, this route has melted out each year providing an open water route in summer, and a route through primarily 1 to 2 m thick ice in winter. An advantage of this route versus the west route is that, during winter, this route is mostly fast ice, i.e. ice that is frozen solid to the coastlines and un-moving. This allows current remote sensing technology to very accurately map ice features and ice hazards, and provide an optimized route to vessels that avoids all significant ice hazards.

For possible transits going east, the Northwest Passage is experiencing reduced ice conditions. The following pair of satellite images shows the dramatic decrease at two specific points in time.

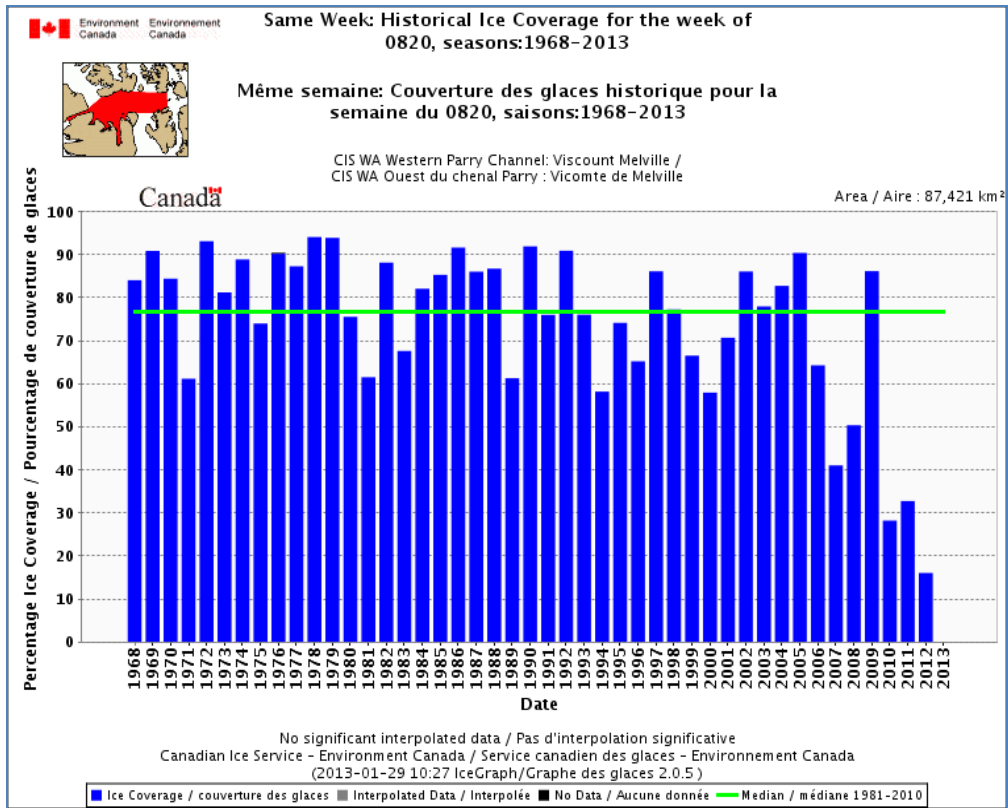


MODIS satellite sensor image of the Northwest Passage, 08 August 2005



MODIS satellite sensor image of the Northwest Passage, 02 August 2012

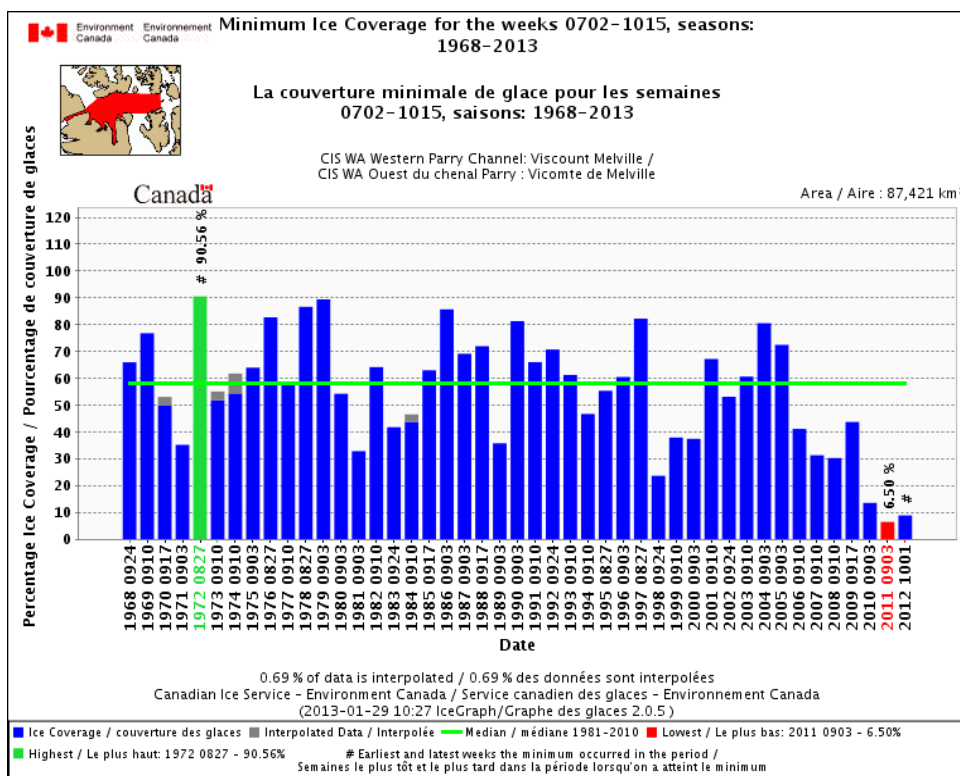
Other than 2009, the graph shown below illustrates how the average coverage has changed from 6-tenths to 9-tenths, to now being 1- to 5-tenths. Based on historical ship transits, ice concentrations below 6-tenths can generally be completely avoided, whereas greater ice concentrations typically require icebreaker support.



Ice cover in the Northwest Passage during the week of 20 August, 1968-2012.



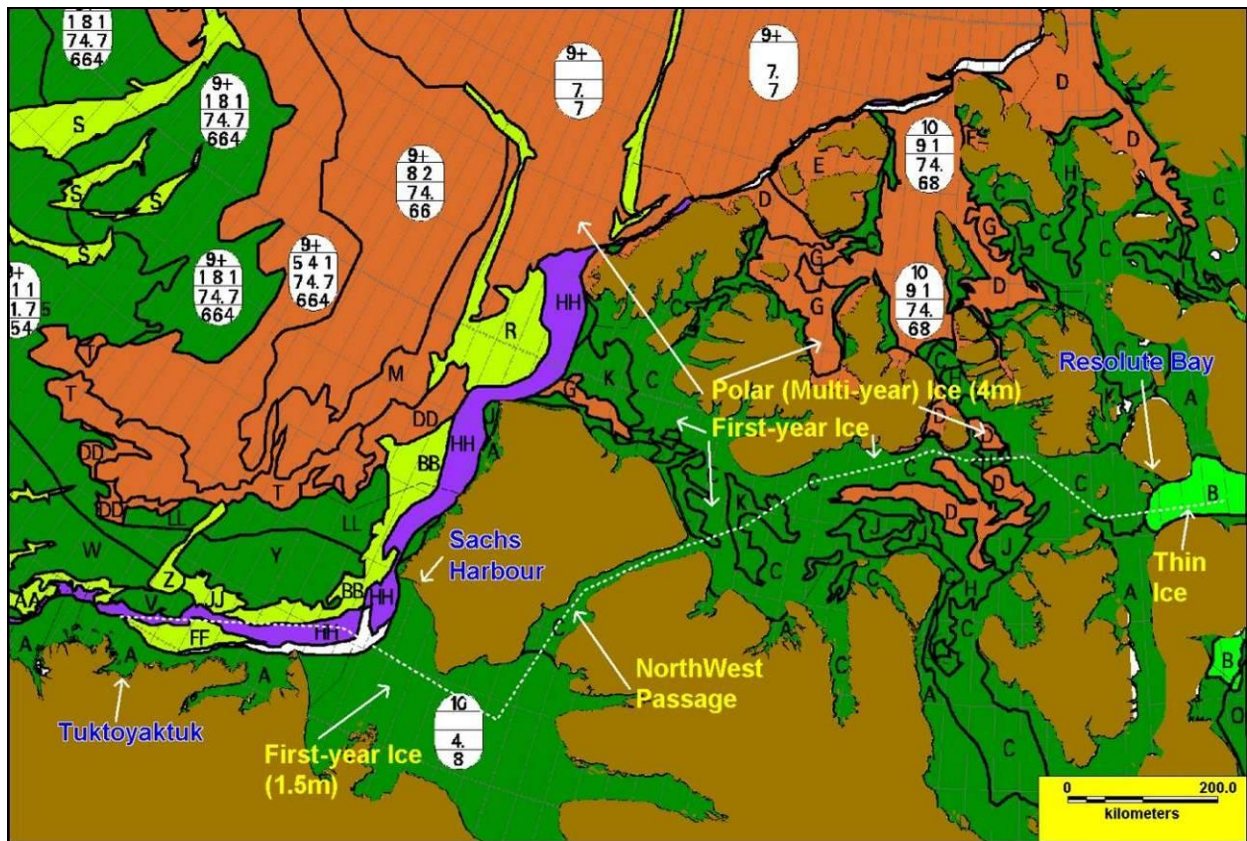
Similar increases in the shipping season length have been noted in the Northwest Passage where concentrations of multi-year ice (average 4 m thick) has decreased from an average of 5- to 7-tenths coverage, to currently 1- to 3-tenths coverage.



Minimum weekly ice cover in the northern Northwest Passage, 1968-2013

During the summer of 2012, the Northwest Passage melted out and an open water route was available. The large areas of open water then allowed the water temperatures to increase, and this delayed the onset of freeze-up. As a result, the first-year ice present along the route in March 2013 averaged 1.5 m in thickness, opposed to 1.8 m in the past which further reduces the required icebreaking requirement of any vessel undertaking a winter voyage in this "new" Arctic ice regime.

The trend to reduced ice conditions in the Canadian Arctic continues in the Northwest Passage in the winter of 2013. Shown below is an ice chart from 25 March 2013, and the total lack of polar ice (multi-year ice) in the Northwest Passage is apparent. In the map below, the recently-formed first-year ice (average 1.5 m thickness) is coloured green, and the thick (3-4 m) polar ice is coloured brown. Note how a transit of the Northwest Passage is possible at this time (all of winter 2012-2013) without passing through any polar ice.

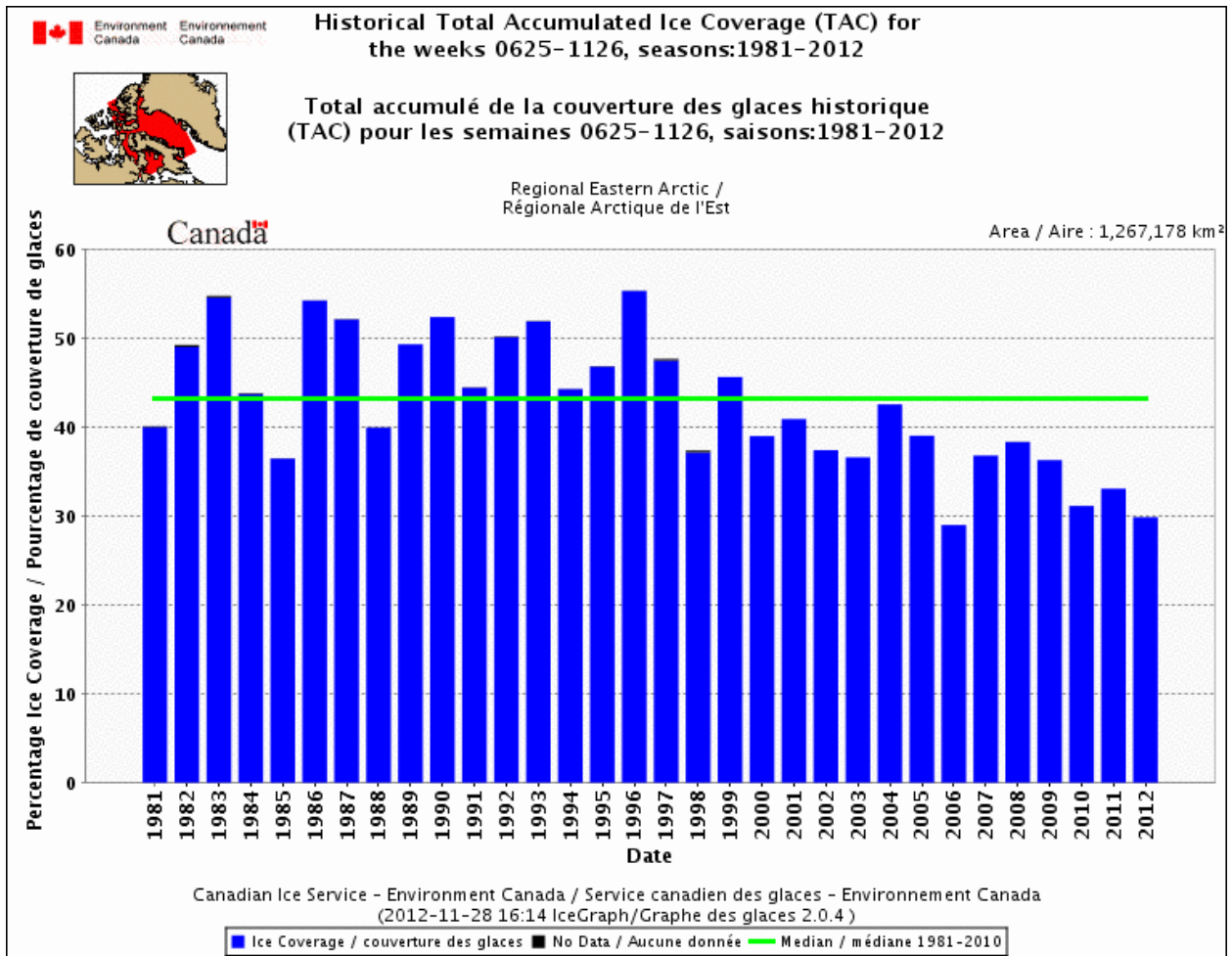


Ice Chart for 25 March 2013. (Environment Canada - Ice Branch)

## 8.4 Ice Condition Changes in Baffin Bay

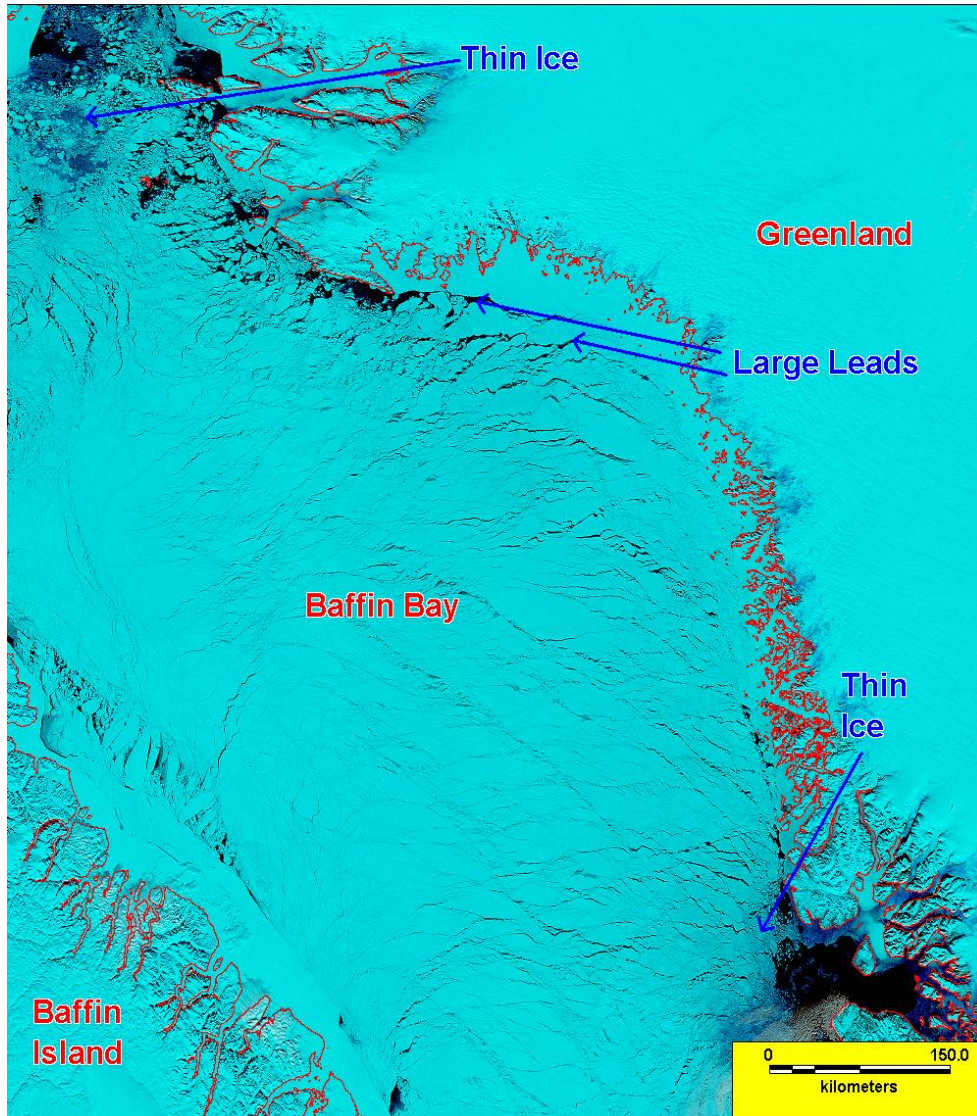
### 8.4.1 Sea-Ice Changes

The trend to reduced ice conditions in the Canadian Arctic continues in Baffin Bay in the winter of 2013. Shown below is a graph of the average ice cover in Baffin Bay since 1981 and the trend is clear. As seen below, 2012 was a light ice year leading into the 2012 2013 winter. Ice formation in Baffin Bay was 1 to 2 weeks later than normal and, as a result, ice thicknesses are slightly less, and break-up is expected to be earlier than normal as well.



Continuing decline of the ice cover in Baffin Bay

As of March 2013, Baffin Bay is in a mid-winter condition with total ice cover throughout as shown below. However, noted below are some ice features that point to an early break-up in spring 2013. The areas of thin ice and the amount of large fractures are all larger than normal. Some of these fracture lines have already opened up into large, elongated areas of open water, known as “leads”.



Baffin Bay Satellite image – 25 March 2013.

#### 8.4.2 Iceberg Production

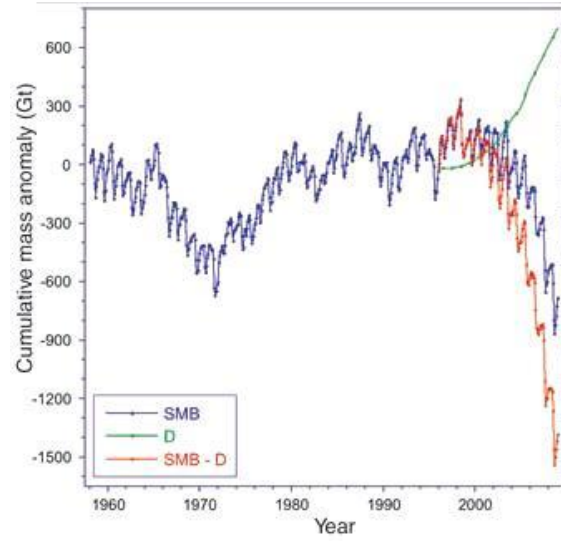
Calving rates of icebergs are influenced by the presence or absence of sea ice at the glacier front, and the dynamics of the ice cap or ice field feeding the glaciers. Although many studies have been published on the decrease of Arctic sea-ice extent and on what drives calving mechanisms in tidewater glaciers (e.g. Benn et al., 2007; Van der Veen et al., 2002), previous research on the relationships between sea-

ice conditions and iceberg calving is limited. Copland et al. (2007) studied the loss of the Ayles Ice Shelf on Ellesmere Island. A large portion of the ice shelf (over 80 km<sup>2</sup>) calved off rapidly in August 2005 during the warmest summer and the lowest sea ice extent on record, in a 14-day period when high offshore winds prevailed. Sea ice usually buttresses Ellesmere Island by the Beaufort Gyre. In the past, high concentrations of permanent fast ice in the area protected Ellesmere's ice shelves from wave impacts and relatively warm ocean water (Copland et al., 2007). The break off of the Ayles Ice Shelf occurred during unusually low sea ice conditions at a time when no fast ice was in place to protect the ice front. Therefore, the removal of the protective sea ice barrier seems to have had a direct relationship to the rapid calving of the ice shelf (Copland et al., 2007).

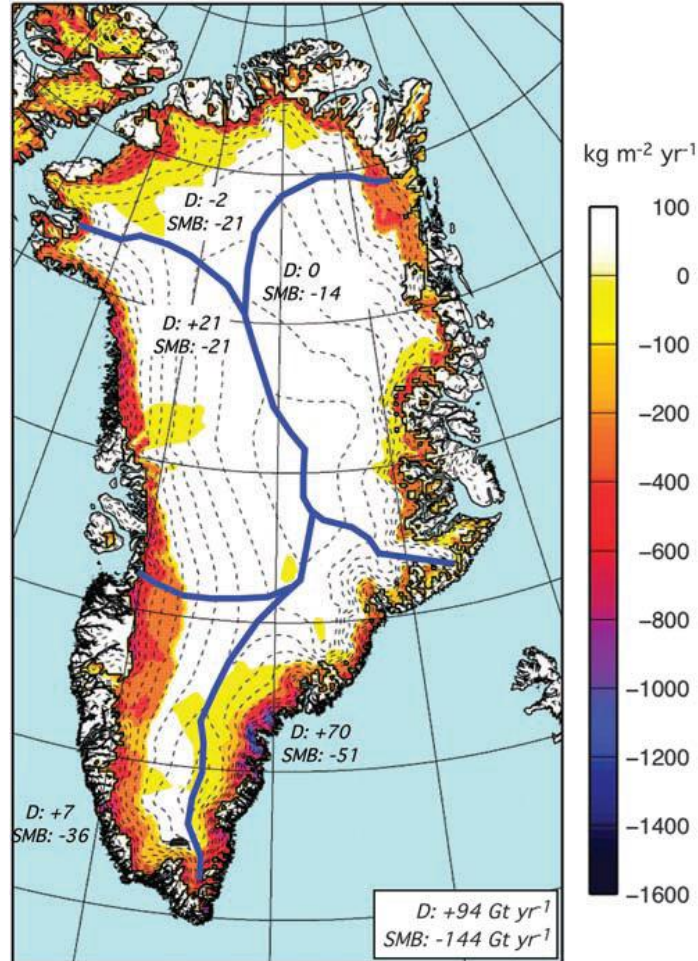
In a previous study, Reeh et al. (2001) found that fast sea ice conditions in front of Nioghalvfjerdingsfjorden Glacier in northeast Greenland have an important impact on the stability of its floating margin. Increased sea ice cover ensures greater stability by protecting the calving front from wave action and winds. Reeh et al., 2001, observed calving activity occurring only after fast sea ice had retreated. Calving events were not observed prior to fast sea ice retreat, but as the fast sea ice broke up, major calving events occurred. The same series of events were observed on other glaciers in northeast Greenland by Higgins (1989, 1991) using aerial photographs.

### **8.4.3 Greenland Ice Cap Dynamics**

Recent field and remote sensing studies along the east and west coastlines of the Greenland ice sheet indicate ubiquitous and accelerated mass loss. This is due to melt, runoff, precipitation, and sublimation, combined with significant increases in ice discharge or ice berg calving via outlet glaciers. In the 1990s, overall mass losses were very small (97 gigatonnes per year), indicating the ice cap was more or less in equilibrium; but by 2007, they had increased to 267 ± 38 gigatonnes per year (Broeke et al. 2009). The following diagram from Brooke and others (2009) shows the annual trend (SMB is surface mass balance or melt, runoff, precipitation, sublimation and D is calving).



Broeke and others (2009) further show in the diagram below that the most extreme losses due to calving, on outlet glaciers in the southern, eastern and western regions of the ice sheet.



Note that these changes, while dramatic in terms of increased production of icebergs, will still take centuries for this ice cap to melt away. This means the iceberg hazard will remain long into the future, although the distributions may change dramatically, as much of Greenland’s central land mass is actually below water level.

#### 8.4.4 Eastern Canadian High Arctic Ice Field Dynamics

Studies show similar trends in the combination of surface mass balance losses, plus iceberg calving losses for ice caps in the Queen Elizabeth Islands when compared with the Greenland Ice Sheet. Between 38% (Melville) and 58% (Devon) of the mass loss from four glaciers monitored here since 1963 occurred between 2000 and 2009. Between 30% (Melville) and 48% (Meighen) occurred between 2005 and 2009. The mean total loss for 2005–2009 was greater than the 1960–2009 mean by between 235 (Devon Ice Cap) and 402  $\text{kg m}^{-2} \text{ a}^{-1}$  (White Glacier) (Sharp et al., 2011). In the QEI, between 2004–2006 and 2007–2009, the rate of mass loss sharply increased from  $316 \pm 8 \text{ Gt yr}^{-1}$  to  $926 \pm 12 \text{ Gt yr}^{-1}$  in direct response to warmer summer temperatures (Gardner et al. 2011).

To put the mass losses occurring in the Queen Elizabeth Islands into a global perspective, the Patagonia icefields between Chili and Argentina lost ice at an average rate of  $286 \pm 11 \text{ Gt yr}^{-1}$  between April 2002 and December 2006. The glaciers of the Gulf of Alaska lost mass at an average rate of  $886 \pm 15 \text{ Gt yr}^{-1}$  for

the years 2004 to 2006, slowing to  $706 \pm 11 \text{ Gt yr}^{-1}$  for the years 2007 to 2009 (Gardner et al. 2011). The sharp increase in mass loss from the Queen Elizabeth Islands and the slowdown in loss from the Gulf of Alaska make the Canadian Arctic Icefields the largest contributor to eustatic sea level rise outside Greenland and Antarctica for the years 2007–2009.

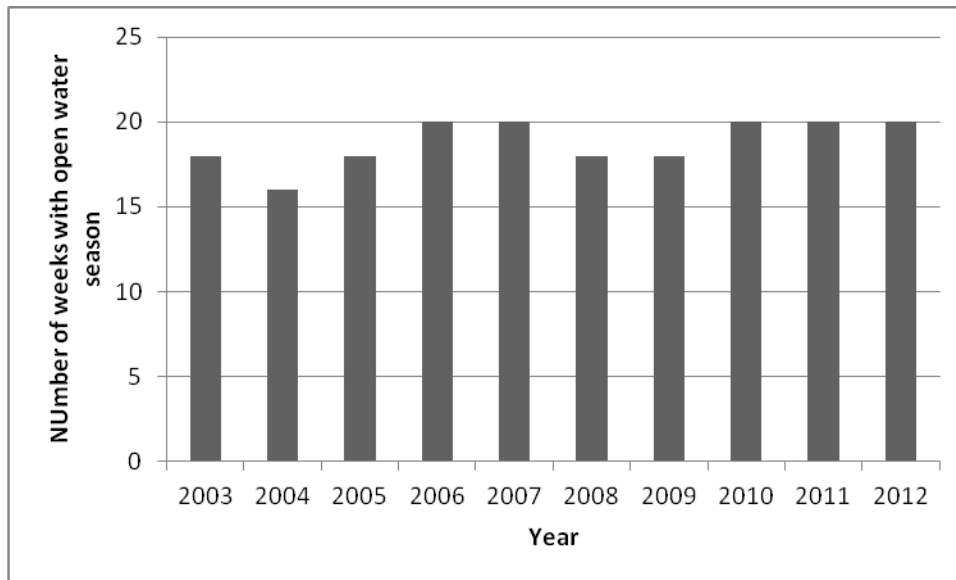
#### 8.4.5 Sea Ice Condition Changes in Hudson Bay

The following table shows the number of weeks of open water season for the last ten years.

Start Date	End Date	Number of Weeks
7-Jul-03	10-Nov-03	18
19-Jul-04	8-Nov-04	16
18-Jul-05	21-Nov-05	18
3-Jul-06	20-Nov-06	20
2-Jul-07	19-Nov-07	20
14-Jul-08	17-Nov-08	18
20-Jul-09	23-Nov-09	18
5-Jul-10	22-Nov-10	20
4-Jul-11	21-Nov-11	20
2-Jul-12	19-Nov-12	20

Graphing these data show there is possibly a small tendency for longer open water seasons to occur, but only to a very minor extent. This is rather different than for the Arctic Ocean indicating as we said at the outset that local basin conditions can be very different than the average tendency.





## 8.5 Implications for Shipping

The decrease in ice season length, reduced ice thicknesses, and decrease in total area of multi-year ice means that we can expect – on average – to see continually increasing shipping seasons throughout the Arctic. Further work will need to be made of each of the routes, especially the Hudson Bay possibility, to get a better picture of what might happen in the future. However, we may also see a great increase in icebergs and ice islands, as well as incursion of multi-year ice into areas where it has previously been blocked from entering by the presence of first-year ice. Unfortunately, there seem to be very few studies of Arctic shipping that focus on the highly specific and variable conditions of real ice situations along the routes. Typical in this respect is the study by Smith and Stephenson (2013), which uses highly complex simulation models, but only at the level of the entire Arctic Ocean basin average conditions, and so, in our opinion, are inapplicable to the issues of navigation.

There is a high degree of variation in ice season length, which means the above predictions will definitely not be accurate; there will be years when conditions revert to very severe. And to repeat, local conditions can be extremely different, both positively and negatively, than averages.

Finally, there is significant uncertainty about the existence of “tipping points”. As Wadhams (2012) explains, there could be a significant change in the rate at which ice cover melts, reaching a point where there is no longer any multiyear ice being formed, which could create a very different climatic regime of unpredictable characteristics. Others have posited more radical changes, such as the sudden melting of the arctic sea ice cover leading to a drastic reversal in the Labrador Current and Gulf Stream, making Greenland and Eastern Canada warm and Europe cold. If these types of events do not occur, then the above considerations hold. If such a condition were to pass, then there could be greatly accelerated melting and increase in shipping seasons.

However, discounting the unpredictable tipping point scenario, these favourable changes are still slow compared to project life spans and their economic planning horizons. A prediction of a 6 month open

water season directly over the North Pole by 2100, or even that unescorted shipping might be possible by 2040 (Smith, 2012), is not useful for the Government of Alberta to decide on an Arctic Energy Gateway investment in 2013. In summary, the best we can conclude now is that more favourable conditions for shipping will almost certainly continue to develop. But the uncertainties mean we must use current conditions for economic analyses. We conclude therefore that:

- Any High Arctic shipping will likely be seasonal for at least the next decade.
- A Churchill shipping route could be year-round, but limited to European markets.
- The transport system should take advantage of short windows of shipping opportunity that continually become more frequent and longer.

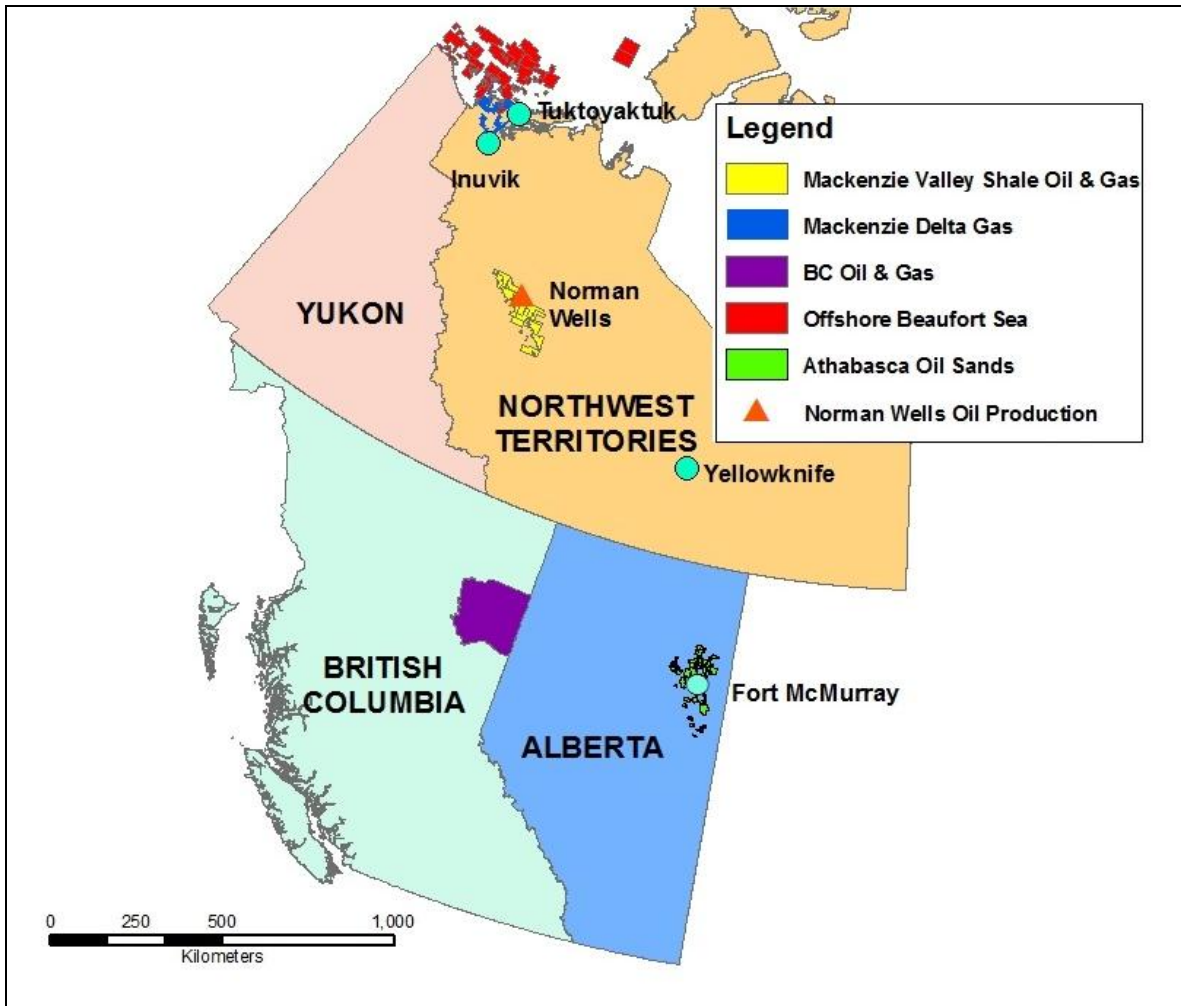
## 9 WESTERN ARCTIC RESOURCE COMPLEMENTARITIES

Infrastructure put into place for exporting oil sands product could have a great positive effect on the feasibility, cost and timing of other petroleum projects in the Mackenzie Valley, Delta, and offshore, including both oil and gas (which could be exported as LNG).

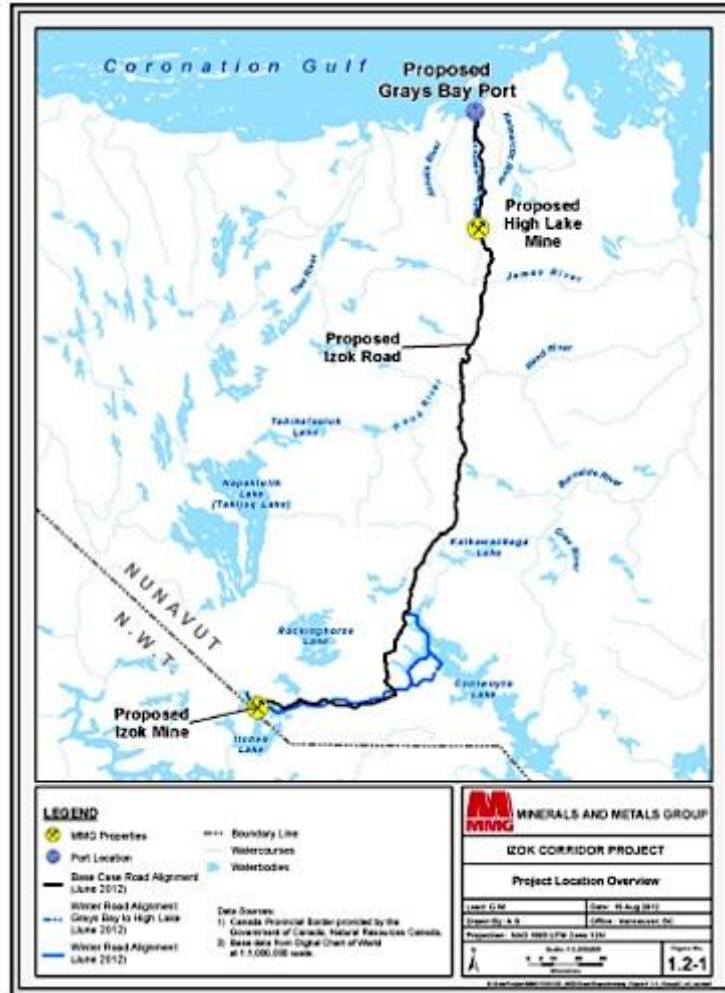
The petroleum resources along the route are:

Resource Area	Estimated # of Barrels of Oil	Cubic feet of Gas	Reference
Offshore Beaufort Sea Oil and Gas	4 to 12 billion	13 to 63 Trillion	<a href="http://en.wikipedia.org/wiki/Sachs_Harbour">http://en.wikipedia.org/wiki/Sachs_Harbour</a>
Mackenzie Delta Gas		6 Trillion	<a href="http://www.aadnc-aandc.gc.ca/eng/1100100037301/1100100037302">http://www.aadnc-aandc.gc.ca/eng/1100100037301/1100100037302</a>
Norman Wells Oil	260 million		<a href="http://www.aadnc-aandc.gc.ca/eng/1100100037301/1100100037302">http://www.aadnc-aandc.gc.ca/eng/1100100037301/1100100037302</a>
Mackenzie Valley Shale oil and gas	604 million	12 Trillion	<a href="http://www.iti.gov.nt.ca/publications/2013/energy/2012_OIL_GASResourcesV4.pdf">http://www.iti.gov.nt.ca/publications/2013/energy/2012_OIL_GASResourcesV4.pdf</a>
Northeastern B.C. Gas		78 Trillion	<a href="http://hornrivernews.com/about/">http://hornrivernews.com/about/</a>

The following map shows their locations.



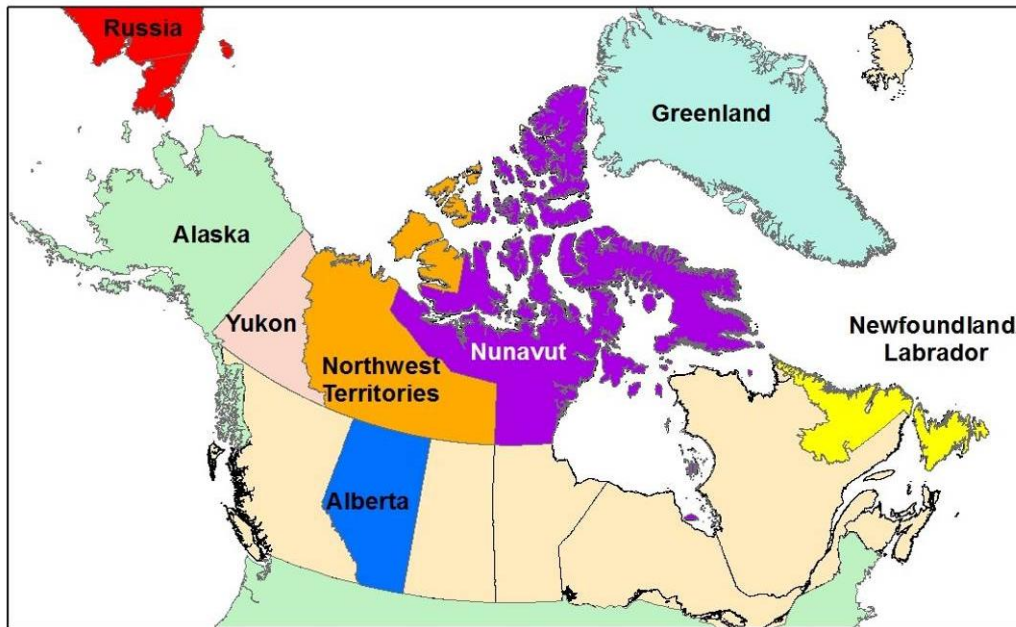
In addition to petroleum resources, there are major mining projects in the region that need marine transport. The MMG Izok Corridor zinc-copper mine is one such project; although currently delayed, it could benefit from lowered costs of shared marine transport infrastructure. The following figure shows the land routes involved.



This is a vast minerals and energy region that is waiting to be developed. Further evaluation of an Arctic Energy Gateway for bitumen should be done in the context of these other resources. They can share land, river and port logistics infrastructure, communications infrastructure, and housing. They can share transportation corridors for pipelines. In the case of shale oil, they can even use the same pipeline. Oil production and storage from the shale deposits and offshore can use the same storage and offloading facilities. There will be major economies of scale in almost all aspects.

## 10 ENVIRONMENTAL, SOCIAL, POLITICAL AND REGULATORY ASPECTS

In this chapter we present an initial overview of the environmental, social and regulatory climate within which an Arctic Energy Gateway will develop. This will assist the Alberta Government in how to present the findings of this technical prefeasibility study and how best to maximize chances for success.



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### 10.1 Social-Political Landscape

#### 10.1.1 The Northwest Territories

##### Mackenzie Gas Pipeline Footprint

A pipeline that is built on the basic footprint of the Mackenzie Gas Pipeline (MGP) benefits from the extensive environmental review, and the political and (general) community support this project ultimately received.

A key concern from a northern perspective will be the comparative benefits of these two projects. The MGP was perceived as an economic game changer in the region, and had the possibility of transformative benefits for aboriginal land claim interests and northern communities. Direct and indirect benefits flowing to Northern communities for their roles in a transportation corridor (i.e. not directly linked to regional production) are likely to be perceived as less significant. That said, an incremental approach could be welcomed as a catalyst by local interests seeking greater economic development within the Inuvialuit Regional Corporation; using rail to transport bitumen to Hay River followed by fuel barges to Tuktoyaktuk could build momentum and rekindle enthusiasm for a Mackenzie Valley Pipeline.

Northern economic benefits negotiated for the MGP include:

1. An ownership stake in pipeline profits through the Aboriginal Pipeline Alliance.
2. Social and community support through the Socio-Economic Agreement and Mackenzie Gas Project Impact Fund.
3. Benefit plans for gas fields and gathering systems.
4. Employment, contracting, and services associated with pipeline construction and operation phases.

The Arctic Energy Gateway could employ a similar strategy to balance environmental risk and associated economic rewards in a manner consistent with regional aboriginal expectations and historical precedents.

The following table describes five discrete aboriginal interests within the proposed development corridor of the Arctic Energy Gateway.

Aboriginal Regions and Communities		
Area	Region	Communities
Northwest Territories	Inuvialuit Regional Settlement Region	Aklavik, Tuktoyaktuk, Ulukhaktok, Paulatuk, Inuvik, Sachs Harbour
	Gwich'in Settlement Area	Inuvik, Aklavik, Fort McPherson, Tsiigehtchic
	Sahtu Settlement Area	Norman Wells, Fort Good Hope, Deline, Tulita, Colville Lake
	Akaiicho Territory Government	Dettah, N'Dilo, Fort Smith, Lutselk'e, Fort Resolution
	Dehcho Region	Fort Simpson, Fort Providence, Fort Liard, Wrigley, Nahanni Butte, Trout Lake, Jean Maria River, Kakisa, Hay River Reserve, West Point reserve
Northwest Alberta	Dene Tha' First Nation	Chateh, Meander River, Bushe River

The National Energy Board's recommendation in 2010 to approve the MGP provides some assurance that many of the social, political, environmental, and economic aspects of constructing a major pipeline up the Mackenzie Valley have been addressed. The economic arrangements (summarized above) in conjunction with 200 more recommended terms and conditions designed to assuage regional concerns culminated in a risk/reward ratio that was broadly acceptable for political interests and affected communities.

From an environmental, regulatory, and socio-political perspective, any assessment of an Arctic Energy Gateway shipping proposal needs to build on the findings of the MGP. Such a proposal would also need to account for the key differences between these two similar development proposals. These include:

- A bitumen pipeline instead of a gas pipeline
- Increased fuel barge transport up the Mackenzie River (in advance of a pipeline)
- Building a tanker off-take system from Tuktoyaktuk to global markets
- Oil storage facilities
- Arctic Shipping, Arctic spill prevention, spill response
- Additional Arctic jurisdictions affected.

### The Government of the Northwest Territories

The Government of the Northwest Territories (GNWT) has a strong incentive to support economic partnerships in this region and, in particular, transportation projects that may have secondary benefits to local economic development. Tellingly, Premier Bob McLeod made it clear that he would consider supporting a south-north bitumen pipeline if the Mackenzie Gas Pipeline was in fact dead. Premier McLeod offered CBC News the following quote, “the N.W.T can’t afford to have its natural resource stranded for another 40 years.”

The GNWT signed (March 2013) a *Devolution Agreement-in-Principle* with the Federal Government. Currently, 100% of state revenues from resource development flow to the Federal Government. Assuming the Agreement is adopted, the GNWT stands to collect 50% of resource revenues derived from such activities on public land up to an annual limit of \$60 million. This agreement will not apply to ownership and resource revenue from the offshore. However, the agreement-in-principle provides that Canada must begin negotiations regarding revenues from offshore resources once the final devolution agreement is achieved.

The GNWT has agreed that one quarter of territorial resource revenues will be passed on to aboriginal governments that sign on to the final devolution agreement. Though the majority of Aboriginal Governments within the Northwest Territories have also signed on to the agreement-in-principle, the Akaitcho Territory government and the Dehcho First Nations have not.

### Inuvialuit Regional Corporation

The Inuvialuit Regional Corporation (IRC) has responsibility for managing the affairs of the Inuvialuit, within the Inuvialuit Settlement Region (ISR), as outlined in their 1984 land claim agreement, the Inuvialuit Final Agreement (IFA). The ISR includes the communities of Aklavik, Inuvik, Paulatuk, Sachs Harbour, Tuktoyaktuk and Ulukhaktok and covers the Mackenzie Delta, as well as the NWT’s Beaufort coastline and also applies to the Canadian Beaufort and a significant part of the Arctic Ocean to the north, west and east of Banks Island.



The IRC continues to be led by former NWT premier Nellie Cournoyea, re-elected in February 2013 for a 9<sup>th</sup> consecutive term as Chief Operating Officer of the IRC. With such a strong political leader, the IRC remains a powerful political organization in the Northwest Territories. Recent signs point to IRC cooperation or endorsement of hydrocarbon-related industries in the region. Upon her re-election, Ms. Cournoyea provided perspective on her new term's agenda: "it will focus on offshore oil and gas exploration, the planned Inuvik to Tuktoyaktuk highway, devolution, and the Inuvialuit self-government file" (*Northern Journal*, 2013).

The Inuvik to Tuktoyaktuk highway was granted final approval and construction was set to begin March 2013. The IRC expects that year round road access to Tuktoyaktuk – its port and hydrocarbon infrastructure - will stimulate new development interest and proposals from the petroleum industry.

Any expectations within IRC that the MGP would be the catalyst for northern economic growth for the Inuvialuit are diminished as industry interest wanes. As a result, the IRC is increasingly inclined to support deep sea exploratory drilling in the Beaufort offshore (practices that in the past the IRC would have criticized as too environmentally risky given the social and economic importance of the marine environment to Inuvialuit). Absent a southbound pipeline, this future hydrocarbon production will also be dependent on marine routes out of the Beaufort.

#### Inuvialuit Game Council

The Inuvialuit Game Council (IGC) represents all Inuvialuit in wildlife management. The IGC is a highly influential organization within regional politics, and has a powerful voice in regulatory matters, including environmental assessment processes. The IGC is unlikely to support any proposal to ship crude oil (and especially another jurisdiction's crude oil) based on grounds of unacceptable environmental risk to present and future wildlife harvesting.

However, a reflection of the IGC's engagement in presently contentious development proposals illustrates a willingness to work directly with proponents. The IGC has recently demonstrated considerable faith in the National Energy Board's regulatory effectiveness, and the Council typically adopts a pragmatic approach to considering industrial proposals.

### **10.1.2 Eastern Route: Nunavut and Greenland**

#### Nunavut

The government of Nunavut has internally concluded that its devolution aspirations, including the transfer from Ottawa of ownership and control of natural resources, are contingent on greatly increased revenues from natural resource exploitation and, in particular, from hydrocarbon extraction. However, there is very limited oil and gas exploration occurring in this territory (essentially limited to seismic exploration in Baffin Bay/Davis Strait, and completely in Danish waters), despite estimates that suggest that Nunavut could contain vast reserves of oil and gas. The great bulk of these potential hydrocarbon supplies are thought to lie in the offshore. In the absence of a devolution deal (still years away), Nunavut has little direct incentive to promote hydrocarbon exploration in its region. New tanker

shipping routes that could also open up transport of Nunavut oil may not therefore be of major economic interest at this time (but could provide impetus for a devolution deal).

In recent years, the Federal Government has sought to open Nunavut waters to oil exploration, but the process has not generated much industrial interest. The relative regulatory complexity of the land claim, the young Territory (Nunavut came into existence in 1999), and opposition in many communities to oil and gas development have likely deterred (or delayed) oil industry investment in this region. However, this situation is changing under the influence of the dramatic offshore exploration activities very close by, in West Greenland waters of Baffin Bay. The National Energy Board (NEB) is presently evaluating a proposal by a seismic company to begin exploration off Baffin Island. This process has gone more slowly than hoped for, by the company in question, but it is not clear yet if the delays are due to NEB processes or community concern in the public hearings; it seems that both factors might be involved.

Shipping through Nunavut (i.e. federal water, but subject to the Nunavut Land Claim Agreement) may create some local economic spin-offs (e.g. pilotage, navigational services), but the proposed benefits may not be enough to allay concerns related to the risk of a catastrophic spill.

All but one of Nunavut's communities are coastal. While commercial fishing is mainly limited in Nunavut to Baffin Bay and Davis Strait (with additional inshore and freshwater char fisheries in some communities), subsistence harvesting occurs in every major waterway in Nunavut and constitutes a major food source (not to mention its cultural importance). Accordingly, opposition to bulk shipments of crude through Nunavut waters can be anticipated both at the community level and through official channels.

### Greenland

It is important to consider Greenland in this analysis, as the shipping route eastward will go down through Greenland (Danish/EU) waters. At present, no opposition can be expected from adjacent Greenland, which has enthusiastically embarked in recent years on its own offshore exploration programme. It is more likely the navigation infrastructure improvements that will occur, will generate a positive response, and the activity will seem as a corroboration of their own processes. Greenland is in the process of becoming a country, although in what form is far from clear, as the population base is so small and few people have higher education and international experience. Offshore petroleum development (along with mining, which requires shipping) is absolutely critical to provide revenue and employment for this independence. Greenland is presently undergoing rapid modernization, and has a culture with strong social, cultural and economic ties to the natural environment. From 1979, a devolution process continues to unfold—this small population (approximately 56,000 citizens) has emerged as a dynamic parliamentary democracy. In 2009, the *Act on Greenland Self Government* (AGSG) resulted in the devolution from Denmark of responsibility for justice, policing and, significantly, natural resources to Greenland. With that, the regulation of hydrocarbon exploration and exploitation passed from the Danish Minister of Energy to Greenland's Bureau of Minerals and Petroleum (BMP).

Official policy and political rhetoric, however, appear to suggest that the development of an offshore oil industry constitutes one of the key ingredients to full independence (although a recent election and resultant transfer of power to a more conservative and traditional party may signal a slowdown in enthusiasm for offshore drilling, if community and employment benefits cannot be more clearly demonstrated).

### 10.1.3 Western Route: Alaska

The United States is not a party to the United Nations Convention on the Law of the Sea (UNCLOS), but adheres to virtually every principle of the Law of the Sea, including innocent passage. This means that it recognizes the right of innocent passage, according foreign vessels the right to transit its territorial waters without interference.

However, there are exceptions to this principle. Depending on the particular shipping plans (time of year, vessel construction, equipment, crew competency), the United States could conceivably object to oil tanker transit, particularly through Bering Strait for reasons of navigational safety and environmental protection. A state's ability to apply domestic laws that interfere with the progress of a foreign vessel through its territorial waters is limited – such laws must be “giving effect to generally accepted international rules or standards” (UNCLOS, art. 21).

U.S. commercial interests set the precedent for tanker transits of the Northwest Passage in 1969 with the successful transit of the *SS Manhattan* (although its cargo was water. However, it is important to consider that oil companies do not ship oil out of U.S. waters east of the Bering Strait by sea. Rather, production facilities (presently limited to the North Slope and near shore) use a pipeline route from Prudhoe Bay to Valdez, Alaska, on the Pacific Ocean—from which point oil continues by tanker.

Absent a legal mechanism for prohibiting the passage of oil tankers through Bering Strait, Alaskan opposition could end up as pressure coming from Washington to Ottawa. This could conceivably affect not only Bering Strait exports, but also access to the Russian Northern Route, despite the eagerness of Russia to expand commercial traffic.

Alaska, a state not unfamiliar both with the economic benefits of the oil industry and with an appreciation for some of the shipping risks, has strong indigenous, environmental, and fishing interests along its coastline. Alaskan opposition to tanker traffic through the Chukchi and Bering Seas could be intense. Citizens groups, NGOs, fisheries interest and regional indigenous organizations have mounted considerable campaigns against offshore drilling proposals and have succeeded in barring oil exploration from some areas of ecological sensitivity (e.g. Bristol Bay). Shell Oil suspended its 2013 drilling programme in the Chukchi and Beaufort Seas after two calamitous seasons which culminated in a litany of regulatory violations and the grounding of its drilling rig off the south coast of Alaska.

In spite of setbacks, the company is still planning for commercial production oil from its Chukchi and Beaufort Sea acreages. The off take system required for these wells will be at least as complex and costly as drilling the exploratory wells themselves. Shell has stated in its exploration plans the intention to construct 350 miles (650 km) of new pipelines from production sites to the existing trans-Alaska

pipeline. This project could cost approximately \$50 billion. The pipeline proposal will encounter a complex regulatory system and intense opposition from the Inupiat and Arctic Energy Alliance (a coalition of environmental non-governmental organizations).

#### **10.1.4 Churchill – Hudson Bay Route**

The Manitoba government actively promotes Manitoba as a transportation corridor and hub and advances policies to promote various initiatives, including the "Mid-Continental Trade Corridor", the "Arctic Gateway", and the "Arctic Bridge".

All of these plans put great emphasis on the Port of Churchill. The port is privately-owned by OmniTRAX inc., which also owns the Hudson Bay Railway with the only rail link between Churchill and The Pas, where it connects with the Canadian National Railway (CNR) line.

The port has for decades been completely reliant on grain exports through the Canadian Wheat Board. Both before and after the dismantling of the CWB's monopoly in 2012, the port has attempted to reinvent itself as a more dynamic full-service industrial port. OmniTRAX is undoubtedly supportive of an expanded role that would include bulk oil shipments through the port.

The town of Churchill, which remains concerned about the long term viability of the port, could be expected to be largely supportive of increased shipping. However, the high reliance on wildlife-related tourism in the region would create anxieties and some opposition to bulk shipments of crude oil should be anticipated.

A pipeline coming either directly from the Fort McMurray area or from the south would cover significant areas of bog and permafrost; this would also be a source of public anxiety and potential opposition from adjacent aboriginal communities which have treaty and land rights.

## **10.2 The Environmental Context and Associated Risks**

### **10.2.1 The Environmental Context**

The development corridor for the Arctic Energy Gateway could impact many of Canada's most pristine and notable Arctic ecologically and biologically significant areas. The project also has implications for sensitive marine environments in the U.S. and Greenlandic national waters. These regions are home to the world's largest seasonal concentrations of many iconic Arctic wildlife species such as polar bears, beluga whales, bowhead whale, narwhal, walrus, ringed and bearded seals, and breeding colonies of seabirds and shorebirds.

#### The Beaufort Sea

The Beaufort Sea ecosystem is shared by Canada and the United States (approx. 55% lies in Canada). It consists of a central, 3500 m deep basin, the Canada Basin, and a continuous continental shelf that lies

between the shelf of the Chukchi Sea to the west and that of the Arctic Archipelago to the east. Between the deep floor of the Canada Basin and the shallow shelves of the Beaufort Sea lies the continental slope. The Beaufort Sea is marked by its sub-Arctic climate and extreme seasonal and inter-annual variability. During the ice-free summer months the region acts as critical feeding, breeding, calving, moulting, and staging ground for the myriad of biota that frequent the region.

### Great Slave Lake

Great Slave Lake is the deepest lake in North America and, by surface area, the ninth largest lake in world. It is the centre of a watershed that drains nearly 25% of Canada's landmass. Great Slave Lake serves as the headwaters for the Mackenzie River.

### Mackenzie River and Delta

The Mackenzie River is the largest North American river flowing into the Arctic. The Mackenzie Delta is the second largest delta in North America. The river and delta form an incredibly productive and unique ecosystem which supports huge populations of anadromous fish, caribou, and the largest breeding colonies of snow geese anywhere in the world.

### Lancaster Sound

While there are several routes that comprise the Northwest Passage and some options with respect to shipping routes, Lancaster Sound is the only practicable eastern exit to the Atlantic Ocean. This marine region's biological productivity and importance to Inuit communities are cited as reasons which underlie the decision to create National Marine Conservation Area (negotiations for its official status as an NMCA are well underway) in Lancaster Sound. In 2011, the Federal government imposed a moratorium on oil and gas exploration, including both seismic testing and drilling. A conflict, in 2009, between the Federal Government (Natural Resources Canada) and regional Inuit who opposed the government's plans to conduct seismic testing in the Sound ended in litigation. Inuit successfully obtained an injunction halting the progress of this ship-based exercise.

## **10.2.2 River Transport**

In 2009, the Northwest Territories Water Board held an information session to better understand the practice and regulation of fuel storage in ice-bound barges in the Inuvialuit Settlement Region. Industrial projects routinely rely on Northern Transportation Company Ltd. (NTCL) single-hulled barges to over-winter fuel in the region. Environment assessments of several of these projects culminated in a study, *Overwintering of Barges in the Beaufort: Assessing Ice Issues and Damage Potential*, commissioned by the National Research Council of Canada as part of the Beaufort Regional Environmental Assessment Program. This report identified a number of environmental problems with barge transportation of fuel on the Mackenzie.

NTCL's barge fleet is single-hulled, a fact which attracts criticism from such groups as the Inuvialuit Game Council and Fisheries Joint Management Committee. Arctic Gateway Portal plans to utilize fuel barges to transport bitumen from Hay River to Tuktoyaktuk would likely necessitate improved (i.e. double-hulled) barges.

### 10.2.3 Sea Transit-Arctic Oil Spills

Arctic spills, more challenging to prevent, respond to, and remediate than those in temperate regions. They present an acute, long-term threat to fresh and saltwater environments. Although naturally occurring hydrocarbon metabolizing bacteria are present in the Arctic Ocean, cold temperatures, multi-year ice, and seasonal ice inhibit their ability to quickly break down hydrocarbons. Further, the traditional suite of oil spill response countermeasures: mechanical recovery *in situ* burning, and the application of chemical dispersant were not specifically designed for the harsh Arctic environment.

Stakeholder groups will be concerned about the possibility of a large marine bitumen oil spill. Canada's oil spill response system lacks the equipment, personnel and logistical capacity to effectively respond to oil spills in the Arctic.

- The number of trained, professional responders who could respond to an oil spill in Canada's Arctic Ocean is well below what would be necessary in the event of a major spill event. Northern community members lack sufficient training as responders. Oil spill response efforts require a massive amount of labour, and almost always rely partly on local community volunteers. In the Arctic, responders will be mobilized from far distances.
- Canadian Coast Guard lacks equipment necessary to respond effectively to oil spills in the Arctic. The Coast Guard maintains around 80 equipment depots throughout Canada, 22 of which are located in the Arctic. The National Energy Board's Review describes these Arctic depots as consisting of "Canadian Coast Guard Arctic community packs containing basic spill control equipment for near-shore vessel spills." The Canadian Coast Guard's capacity to mobilize personnel for an Arctic response is unknown and untested.
- Two of the three primary response organizations, the NEB and DAAND, have minimal personnel capacity to respond to spills. No oil spill response organizations are certified to work in the Arctic.
- Canada's environmental sensitivity mapping for the Arctic is out of date. In 2004, Environment Canada updated its sensitivity atlas for the Beaufort Sea with data from 1997 and 2003. Atlases covering the rest of the Arctic have not been updated since the early-mid 1990s.
- Canada has a decentralized emergency management command structure criticized as less effective than its U.S. counterpart. Canada currently uses an *Incident Management System* to coordinate oil spill response efforts while the United States adopted an *Incident Command System*. Canada's system lacks a "unified command" structure with a central command body (FOOSC). The unified command is almost ubiquitously cited as a key component in effective

response measures. Canada’s 2010 Auditor General’s report on oil spill response from vessels questions Canada’s choice of the response management system over the incident command system.

Marine Mammals

Many environmental concerns in relation to bulk tanker oil shipments apply across Arctic waters. The Northwest Passage (or, more accurately, passages) provides navigational routes not only for human transport. Marine mammals use many of the same routes, seasonally, in and out of the Arctic Archipelago from both the east (via Lancaster Sound) and the west (via Amundsen Gulf and McClure Strait). Disruption of marine mammal activities may adversely impact the indigenous communities who rely on them for their traditional harvesting activities.

Migrating marine mammals in the Northwest Passage include narwhal, beluga, bowhead, and harp seals. Killer whales are also sighted (increasingly) in these waters. Several arctic marine mammal and fish species are listed under COSEWIC and SARA. In addition, there are resident walrus and seal populations that remain in Arctic waters year-round. Indeed, in summer months, over 70% of the world’s population of narwhal and beluga reside in waters between the Beaufort and Baffin Bay/Davis Strait (many in or immediately adjacent to the principle shipping routes through the Northwest Passage).

There is evidence to suggest that Arctic whale populations, less exposed to ship traffic and attendant noise, are more susceptible than other whales to this disturbance. Narwhal, beluga and bowhead all exhibit dramatic ship avoidance strategies. Nevertheless, the seismic work conducted in the Beaufort since 2009, following current marine mammal detection and avoidance procedures has worked entirely satisfactorily, and has involved Inuvialuit observers successfully.

Recurrent and large-scale shipping would likely necessitate mitigation measures in several key regions, including waters used by Inuvialuit in the Beaufort, offshore the North Slope of Alaska, and in Nunavut in Lancaster Sound. Such mitigation might include: marine mammal observers on board, route modifications in consultation with indigenous (Inuit, Inuvialuit, Inupiat) wildlife managers and federal agencies (DFO).

Summary of Project Potential vs. Risk			
Region	Potential Economic Benefit	Primary Risk	Aboriginal Subsistence Value
Great Slave Lake	Moderate	◆ Single hulled fuel barge	High

		accident or spill	
<b>Mackenzie River and Delta</b>	High	<ul style="list-style-type: none"> <li>◆ Single hulled fuel barge accident or spill</li> <li>◆ Pipeline leak or Rupture</li> </ul>	High
<b>U.S. and Canadian Beaufort Seas</b>	Uncertain	<ul style="list-style-type: none"> <li>◆ Storage facility leak or accident</li> <li>◆ Pipeline leak or rupture</li> <li>◆ Ship-based spill</li> </ul>	High
<b>Chukchi Sea</b>	Uncertain	<ul style="list-style-type: none"> <li>◆ Ship-based spill</li> </ul>	High
<b>Bering Strait</b>	Unlikely	<ul style="list-style-type: none"> <li>◆ Ship-based spill</li> </ul>	High
<b>Lancaster Sound</b>	Uncertain	<ul style="list-style-type: none"> <li>◆ Ship-based spill</li> </ul>	High
<b>Baffin Bay/Davis Strait</b>	Unlikely	<ul style="list-style-type: none"> <li>◆ Ship-based spill</li> </ul>	High
<b>Internal waters of the Arctic Archipelagos</b>	Uncertain	<ul style="list-style-type: none"> <li>◆ Ship-based spill</li> </ul>	High

## 10.3 Regulatory Environment

### 10.3.1 International: IMO

The International Maritime Organization (IMO) currently has voluntary Polar Guidelines for ships operating in ice-covered waters

IMO is in the process of developing a Polar Code which will include mandatory provisions and recommended guidelines for most vessels operating in polar waters. The code will address design, construction, crew requirements and environmental protection safeguards. An initial target completion date of 2012 has not been met, and there is some scepticism regarding the revised 2014-5 target.

### 10.3.2 Liability

Across Canada, distinct liability regimes govern different aspects of hydrocarbon resource development (e.g., offshore exploration and production, transportation by pipeline, transportation by tanker).



Canada's current offshore liability regime imposes limited absolute liability on operators and "channels" liability onto the operator – the polluter pays principle.

Legislation applicable to liability issues of interest to barging, shipping, and pipelines to transport hydrocarbons to and from Canada's Beaufort Sea includes the *Canada Oil and Gas Operations Act* (COGOA) for pipelines and the *Canada Shipping Act* for a spill from a tanker or barge. Original liability limits were first established in 1987 and have not been revised since. In 2013 the federal government is expected to table new liability legislation applicable to petroleum transport and production. In addition, many Arctic marine waters also fall within the boundaries of a number of different land claim agreements.

### 10.3.3 CEEA and MVEIRB

Though the National Energy Board has policies for coordinating with the Inuvialuit Environmental Review Board (see below) under the requirements of the old *Canadian Environmental Assessment Act*, the NEB's *Filing Requirements for Offshore Drilling in the Canadian Arctic* make no reference to the provisions of *CEAA 2012*. It is unclear how NEB environmental assessments will proceed under *CEAA 2012*, as the NEB's Filing Manual is currently being updated to reflect changes to the federal environmental assessment regime.

The Mackenzie Valley Environmental Impact Review Board is a co-management board responsible for the environmental impact assessment process in the Mackenzie Valley. Aspects of any pipeline development through the Mackenzie Valley will necessarily involve participation of this board. The Board consists of nine federally-appointed members and eight Board members appointed in equal numbers from nominations submitted by the federal and territorial governments and from aboriginal land claimant organizations.

### 10.3.4 The Inuvialuit Final Agreement

Whether by pipeline or fuel barge, the Arctic Energy Gateway's plans to centre off-take system in Tuktoyaktuk, within the Inuvialuit Settlement Region (ISR). The Inuvialuit Final Agreement (IFA, the first comprehensive Arctic land claim agreement, signed in 1984). The IFA's resource management system will be triggered in two unique, but concurrent ways: (1) negotiation of a participation agreement with the Inuvialuit Land Administration and (2) a successful project screening or review by the Inuvialuit Environmental Impact Screening Committee and/or the Environmental Impact Review Board.

An Arctic Energy Gateway will require substantial use of Inuvialuit lands in and around the community of Tuktoyaktuk. The Inuvialuit Regional Corporation (IRC) was created to manage the affairs of the Inuvialuit including their private lands. The IFA grants the Inuvialuit exclusive ownership of surface (71b lands) and subsurface (71a lands) rights to nearly 5000 sq. miles of land. The division of the IRC that administers and manages Inuvialuit lands is the Inuvialuit Land Administrations (ILA).

The ILA and project proponents will typically negotiate voluntary cooperation agreement, and the IFA provides that "to the extent that those agreements conform with government requirements (such as benefit agreements) the government may accept them as sufficient to satisfy its approval process." The

ILA has the authority to negotiate an “appropriate land rent,” in addition to a Participation Agreement. The Participation Agreement can contain terms and conditions related to the following areas:

1. Inspection costs
2. Wildlife compensation, restoration, and mitigation
3. Employment, service and supply contracts
4. Educations and training
5. Equity participation or other similar types of participatory benefits.

### Regional Environment Assessment

The other aspects of the IFA that will be significant from a political/regulatory perspective are the environmental assessment institutions and co-management boards that feed into review and approval processes. The Canada Environmental Assessment Act (CEAA) also applies to such a project within the ISR.

The first step in the *IFA* environmental assessment process is submission of a Project Description to a screening panel that must then make a decision as to whether the development could have a significant negative impact on present or future wildlife harvesting, in which case the screening panel must refer the development to the Environmental Impact Review Board (EISC).

The EIRB will prepare a final report with its recommendations to be submitted to the relevant federal authority, with terms and conditions the EIRB deems necessary. Terms and conditions can relate to:

1. the ability to meet present economic, social and cultural needs while preserving the natural environment for generations to come;
2. preserving the ability to continue with activities such as hunting, trapping, fishing;
3. mitigative and remedial measures;
4. appropriate monitoring requirements; and
5. an estimate of the potential liability of the developer in a worst case scenario.

The federal authority will choose to accept, alter, or reject these recommendations. No permit or license shall be issued without final approval.

### **10.3.5 Nunavut**

Any Eastern shipping route to the Atlantic through the Northwest Passage would cross marine areas within Nunavut and therefore within the ambit of the Nunavut Land Claims Agreement (NLCA). Industrial projects within Nunavut ordinarily trigger jurisdiction of the Nunavut Impact Review Board (NIRB), which assesses impacts of proposed development projects and makes approval and licensing recommendations to the responsible territorial or federal Minister (as the case may be). The NIRB places great emphasis on ecosystemic and human health in its assessment of development proposals. The NIRB has imposed significant restrictions on industrial shipping proposals within Nunavut including wildlife monitoring obligations and route modifications.

However, bulk carriers of unrefined oil products not originating in the Territory would not likely be associated with any industrial project within the Nunavut Settlement Area and would instead be transiting the region. Accordingly, such ship movements would not be subject to NIRB overview (NLCA art. 12.12.2).

### 10.3.6 National and Regional Regulation of Oil Spills

Regulatory authority for responding to oil spill depends on the nature of the spill. An operator has initial authority over production related incidents with, cascading support from outside agencies and government.

Environment Canada has the lead in implementing the *National Environmental Emergencies Contingency Plan*, which describes government responsibilities during environmental emergencies including oil spills. In addition to this national plan, each marine area of Canada has a regional version. The *Arctic Regional Environmental Emergency Plan* outlines the framework, purpose, functions and composition of the team, notification and activation procedures that would be followed in the event of a spill, and the classification and escalation of response to environmental emergencies.

Transport Canada and the Canadian Coast Guard lead the implementation of the *National Marine Oil Spill Preparedness and Response Regime*. Each has delineated responsibilities for the implementation of the regime, which also relies on a strong partnership between government and industry.

In 1993 the CCG began to devolve its ability to respond to a major oil spill to the private sector through the establishment and certification of Response Organizations (RO). A goal of this shift towards a partnership with industry to deal with marine oil spills was an enhanced capacity to plan for, respond to, and remediate large spills.

All ships in Canadian waters or oil handling facilities are required to have an oil pollution emergency plan on hand and arrangement with *Certified Response Organization* (certified by Transport Canada) Certification criteria outlined by *Response Organizations and Oil Handling Facilities Regulations*. There are five Certified Response Organizations. Presently an RO does not exist for the Arctic, in its stead the National Energy Board acts as the RO. The certification system for private ROs only requires spill response capacity up to 10,000 tonnes. The ROs are owned directly or in an indirect way by industry.

### 10.3.7 The Arctic

Canada's national approach to spill preparedness and response is attenuated in the Arctic. For ship-based or phantom spills the response structure is consistent with the national regime. It should be noted that although the structure remains the same, the level of resources the system can bring to bear in an Arctic context is not clear.

In the Arctic the fundamental difference in responding to oil spills, which are related to oil and gas drilling or production is that the NEB, under section 25(4) of COGOA acts as the RO. The specific roles and responsibilities of government agencies and industry in the event of an oil spill in Arctic Canada are as follows:

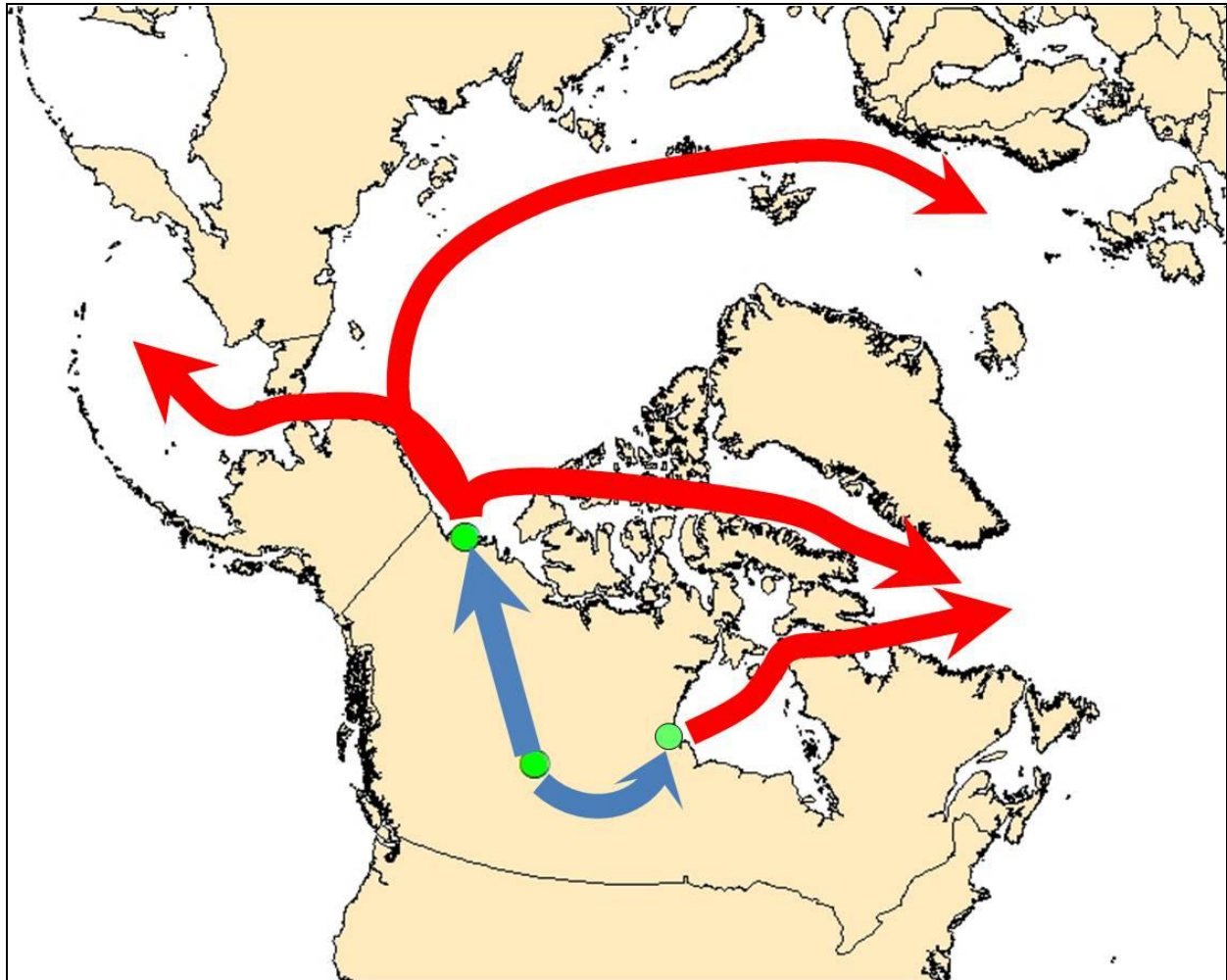
The NEB is the primary oversight body for spill response. Section 25(4) of COGOA also states that the Chief Conservation Officer at the Board can authorize and direct workers to enter the spill area, take over the management and control of activities, and take all reasonable measures to prevent further spill and mitigate damages. As the lead agency for spill response from offshore exploration and production facilities under the *Northwest Territories/Nunavut Spills Working Agreement*, the NEB is responsible for the initial evaluation of the spill, spill coordination, and supervision of containment and clean-up measures. The NEB can monitor the clean-up efforts, assist the polluter if their resources aren't adequate, or direct the cleanup if the operator is unable or unwilling to respond to the spill. Positive reporting obligations are imposed on operators.

Arctic REET (Regional Environmental Emergencies Team) is an interagency committee that includes representatives from federal, territorial and Aboriginal organizations and is chaired by a representative of Environment Canada. The REET is to provide consolidated environmental advice to responsible agencies in the event of an oil spill. As mentioned above, this organization is required under the National Contingency Plan, which is a regulatory requirement under federal legislation.

The Federal Government has in recent years exhibited a very strong political desire to rationalize review processes for industrial projects in the north. This desire extends to efforts to engineer certainty in terms of outcomes and promote a stable investment climate in the Arctic. The Canadian Environmental Assessment Act (CEAA) 2012, in particular, is an attempt to address some of the historical barriers to timely resource development and to modernize the regulatory system. This initiative was in many ways informed or inspired by the widespread dissatisfaction (from all sides) with the Joint Review Panel on the Mackenzie pipeline process. Significant changes include an approach that eliminates the automatic triggering of environmental assessments with respect to many projects, and also streamlines the required or prescribed environmental assessment of certain “designated activities” (e.g. pipelines). Further, the previous environmental assessment regime mandated project proponents and the responsible federal authority to consider a broad list environmental considerations connected to other legislation (e.g. Species at Risk Act). With respect to activities within the National Energy Board’s purview (with the notable exception of Arctic drilling), final authority now largely rests with the federal government (and not the Board). A full assessment of the efficacy of these changes can only occur once large scale projects have proceeded through this new system

## 11 A SCENARIO FOR DEVELOPING THE ARCTIC ENERGY GATEWAY

Alberta has several distinct options in an Arctic Energy Gateway to consider, as the following map indicates. The blue arrows show land transport to ports at Tuktoyaktuk and Churchill. The red arrows show marine transport to Atlantic and Pacific markets.



Our report has demonstrated that all these routes are technically feasible.

However, it is obvious that economic considerations involved with tackling the very different sea ice regimes will make some more important than others. Therefore, we present in this section, a summary of what we see as a way to open the Arctic Energy Gateway that is: modular, to take into account the expected improvement of ice conditions and learn from experience; fast to start up, to improve economics; risk averse, to minimize the hazards it presents to the environment; regionally-based, to build support. We suggest the following scenario for the Mackenzie Delta region, to initiate action. This is a highly simplified scenario, as there are possibilities for modification in many aspects and incorporation of petroleum product from many other sources along the region.

## 11.1 Mackenzie Delta Transportation System

### 11.1.1 Pilot Startup

The project could begin with a pilot level activity by sending dilbit to Hay River by rail for transfer to barges, which would unload at Tuktoyaktuk. The dilbit would be separated and the barges return it to Hay River. Bitumen would be stored on land or tanker somewhere in the Delta region and loaded using a temporary offshore loading terminal, to open water tankers operating in summer. Standby icebreaker escort would assist vessels to transit possible choke points along the route at season start and end.

Only minor construction of new equipment would be required, principally, port/loading facilities for barge transport, and double-hulled barges to reduce environmental risk. Constructing purpose-designed barges would also allow for the possibility of heating the dilbit, reducing or eliminating the diluent content, and transferring directly to tankers at sea.

This startup scenario will allow for export over Alaska to Asia-Pacific markets, and for a shorter season, along the Russian route to Europe and on a test, opportunity basis for still shorter periods, through the Northwest Passage to Europe.

The annual throughput is primarily limited by the barge component at 5,940 bbl/day per spread of 6 barges which translates in a normal season to some 831,600 bbls/year and in a good year with special barges some 1.2 MM bbls/year (per spread of 6 barges). More than one spread of barges would be used to increase throughput.

In terms of technology and construction requirements, this scenario could be put into action by summer 2015.

### 11.1.2 Ramping up Production

A pipeline is probably the best solution to transport large volumes to the Arctic coast. Incorporating the existing Norman Wells pipeline into a line from Fort McMurray to the Mackenzie Delta might significantly speed up export of increased volumes of dilbit. Given the expected positive uncertainties about reduction in Arctic ice cover, it might be considered useful to gain more experience with terminals and tanker routes before committing to full scale design/construction, while still expanding the pilot shipment levels.

The pipeline might be a single line, transporting dilbit for export. It would be produced all year and offloaded to tankers in summer, spring and fall. In winter, product is stored, either on land or using tankers as well. The loading terminal is to be removed for winter. Icebreakers and ice class tankers complement open water vessels to allow for extended season shipping in fall and spring as well as summer.

Markets are the same as for the pilot level scenario.

Using the existing Norman Wells pipeline limits throughput to 13,900 bbl/day of bitumen.

### **11.1.3 Year Round Production and Year Round Export**

At the appropriate time, the pipeline would be designed to be completed with the Norman Well line possibly converted for diluent return or superseded by a fully twinned pipeline line at maximum throughput. A purpose-built port, land-based storage farms and a permanent offshore loading terminal would be constructed on the coast. Specially designed tankers and icebreaker escort vessels would be built.

While all routes are feasible from a technology perspective, in the next decade, it is most likely that the economics will favour the Alaska route to Asia-Pacific markets for year round export. However, the existence of specially-built high ice class vessels will allow for greatly extended seasons through the other routes as well.

If a new pipeline is built, rates can be boosted to 50,000 or 100,000 bbl/day.

### **11.2 Churchill Transportation System**

At the same time, or as an option, Churchill can be used.

The scenario would be similar to exporting through the Delta region. A combination of road and rail would ship small quantities to Churchill for export in the summer season. It would only require the building of temporary land storage facilities at Churchill.

Export would favor European - Atlantic markets.

This route could be initiated in 2014, with small test shipments even in 2013 if desired.

This route could be made suitable for all year production and export by extending the pipeline infrastructure to Churchill in an analogous manner to the Delta region.

## 12 TECHNOLOGICAL CHALLENGES AND INNOVATION

From a technical point of view, this report concludes it is entirely feasible to export petroleum through a Tuktoyaktuk or a Churchill-centred marine terminal from a pipeline feed. Existing technology and non-ice adapted tankers will allow for seasonal export. Achieving longer shipping seasons can be done by existing technologies, although at a high cost. The arctic, especially the marine arctic, is a frontier and a harsh and dangerous one. Therefore, it is very important to consider the areas where technological advances could extend seasonality, lower costs, increase safety and minimize environmental risk, which we summarize in the following table.

Component	Key Advances Needed
Barges	Double hulls or other protection method to limit discharge if structure is breached, but without increasing draft, which is a primary limitation
	Cost effective, non-environmentally-disruptive ways of extending season through ice breaking and management
Pipelines	Methods for coping with rapid and extensive foundation changes due to permafrost melting under the influence of global climate change
	Remote instrumentation and surveillance devices to ensure pipeline and foundation integrity
Ports and Loading Terminals	Ways of ensuring foundation stability and channel clearances under conditions of different shore ice regimes, storm surges and river drainage patterns from global climate change
Navigation	Routes need extensive surveying to bring up to international standards. Navigational aids adapted to arctic conditions are required. Communication infrastructure needs improvement.
	Meteorological and oceanographic data are required in much greater detail and in real time; specialized instruments need to be made to allow these instruments to work in harsh arctic environments. Forecasting techniques need to be improved for arctic weather and current regimes, and ice movement, growth and decay.
	Integrated ice hazard surveillance, advisory and management systems have not been implemented; the technology is available but the marine industry has not yet adopted it for high arctic applications. This will greatly improve safety and vessel



	transit times, while maintaining acceptable safety and environmental risk profiles.
	Satellite imagery available at much lower cost and closer to real time; artificial intelligence techniques developed to lower cost and speed up imagery interpretation
	Training and standards for ice advisors and observers. The marine industry is good for experiential-based ice navigation, but weak on admitting scientific-based professionals into this area. Special need to develop training and career opportunities for native northerners in these areas.
	Use of robotics like UAVs as local sensing platforms and intelligent, miniaturized sensors to gather data and analyse the complex ice environment around the vessels.
<b>Vessels</b>	Continue to improve designs like Double Acting Ships, which can run astern in ice to greatly enhance icebreaking and manoeuvrability in ice; hull design in ice; propulsion control systems; bridge systems integrated into polar communications and local environmental sensing and analysis networks
	Icebreaker design for this particular type of task
	Convoy management, logistics, resupply, repair
<b>Environment</b>	Impact on susceptible species of noise, emissions, spills and patterns of icebreaking
<b>Spills</b>	Techniques for spill detection and tracking in and under ice need to be and can be improved; cleanup techniques for oil in ice are very limited
<b>Communication</b>	It is imperative that proper means of communication will be made available and all parties are well integrated into a combined system

In Canada, there is little involvement overall with this kind of innovation issue, while in Scandinavia, there is a great deal of investment going on now, and in other countries like Holland, a sudden recent realization that this frontier offers significant industrial opportunities based on innovation. In these countries, the state, universities, research centres and private firms are advancing rapidly on areas such as: remote sensing of ice, decision-support systems for operations in ice, icebreaking vessel design, research on ice physics and engineering properties, shoreline processes affected by ice, vessel traffic systems for ice convoys, ship power plants and control systems for ice operations, spill cleanup in ice.

There are some international groups which are discussing innovations and advances, such as the IICWG group, under IMO JCOM. The recently completed design standards Barents 2020 (2012) are also key reference documents suggesting innovation requirements, along with The Mariport Group (2007), Goodyear and Clusen (2012) and Imaituk Inc. (2011).

## 13 IMPORTANCE TO ALBERTA

The obvious benefit of this project is that an Arctic Energy Gateway would assure Alberta access to the sea for exporting bitumen blend. However, there are many more potential that should be noted, some of them quite superior to pursuing the traditional export routes.

**First**, our initial analysis suggests that the socio-political and environmental climate may be more favourable to an arctic route than to a US or BC pipeline route. Alberta promoting a northern route might gain allies rather than enemies.

**Second**, this route offers Alberta the opportunity to get to markets that are not just the US, and also to markets that are both Atlantic and Asian. The increased breadth of these market opportunities and the flexibility to choose the ones with optimal returns is a significant increased benefit offered by the Arctic Energy Gateway.

**Third**, there are major resource development synergies that the Mackenzie Valley option route offers. As pointed out above, there are significant oil and gas reserves along the Mackenzie Valley route whose development could be accelerated if bitumen blend export infrastructure were in place. Alberta companies are in a privileged position to develop these resources. In addition, all these facilities would benefit from decreased costs by sharing parts of the new infrastructure put in place.

**Fourth**, infrastructure sharing also includes minerals. For example the massive Izok Lake project in the NWT will probably need to export ore west over Alaska. Similar logistics, supply, operation and transport considerations apply to both petroleum and mineral development projects.

**Fifth**, given that the land transport segment of the Mackenzie Valley option would occur in the NWT, it is likely that Alberta would also benefit much more from the construction and operations phase of this segment than if a pipeline were constructed through BC or the USA. Alberta companies could also be heavily involved in designing, building and operating terminal and port facilities on the Beaufort Sea coast.

**Sixth**, we note in the previous chapter that the Arctic is a frontier, requiring advanced technological innovation in many different areas. There are numerous opportunities for creation and growth of high-tech companies in Alberta to make the novel products and services this frontier industry will require. In the past, it was innovations in naval architecture and civil engineering that dominated, as illustrated in Chapter 2. In the future, we will see incremental innovation in these same areas, but the main areas for radical improvements will be in these types of fields mentioned in the previous chapter: communications, software, robotics, sensors, cold weather power supplies, bioremediation of spills, new materials – all areas where Alberta could become an important player.

As was pointed out in the introductory chapter above, Alberta once led the world in R&D, innovation and business development in this area. While it is not likely that Alberta would be able to reacquire the overwhelming global dominance in this industry it once enjoyed, there are still enormous opportunities for industrial growth. To realize these opportunities will require imaginative leadership and stimulus from the Provincial Government. After the industry collapsed in Alberta, Norway and Newfoundland continued to invest and leadership has now passed to them. However, this offers the possibility for important and novel collaborations between Alberta and these two principal rival regions: Norway requires access to the resource and Newfoundland is far too small to be a major industrial player by itself. Alberta could promote a variety of mechanisms to allow all 3 regions to win by novel forms of collaboration.

**Seventh**, Alberta needs to know that it can play a leading role in the opening of the Northwest Passage. This will be a revolution in global logistics, equal in impact to the opening of the Suez or Panama Canals. Canatec has guided individual vessels and convoys through this route and analysed power requirements and transit times for different types of vessels. This route will open little by little, as it has been doing over the past 5 years. The prize for Canada is enormous, but if we do nothing, the Russian route will become the standard choice. If Alberta had developed full port and logistics facilities on the Beaufort Sea coast, and opened the western route fully over Alaska for bitumen blend export, then without any question, Albertan companies would be in the lead position to extend this route in the next phase to other commercial shipping and east through the Northwest passage. Billions of dollars will need to be invested in ports, harbours, navigational aids, bathymetry, specialized ice metocean instruments, remote sensing, environmental protection, vessels, icebreakers, supply ships, crewing and so on. If Alberta would realize once more that its northern economic zone of influence extends to the Beaufort Sea, in fruitful collaboration with the NWT, then involvement in a project like the Northwest Passage becomes inevitable.

**Eighth**, there are major benefits to other parts of Canada. If the Mackenzie Valley option goes ahead, the NWT will experience enormous growth in terms of industrial activity and population, which also have the potential for negative outcomes to some social sectors if not well managed. Nunavut and the Yukon could participate to a lesser degree through employment, port development and related logistical improvements. The marine industry located in BC and the East Coast will benefit, especially Newfoundland and Labrador. Given that Newfoundland has a longstanding and vigorous provincial policy to exploit arctic marine resources and develop high-tech offshore business, there is obvious potential for novel forms of cooperation between the two provinces to build critical mass and dominate key global markets. Alberta could take a leadership role within Canadian confederation, on the future of the Arctic.

## 14 RECOMMENDATIONS

We recommend that the benefits to the Province appear so important that the government should, without delay:

6. Explore the concept more thoroughly, by commissioning studies at a feasibility level of the environmental, social/political and economic situations, and taking this very small technical pre-feasibility study to the next level of detail. These studies should be focussed on the design and promotion of a small scale, low risk, low profile, quick start-up pilot type of project to test stakeholder and public reaction, prove feasibility, gather operational experience to improve full system design parameters and generate revenue from export.
7. Enter into discussions with the Governments of the NWT, Yukon and Manitoba, which will be essential partners in an Arctic Energy Gateway, to discover their views on such a project, and in partnership with them, initiate contacts with northern indigenous peoples' organizations to ensure relationships are productive from the outset.
8. Begin discussions with the major oil sands industry stakeholders to assist them in realizing this is possibly not only a viable alternative for export, but possibly a far better option than what they have considered to date.
9. Begin discussions with petroleum companies that are investigating exploration and production options for their leases in the Beaufort offshore to start developing creative collaboration that will benefit all producers.
10. Promote the concept with Asian petroleum companies, shipping companies and ship design/building companies by giving them favourable signals and general guidelines. The primary target should be China, for its ambitions to develop Arctic shipping and need to secure Arctic mineral and petroleum resources; to date they are focussing on the Russian route and links with Norway and Iceland. The secondary target should be Korea, for its ship design and building capability, as well as gas imports. Third, we would suggest Singapore, as being vitally concerned with not losing its position in world shipping management/finance, by getting involved in the Arctic.



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## **APPENDIX – AUTHORS AND CONTRIBUTORS**

Canatec is a Calgary-headquartered company whose principals have worked for the arctic offshore petroleum business around the world for more than three decades. Canatec’s core expertise is in sea- and glacial ice hazard surveillance and management to make offshore Arctic marine operations safer, more efficient and more environmentally responsible.

Ausenco PSI was contracted by Canatec for the pipeline chapter, based on their extensive worldwide and arctic experience with this technology. Ausenco is a large international consulting engineering firm. LOWMarine was contracted to provide the initial analysis of regulatory, political and social considerations. LOWMarine is a marine affairs and arctic consulting company located in Winnipeg and Iqaluit.

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