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13 EFFECTS OF THE ENVIRONMENT ON THE PROJECT

13.1 Introduction

The *Hebron Development Project Scoping Document* (Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB) 2009) requires a description of relevant physical environment parameters, including "Effects of the environment on the Project". Section 2(1) of the *Canadian Environmental Assessment Act* (CEAA) defines environmental effect to include "any change to the project that may be caused by the environment". This chapter provides a discussion of the expected and potential effects of the oceanographic environment on the Project's design, construction and operation.

Currently, there are three operating oil and gas fields on the Grand Banks within approximately 50 km of the proposed Hebron Project location. One is producing using a Gravity Base Structure (GBS) platform (Hibernia) and the other two (White Rose and Terra Nova) are being developed with Floating Production Storage and Offloading vessels. The Hibernia project has been in operation since 1997 and has produced over 680 MMbbls of oil. The Terra Nova project commenced operations in 2002 and has produced over 294 MMbbls, whereas White Rose has been operational since 2005, with over 141 MMbbls of oil produced to date. As with the Hebron Project, these developments were designed to withstand the environmental conditions that occur in this area, and they have demonstrated that oil and gas projects can be successfully operated in the same environmental conditions within which Hebron will be situated.

13.2 Context

Ultimately, to mitigate the effects of the physical environment on the Project, there must be adequate planning, design and operations procedures that consider the expected normal and extreme physical environmental conditions that may be encountered.

There must also be adequate monitoring and forecasting of physical environment conditions. Through adequate monitoring and forecasting, Project activities can be adjusted to maintain a safe working environment. All outside activities are affected by the physical environment.

This description considers those marine environment parameters discussed in Sections 3.1.2 and 3.2.2 for the Nearshore and Offshore Study Areas, respectively.

13.3 Nearshore Potential Marine Effects

13.3.1 Bathymetry

Nearshore bottom topography is complicated, with steep drops along the coast and narrow central channels and small coves. During construction of the GBS, bathymetry will be considered for installation of mooring systems and for marine operations and traffic management such as barge towing, vessel and remotely-operated vehicle (ROV) manoeuvring.

The GBS drydock site is situated in Great Mosquito Cove. The cove is 1.5 km long and has an average width of 500 m. The GBS drydock is approximately 16.5 m deep and has a diameter of 180 m. The coastline approaching Great Mosquito Cove drops sharply to depths of 30 to 88 m and in the Cove, depths increase from 13 to 33 m at only 300 m from shore, reaching 45 m in the middle. At the mouth of Great Mosquito Cove, the water is deep, ranging from 51 to 132 m near the centre of Bull Arm.

Bathymetry may be a factor during tow-out, depending on final GBS dimensions and route selected. If required, dredging may be undertaken within the tow-out channel to provide sufficient depth.

All of these factors will be considered in the Project development; however, none of these suggest that a bathymetric “effect” on the Project could occur. These sorts of activities have been successfully carried out previously for other developments.

13.3.2 Wind, Waves and Currents

Extreme wind, waves and currents have the potential to increase stress on surfaces and vessels and disrupt scheduling of marine operations. Wind, waves and currents will be considered during construction of the GBS, mooring system design, barge manoeuvring, tow vessel, support vessel and ROV operations.

For the nearshore, extreme wind, waves and currents can affect towing operations and vessel manoeuvring and increase stress on moorings, which can lead to mooring failure. Also, extremes can increase stress on or over-top the bund wall and/or row(s) of sheet pile that surround the existing GBS drydock facility at Bull Arm, leading to flooding and/or failure of the bund wall.

The *Hibernia Development Project Environmental Specifications* (Topside Engineering 1992) reports a 100-year extreme maximum significant wave height (Hs) of 2.6 m and extreme heights of 4.8 m for two deepwater sites in Bull Arm in winter months. The 100-year extreme current for deepwater sites in Bull Arm ranges from 1 m/s at depths of 5 to 80 m to 0.4 m/s at the surface (Section 3.1.3.2).

Site-specific weather and oceanographic data are typically collected as part of a physical environment monitoring program, which would enhance the physical database for the area, and will be collected for the Hebron Project.

These values and their potential effects will be considered for all marine Project activities in the nearshore region.

All wind, wave and current extreme value estimates will be considered in the design of moorings and the operation of vessels and barges.

13.3.3 Tsunamis

A detailed discussion on tsunamis is provided in Section 3.1.2.3. The following is a summary of observations from that Section.

While tsunamis have been observed in eastern Newfoundland and their effects can be devastating, they are not a frequent occurrence in this part of Canada. Based on the limited historical record, it can be estimated that a return period of approximately 50 to 100 years, or longer for a destructive tsunami like the 1929 event, might be possible for parts of Newfoundland; this would likely be much longer for Bull Arm, given its more sheltered location (compared with the tip of the Burin Peninsula in 1929) from the open ocean. The fact that construction nearshore will take place over approximately four years, a relatively “short” lifetime, means that the likelihood of occurrence during this period is low and therefore, it is estimated there is a low risk of tsunamis effects for the Project nearshore.

13.3.4 Tides, Water Levels, and Storm Surge

The first stage of GBS construction will be to re-instate the drydock at Great Mosquito Cove. The drydock will be enclosed by a bund wall and/or row(s) of sheet pile that will subsequently be removed (ExxonMobil Canada Properties (EMCP) 2009). Tides and storm surges can raise water levels considerably. Therefore, the potential exists for flooding of the drydock and this will be considered during the construction phase.

An estimate of 100-year maximum water level is +1.52 m above mean water level (MWL) (Marex 1992). This includes the standard deviation of the MWL, the dominant (M2 and S2) tide, the 50-year storm surge and the standard deviation of the 50-year surge. A 100-year minimum water level of -1.20 m below MWL is similarly estimated.

A more conservative estimate of extreme maximum water level would be +1.68 m above MWL taken as the sum of highest astronomical tide (HAT) (0.80 m above MWL) and the 100-year positive surge amplitude (0.88 m above MWL). Similarly, a more conservative estimate of extreme minimum water level would be -1.45 m below MWL taken as the sum of lowest astronomical tide (LAT) (-0.91 m below MWL) and the 100-year negative surge amplitude (-0.54 m below MWL) (Marex 1992).

All tide, water level and storm surge extreme estimates will be considered in the design of moorings and the operation of vessels and barges.

13.3.5 Temperature

The design, construction and installation of the GBS will consider the sea temperature. Low water temperatures can lead to vessel icing and exposure to water at this temperature may pose a risk to personnel and to exposed surfaces. There will be need for winter protection during open construction.

Surface sea temperature in the area can fall below 0°C from January to August; therefore, exposure to water at this temperature may pose a risk to personnel and to exposed surfaces. The combination of low air and sea temperature, strong winds and high waves can lead to vessel icing. A vessel, or structure in the case of the GBS, itself is also a critical factor for icing potential. The size and hull design (which may affect the amount of spray produced) and the amount of superstructure present (which can act as a "trap" for spray accumulation) are other considerations.

13.3.6 Sea Ice and Icebergs

Pack ice presence in Trinity Bay from year to year is variable, based on a review of the weekly Canadian Ice Service (CIS) charts from 1983 to 2008, inclusive (Environment Canada CIS 2010). Trinity Bay has pack ice in one form or another present on a ratio of one-in-three years. Most sea ice within the bay is formed off southern Labrador and drifts south to enter the bay around the mid-March timeframe. From mid-March through to early May, the bay experiences first year ice (see Table 3-10), which can range in thickness from 30 to 120 cm.

The Trinity Bay region does not lie on a primary aerial ice reconnaissance route; the low numbers of icebergs sighted each year, therefore, may be related to the low number of flights over that area. If this is true, the number of icebergs in the Trinity Bay area may be under-detected and under-reported. In addition, iceberg distribution can fluctuate greatly from year to year. The maximum number of icebergs sighted in one year (1979) over the period of study was 129; the mean annual number for Trinity Bay is 32. The majority (89 percent) of the icebergs observed in Trinity Bay fall within the small to medium categories.

Sea ice conditions will be monitored and managed in accordance with the Ice Management Plan. The Ice Management Plan, which will be developed for offshore operations, will outline requirements for monitoring and managing sea ice conditions for the Hebron Platform.

13.3.7 Geohazard

While there are not enough data at Bull Arm to rule out the presence of any geohazards, it does have a successful track record as a development site.

13.3.8 Climate Change

The nearshore construction will take place over approximately four years, a relatively short period, so that climate change is unlikely to have an environmental effect within that timeframe.

13.4 Offshore Potential Marine Effects

13.4.1 Bathymetry

Depending on final Hebron Platform dimensions, and route selected, bathymetry, particularly clearance over the Offshore Project Area, will be relevant for Hebron Platform tow-out and installation on the seabed, though no "effect" of the bathymetry is expected. The tow-out routes will be carefully selected and confirmed for suitability (depth). If required, sections of the tow-out channel may require dredging.

13.4.2 Wind, Waves and Currents

Extreme wind, waves and currents have the potential to increase stress on surfaces and vessels and disrupt scheduling and operations. The design, installation and operation of the Hebron Platform, offshore loading system (OLS) and supporting infrastructure will consider wind, wave and currents loads. Wind, wave and current data are typically collected as part of a physical environment monitoring program, which would enhance the physical database for the area.

The Hebron Metocean Criteria (ExxonMobil 2009) reports a 1-year return period extreme Hs of 10.5 m and associated 1-hour wind speed at 10 m of 26.2 m/s. The 100-year return period extreme Hs is 14.8 m, with an associated 1-hour wind speed of 33.2 m/s. The maximum individual wave height for a 1-year return period is 19.7 m, and for 100-years is 27.8 m. Extreme crest elevations are 13.3 m for a 1-year return period and 19.4 m for 100-years.

Estimates of one-year return period currents range from 0.64 m/s near-surface to 0.46 m/s at mid-depth, to 0.42 m/s near-bottom (ExxonMobil 2009). One hundred-year return period currents range from 1.16 m/s near-surface to 0.77 m/s at mid-depth, to 0.66 m/s near-bottom. The near-surface value of 1.16 m/s is comparable to the maximum measured currents reported by Bedford Institute of Oceanography of 0.96 m/s at 18 m (Gregory *et al.* 1996). The largest near-surface currents occur from August to October, while mid-depth and near-bottom currents are greatest from September to March (ExxonMobil 2009).

Wave conditions offshore will limit supply vessel loading and offloading of cargo. In addition, vessel iceberg towing and spill response operations, if required, would be affected. The sea state may limit the safety and effectiveness of supply vessel operations (*e.g.*, deployment and use of spill containment equipment, or the deflection of icebergs).

Based on favourable persistence analysis of historical Grand Banks conditions, the average length of time that, in any given month, seas (including swell) will persist below the given Beaufort Force (BF) (see Table 13-1) sea state thresholds[1] is illustrated in Figure 13-1.

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[1] Beaufort Scale (*e.g.*, http://www.tc.gc.ca/MarineSafety/Tp/Tp10038/80-wi-beaufort-scale.htm)

Table 13-1 Beaufort Force Scale

Hs (m)	Beaufort Force Scale
<1.0	3
≥1.0 and ≤1.5	4
>1.5 and ≤0.5	5
>2.5 and ≤4.0	6
>4.0 and ≤5.5	7
>5.5 and ≤7.5	8
>7.5 and ≤10.0	8
>10.0 and ≤12.5	10
>12.5 and ≤16.0	11
>16	12

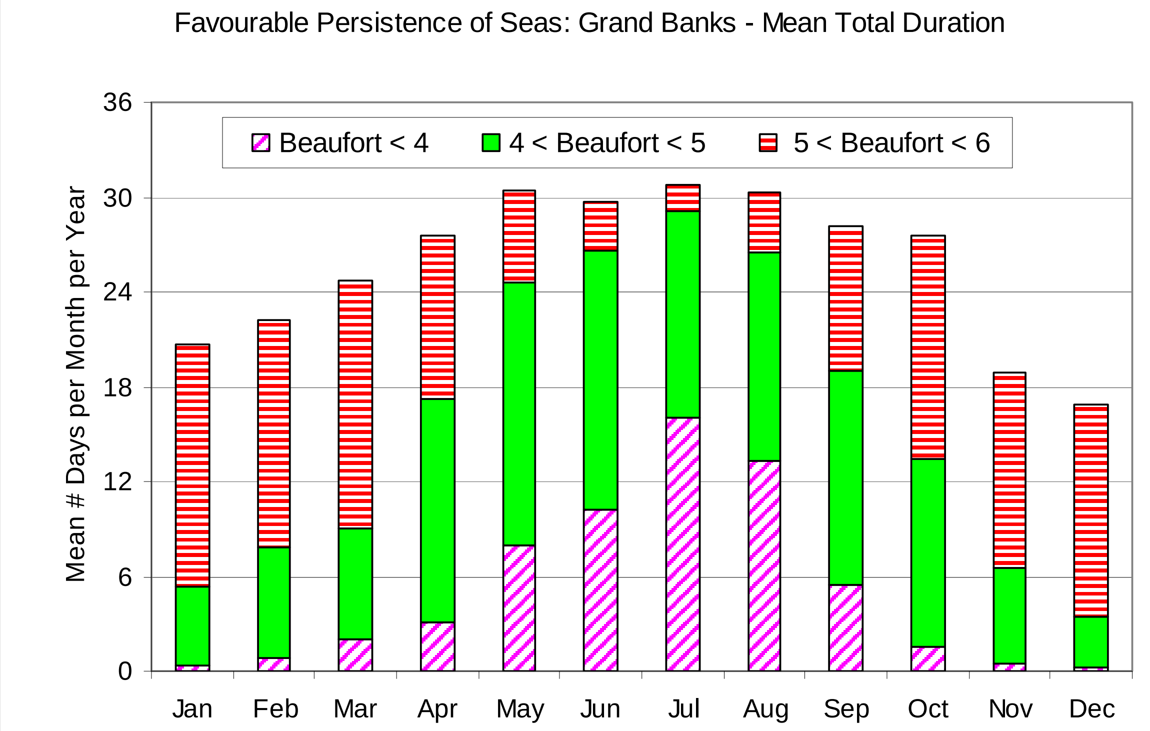

Figure 13-1 **Favourable Persistence of Seas: Grand Banks - Mean Total Duration**

The analysis was of the nine-year Hibernia wind, wave, and current (for five-year) time-series, where waves include swell. BF was assigned based on Hs, with the following mapping as a function of probable maximum height of waves:

An intent of the work is to quantify conditions and show that while seas can get quite large on the Grand Banks, there are windows of opportunity that, depending on the threshold, may be conducive to marine operations. For example, in November to February, less than one day per month would have conditions that are below BF4 (Hs = 1.5 m), while in June to August, it is over 10 days per month. During the winter, approximately 8 to 12 days per month could have conditions persist above BF6 (*i.e.*, waves over 4 m, near gale force or higher). Conversely, in the summer, these conditions will be experienced rarely, as the bars top out at approximately 30 days; conditions are more favourable to marine operations in summer.

Another wave-related environmental influence on vessel operations is iceberg towing and deflection, which can be routinely required during ice season. Marine conditions can play an important role in the success of these activities. Several observations (*e.g.*, as recently described by McClintock *et al.* 2007) are noted here in this regard.

Propeller washing, generally a successful technique for small ice mass deflection, can be difficult in high seas and reduced in its effectiveness. High sea states can further complicate matters, as they may affect the success of radar detection of smaller icebergs and growlers.

High sea states can sometimes increase the risk of tow line slippage during iceberg towing. Tow techniques, including the two-vessel iceberg net tow (C-CORE 2004), offer benefits of improved safety (including less crew time on back decks of supply vessels) and efficiency in higher sea states, and is one potential mitigation of wave effects on vessel operations.

These examples serve to illustrate, that in addition to design considerations, the marine environment can affect Project activities. EMCP will establish appropriate plans and procedures for all activities to maximize the safety of personnel, equipment and the environment, and to optimize the likelihood for success in all such undertakings.

13.4.3 Tsunamis

A detailed discussion on tsunamis is provided in Section 3.2.2.3. The following is a summary of observations as relates to potential effects.

The wave height of a passing tsunami offshore is small, approximately 1 m or less, and is not expected to be an issue for the offshore operation, particularly given the long period of the waves. Associated current speeds up to 70 cm/s could possibly be a concern for moorings and hoses. Tsunamis Warning Systems are aimed at managing coastal risk; however, they may also provide useful mitigative information for offshore operations. Given the low likelihood of tsunami occurrence and the anticipated low consequence should they occur, no tsunami effects offshore are anticipated.

13.4.4 Tides and Storm Surges

Tides and storm surges can cause an increase or decrease of water levels as large as 50 cm. These factors will be considered for the tow-out, installation and operation of the Hebron Platform.

13.4.5 Temperature

Sea temperature, combined with strong winds and high seas, is a contributing factor for marine vessel and structure icing during Project operations in winter.

13.4.6 Sea Ice and Icebergs

The Hebron location has experienced sea ice incursions in approximately 25 percent of the years spanning 1972 to 2008. These incursions are bi-modal and have peak probabilities centered on two periods: the first peak in the last week of February; and the second in the first week of April. The duration of the incursions vary from a low of one week to a high of seven weeks. Of the 11 years that ice was present, the average duration was three weeks. These statistics are based on Environment Canada CIS's Sea Ice Charts (1983 to 2008).

The number of icebergs drifting south of 48°N each year has varied from a low of zero in 1966 and 2006 to a high of 2,202 in 1984, with the average over the last 20 years (using 1989 to 2008 PAL data) ranging between 725 to 752 icebergs. Of these, only a small proportion has passed through the Offshore Project Area. Over the last 10 years, the average annual number of icebergs sighted in the Hebron Offshore Project Area has been 31. The majority (73 percent) of the icebergs south of 48°N fall within the small to medium categories.

The design, installation and operation of the Hebron Platform, OLS and supporting infrastructure will consider sea ice and icebergs. An Ice Management Plan will be prepared and ice conditions will be monitored.

13.4.7 Geohazard

In terms of other constraints to development, no shallow faults have been identified that penetrate the near-surface stratigraphy within the vicinity of the Hebron Platform. Potential shallow gas pockets have not been identified within the upper 100 m or more of the sediment column (McGregor and Fugro Jacques GeoSurveys 1998; Sonnichsen and King 2005). Boulders may be present at, or beneath the seabed, and potentially at depths of tens of metres sub-seabed (Sonnichsen and King 2005). As evidenced in seismic profiles, there is potential for near-surface channels within the Offshore Project Area. A detailed geohazard assessment will have to be performed at any drilling locations selected, via a dedicated geohazard survey (or based on existing data) as per Canada-Newfoundland and Labrador offshore Petroleum Board (C-NLOPB) guidelines.

The earthquake-generation process in eastern Canada is indirect, and potential zones of weakness are widespread, resulting in diffuse seismicity patterns. Earthquakes may take place on a series of buried crustal faults, in locations that cannot be precisely foreseen. Most earthquakes show predominantly thrust faulting, with some strike-slip component, consistent with high regional compressive stresses; however, there are not any focal mechanisms for earthquakes in the Jeanne d’Arc or other nearby basins. The Hebron Platform is located within the eastern Canadian continental margin that is characterized by low to moderate levels of seismic activity, with infrequent large earthquakes (URS Corporation 2006) While overall rates of seismicity are relatively low, there are zones of clustered higher rate seismicity and historical earthquakes up to Magnitude 7.3 (1929 Grand Banks earthquake) have occurred in the region. There are currently no data indicating known seismic source faults in the vicinity of the proposed Hebron Platform. A seismic hazards study determined the following return periods for various levels of earthquakes at the Hebron Platform (URS Corporation 2006):

- Abnormal Level Earthquake: 3,000 years
- Extreme Level Earthquake: 600 years
- Operating Level Earthquake: 300 years
- Safety Level Earthquake: 3,000 years

The Operating and Safety Level Earthquake risk levels are usually determined by the facility owner (URS Corporation 2006).

13.4.8 Climate Change

A detailed discussion on climate change is provided in Section 3.2.6. The following is a summary of considerations for the offshore:

- Sea-level rise: Estimates of sea level rise globally over the next 50 years due to climate change alone are from 2.5 cm (Kolker and Hameed 2007) to as much as 15 cm (Hu *et al*. 2009). The productive life of the Hebron Project is currently estimated at 30 years; therefore, sea level rise to some degree may occur. The design of the Hebron Platform will account for sea level rise
- Waves: Increased storm intensity may result in higher associated peak wave heights and more frequent occurrence of extreme wave events. However, climate simulations for the next century show almost no change in peak Hs for the western North Atlantic, consistent with recent trends in observed data. With increased temperature, more tropical storms can be expected to survive farther north, bringing with them higher waves during the tropical storm season. The design of the Hebron Platform will account for more frequent occurrence of peak wave heights
- Sea Surface Temperatures: there is considerable uncertainty as to the question of warming sea surface temperatures, since glacial melt north of Newfoundland would exert a cooling influence on the offshore waters. A slight change of sea surface temperature may not directly affect the Project, but may contribute to increased storm frequency and icing intensity

The Project will be designed to withstand these possible variations in normal and extreme marine environment conditions.

13.4.9 Biofouling

Biofouling epiflora and epifauna are usually found in the photic zone, and the species found in the upper 50 m (during studies in the North Sea) are primarily comprised of seaweeds, hydroids, soft corals, anemones and mussels. Below 50 m, the biofouling communities are primarily comprised of hydroids, soft corals, anemones and tubeworms (Welaptega 1993, in Husky 2000).

While biofouling epifauna and epiflora do attach themselves to the walls of the Hibernia platform within the depths of light penetration, they do not make visual inspections more difficult or contribute to fatigue or corrosion to the infrastructure of the platform (HMDC 2005).

13.5 Environmental Events

The selection of appropriate events is a key to identifying risks that are most realistic within the context of the assessment (Table 13-2). In order to accomplish this, it is necessary to address a wide range of events. The following is a discussion of the events that could be considered as having a potential effect, together with how adverse that effect might be, and an indication of mitigations that should be implemented to reduce the hazard.

Table 13-2 Environmental Effects on the Project

Marine Environmental Event	Mitigation
Nearshore Events	
Wind / Waves – ROV operations	Safe Operating Procedures, Site Monitoring / Forecasts
Wind / Waves – barge, tug or support vessel operations	Safe Operating Procedures, Site Monitoring / Forecasts
Wind / Waves – access to GBS at deepwater site	Safe Operating Procedures, Site Monitoring / Forecasts / FEED / Facility Design
Waves – bund wall failure	Site Monitoring / Forecasts / FEED / Facility Design
Waves / Currents – mooring failure	Site Monitoring / Forecasts / FEED / Facility Design
Storm surges / high water levels - flooding and damage to drydock/bund wall	Site Monitoring / Forecasts / FEED / Facility Design
Sea Temperature - contributor to vessel and structure icing potential	Site Monitoring / Forecasts
Sea Temperature - exposure to personnel	Safe Operating Procedures
Offshore Events	
Tsunamis – OLS / Tanker disruption (high currents)	Warning Systems, Site Monitoring / Forecasts / FEED / Facility Design
Wind / Waves – tug or support vessel operations (*e.g.*, ice, spill response, Search and Rescue)	Safe Operating Procedures, Site Monitoring / Forecasts
Waves / Low water level – affecting Hebron Platform installation on seabed	Safe Operating Procedures, Site Monitoring / Forecasts / FEED / Facility Design
Currents – OLS / Tanker disruption	Site Monitoring / Forecasts
Sea Temperature - contributor to vessel and structure icing potential	Site Monitoring / Forecasts / FEED / Facility Design
Sea Temperature - exposure to personnel	Safe Operating Procedures
Seasonally-occurring Sea Ice and Icebergs	Ice Management Plan / FEED / Facility Design
Climate Change – Sea level rise	FEED / Facility Design
Climate Change - Waves	FEED / Facility Design
Climate Change - Sea Surface Temperature	FEED / Facility Design
Climate Change - Sea Ice and Icebergs	Ice Management Plans / FEED / Facility Design

13.5.1 Mitigation Measures

The range of effects on the Project due to the physical environment can range from minor facility improvement to catastrophic failure. The primary mitigation tool is the use of sound planning. All engineering design will adhere to national / international standards. These standards document the proper engineering design for site-specific normal and extreme physical environmental conditions and provide design criteria that the regulatory agencies consider satisfactory for withstanding the potential physical environmental conditions. These codes consider physical environmental criteria such as temperature, wind, snow, wave and ice loading, and drainage. In addition, the design life is taken into consideration so that materials are chosen with sufficient durability and corrosion resistance.

Physical management of icebergs in the Offshore Study Area is conducted well up-stream in an attempt to deflect any icebergs that may encroach on the operational areas of production facilities. In general terms, most physical iceberg management consists of towing or deflecting the iceberg off its free-drifting track. The attempts historically consisted of deploying a long floating tow rope around the iceberg, and then applying force with a supply vessel in the direction they desired the iceberg to move. In the past 30 years, other methods have been used with varying degrees of success, but this basic method has remained the staple of iceberg management, having been used in nearly 500 documented iceberg tows. The recent development of an iceberg tow net has gained popularity for management operation on the Grand Banks. The iceberg tow net was designed to reduce the amount of rope slippage and provide a reduction in iceberg rolling while being managed.

Sea ice management procedures have long been used in Canadian water (*e.g.*, to break up sea ice to assist shipping). Because of the loose nature of the pack in the area of the Grand Banks, sea ice management primarily consists of using support vessels to break up any large ice floes that meet or exceed the design limits of the facility. Over the 2008 and 2009 ice seasons, experience has been gained using water cannons to open a path in the pack as it advanced towards facilities. The method used a support vessel stationed a few hundred metres ahead of the production facility. By sweeping the vessels water cannon left and right, a path or lead is opened up, keeping the loose pack clear of the facility.

Beginning in late 1988, all operators on the Grand Banks adopted a coordinated ice management approach. Under this system, the joint operators share ice information and ice management resources, along with adopting a strategy and procedures for managing icebergs over the whole Jeanne d’Arc Basin area. EMCP will explore synergies with existing operations regarding ice management.

13.5.2 Definition of Significance

A significant effect of the environment on the Project is determined to be one that:

- Harms Project personnel or the public
- Results in a substantial delay in construction (*e.g.*, more than one season) or shutdown of producing operations
- Damages infrastructure and compromises public safety
- Damages infrastructure to the extent that repair is not economically or technically feasible

It should be noted that:

- Tsunami frequency or likelihood is improbable for nearshore (unlikely so as to assume will not occur) and remote for offshore (unlikely but possible) (*i.e.*, these are <<10 events/year)
- Particularly with climate change events, there is an element of uncertainty as to the "change" and whether it is greater or less (*e.g.*, for large waves) and/or by how much (*e.g.*, sea level rise).

13.6 Conclusion

The Project design and operations planning incorporates metocean criteria. Physical metocean site monitoring will be undertaken. As such, no significant effects on the Project are anticipated. The effects of ice, including icebergs, on the Project are predicted to be minimal. GBS design basis incorporates the potential for ice impact with the structure. This, in addition to the provision of ice management procedures, will result in a minimal effect from sea ice or icebergs on the Project. Therefore, there are no likely significant environmental effects on the Project.