Environmental Assessment Certificate Application

LNG Canada Export Terminal

Section 11 – Effects of the Environment on the Project

October 2014

LNG CANADA
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Joint venture companies

Mitsubishi Corporation

11 EFFECTS OF THE ENVIRONMENT ON THE PROJECT

Local environmental conditions, such as severe or extreme weather, can have adverse effects on a project and are typically mitigated by standard design (e.g., engineering standards) and management (e.g., construction scheduling) practices. Pursuant to CEAA 2012 (section 19(1)(h)), this section of the Application assesses the environmental conditions that have the potential to adversely affect the Project. As specified in the AIR (BCEAO 2014), the Project could be subject to the following environmental factors:

- climate change
  - temperature and precipitation, and
  - sea level rise.
- extreme weather events
  - temperature
  - precipitation and flooding, and
  - wind and waves.
- seismic activity and tsunamis, and
- forest fires.

Risks to the Project associated with an occurrence of these natural events during construction, operation, and decommissioning are assessed and proposed engineering and design mitigation measures are outlined.

11.1 Spatial and Temporal Boundaries

The spatial boundaries include all land and marine components in the Project footprint. The temporal boundaries are the construction, operation, and decommissioning phases of the Project. Project construction for the first phase is anticipated to be completed approximately five to six years after issuance of permits. Additional infrastructure components may be added as market demand requires. The operation phase is expected to last for a minimum of 25 years, and decommissioning is expected to be approximately two years at the end of the Project life.

11.2 Methods

The assessment of potential effects of the environment on the Project and recommended mitigation measures are based on:

- detailed knowledge about the Project (e.g., basis of design)
- environmental conditions and potential sensitivities, and
- literature review.

In particular, baseline climate conditions were determined from an analysis conducted by LNG Canada. This analysis was based on climatological and oceanographic data from National Climatic Data Center of the National Oceanic and Atmospheric Administration (NOAA) of the United States (NCDC NOAA 2014), the National Climate Data and Information Archive of Canada (Government of Canada 2014), Fisheries and Oceans Canada (DFO 2014), the Canadian Hydrographic Service (CHS 2014), and Environment Canada (EC 2014). The analysis focused on determining design parameters such as wind, waves, precipitation, and temperature. Analyzed data records range from 1 to 40 years and were complemented by modelling and data calibration. Climate change effects were modelled using the Regional Analysis Tool, developed by the Pacific Climate Impact Consortium (PCIC) (PCIC 2013a, 2013b), which uses a standard set of climate model projections. Baseline forest fire conditions are based on historical forest fire data obtained from DataBC.

Where data were unavailable, recommendations are provided for future studies and assessments. Each potential environmental factor is discussed in the subsequent sections using the following structure:

- a description of the potential environmental factor and, where possible, future projections
- the mechanism of the effect on the Project
- options for mitigating the potential adverse effect and reducing the risk associated with each potential factor, and
- potential effects of the environmental factor on the Project.

11.3 Climate Change

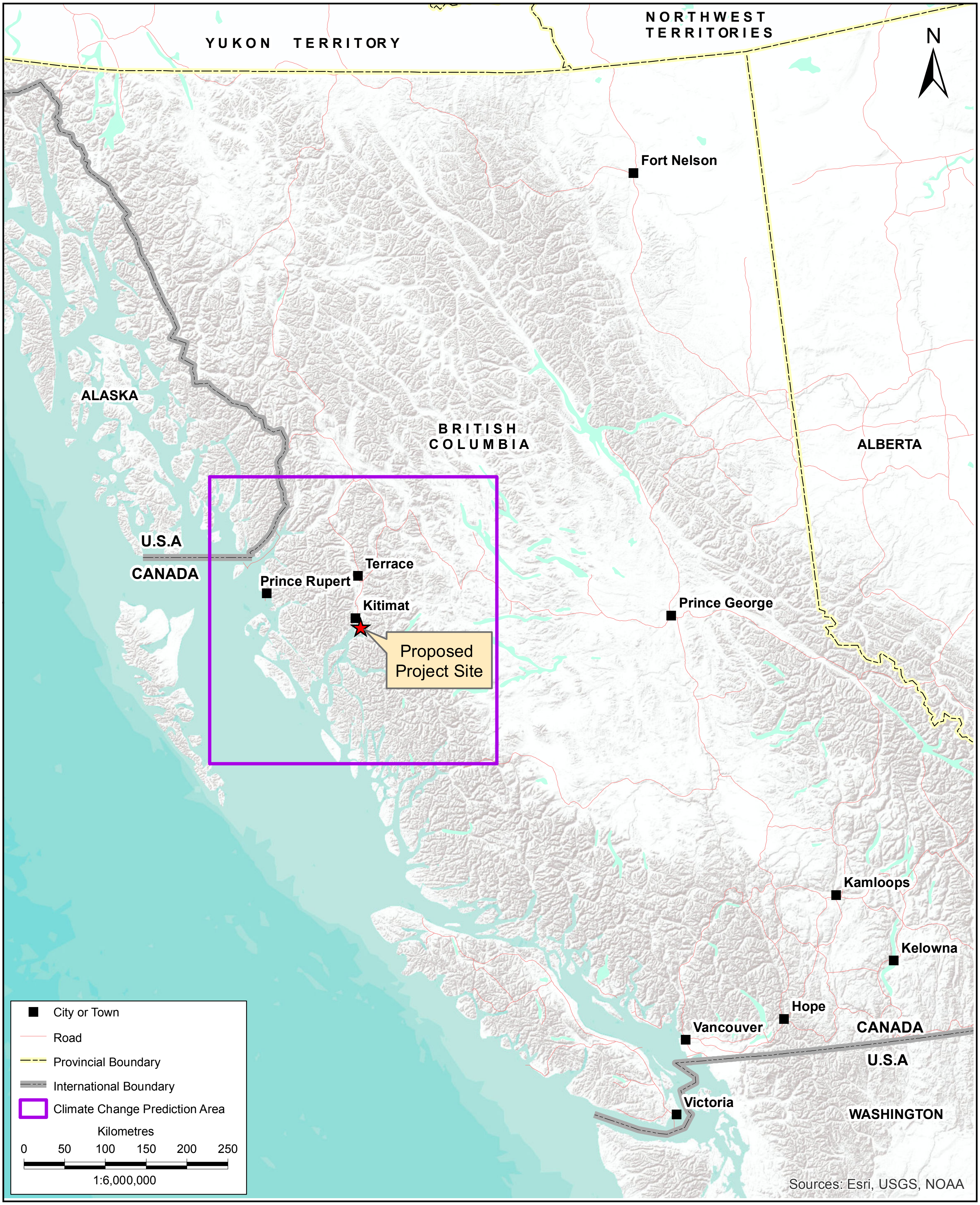
Increasing concentrations of GHGs in the atmosphere are a major contributor to the changing global climate. On a global basis, it is projected that increasing emissions of GHGs will lead to further warming and changes in all aspects of the climate system. Even if global emissions were to be reduced drastically and immediately, changes in climate related to recent global emissions can be expected for many decades to come (IPCC 2013).

11.3.1 Environmental Factors

11.3.1.1 Temperature and Precipitation

The current climate of the forecasted region (see Figure 11.3-1) is characterized as a northern temperate rainforest climate, influenced by the Pacific air streams. The region selected for the projections (see Figure 11.3-1) is following the far field CALMET model area for the air quality assessment (Section 5.2). The area captures potential marine, air, rail, and road routes required for operation of the Project.

The baseline climate for the forecasted region, as produced by the PCIC Regional Analysis Tool (PCIC 2013a), includes moderate temperatures (annual median: 3.4°C), with mild summers and winters. This temperature regime causes Douglas Channel and Kitimat Arm to be typically ice free throughout the year. However, a thin layer of ice can form on sheltered water during winter months, but usually not to the extent that it could hinder marine navigation or affect operation of marine facilities. The region receives high levels of precipitation (4.8 mm/day) because of orographic rain formation (moist air rises then cools when it reaches the coastal mountains). Much of this precipitation falls as snow during the winter (median: 330 mm); however, freezing periods are generally not severe or long lasting. Additional baseline climate characteristics for the forecasted region around Kitimat are listed in Table 11.3-1 (PCIC 2013a).



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EFFECTS OF THE ENVIRONMENT ON THE PROJECT

REGION CONSIDERED FOR CLIMATE CHANGE PREDICTION

LNG CANADA
KITIMAT, BRITISH COLUMBIA

PROJECTION: BC Albers	DRAWN BY: NP
DATUM: NAD 83	CHECKED BY: SW
DATE: 22-JAN-14	FIGURE NO. **11.3-1**

Table 11.3-1: Projected Change from the 1961 to 1990 Baseline for the Kitimat Region

Variable	Season	Baseline (1961–1990)	Projected Change from 1961–1990 Baseline			
			2020s (2010–2039)		2050s (2040–2069)	
		Ensemble Median	Ensemble Median	Range (25th to 75th percentile)	Ensemble Median	Range (25th to 75th percentile)
Mean Temperature (ºC)	Annual	3.4	+1.2	+0.7 to +1.4	+1.8	+1.4 to +2.2
	Summer	10.3	+0.9	+0.7 to +1.1	+1.6	+1.3 to +2.2
	Winter	-3.8	+1.2	+0.5 to +2.2	+2.3	+1.2 to +3.1
Max Temperature (ºC)	Annual	8	+1.1	+1.1 to +1.6	+1.9	+1.4 to +2.2
	Summer	16	+0.9	+0.9 to +1.2	+1.7	+1.4 to +1.9
	Winter	-1	+2	+1.6 to + 2.1	+2.7	+2.1 to 3.1
Min Temperature (ºC)	Annual	0	+1.5	+1.5 to +1.9	+2.4	+1.9 to +2.8
	Summer	8	+0.9	+0.9 to +1.1	+1.8	+1.2 to +2
	Winter	-8	+2.7	+2.2 to +3	+3.5	+2.9 to +4
Precipitation	Annual	4.8 mm/day	+4%	+1% to +6%	+6%	+4% to +10%
	Summer	2.9 mm/day	-1%	-3% to +7%	-1%	-9% to +5%
	Winter	5.7 mm/day	+4%	0% to +11%	+6%	+2% to +12%
Number of Frost-free Days	Annual	247 days	+19 days	+11 to +23	+29 days	+21 to +38 days
Snowfall	Winter	330 mm	-9%	-19% to -3%	-17%	-8% to -26%
	Spring	204 mm	-13%	-23% to -6%	-23%	-16% to -29%

NOTES:

Summer includes June, July, and August.

Winter includes December, January, and February.

Spring includes March, April, and May.

The ensemble median is a mid-point value from the PCIC set of model projections. The range values represent the 25th and 75th percentiles and hence 50% of the projections in the set (interquartile model spread).

Projections for future climate depend on the models used, model-specific algorithms and underlying assumptions, and on the emission pathways chosen. To obtain a reasonable range and reduce the uncertainty attached to climate forecasting through reliance on a single model, the use of an ensemble (mean and median) of multiple models is preferred to reduce the strong random bias present within single models (Murdock and Spittlehouse 2011).

To represent future conditions at the Project site, climate change data projections for the Kitimat area (see Figure 11.3-1) were obtained using PCIC's online Regional Analysis Tool (PCIC 2013a). The

PCIC21 analysis ensemble, predefined by PCIC, was selected for this assessment. This ensemble combines 10 models[1] and 21 different projections (including the IPCC-defined A1, A1B1, and A2 emission scenarios[2]) that were recommended by Murdock and Spittlehouse (2011) for climate change analyses with a timeframe of 2050s or earlier and with a focus on capturing the potential range of regional change. The PCIC21 ensemble includes the widely used third-generation coupled global climate model (CGCM3 A2 run 4) from Environment Canada's Canadian Centre for Climate Modelling and Analysis, as well as the Hadley Centre Global Environment Model (HadGEM, A1B run1) and the Hadley Centre Coupled Model (HadCM3, B1 run1). This set of three models was recommended as a minimum by Murdock and Spittlehouse (2011) for climate change forecasting.

The climate change projections of the individual climate variables are presented as the difference between the baseline period and two future periods. The baseline period for the Regional Analysis Tool is set by PCIC to a 30-year period from 1961 to 1990 (see Table 11.3-1). The future periods chosen for the climate projections are the 2020s and 2050s to capture the expected service life of the Project. PCIC predefines the 2020s and 2050s as 2010 to 2039 and 2040 to 2069, respectively. Table 11.3-1 presents climate change prediction results from the Regional Analysis Tool in terms of the ensemble median and the interquartile range (25th to 75th percentile) of the different models and modelled results. The seasons selected for analysis are based on the selection in the Plan2Adapt tool by PCIC (2013b) and focus on annual, winter, and summer values. Snowfall is only shown for the relevant seasons (winter and spring).

Relative to the baseline time horizon of 1961 to 1990, the mean annual air temperature is projected to increase by 1.2°C by the 2020s and by 1.8°C by the 2050s. Winter months are expected to experience a greater temperature increase than summer months, which is true for most of Canada (ICLR 2012).

Mean annual precipitation changes are projected to be +4% by the 2020s and +6% by the 2050s, compared with a baseline of 4.8 mm/day during 1961 to 1990. The number of frost-free days per year is predicted to increase from 247 to 266 days in the 2020s and to 276 days in the 2050s as the winter shortens and the summer lengthens.

With a warming climate, on average less precipitation will fall as snow, with expected changes in snow cover. The median of the climate models and scenarios indicates a decrease in winter snowfall of 9% into

[1] The 10 models of the predefined PCIC21 compilation are the following: CCCMA_CGCM3, CSIRO_MK30, GFDL_CM21, GISS_EH, MIROC32_HIRES, MPI_ECHAM5, MRI_CGCM232A, NCAR_CCSM30, UKMO_HADCM3, UKMO_HADGEM1. The PCIC21 ensemble compilation slightly differs from the recommendations in Murdock and Spittlehouse (2011) because it contains one additional model (MIROC32_HIRES) and more projections (total of 21).

[2] The A1, A1B, and A2 emission scenarios are possible future emissions of GHGs, with each scenario based on different assumptions for population growth, technological development, sources of energy, and global cooperation (IPCC 2000).

the 2020s and 17% into the 2050s. Median spring snowfall is predicted to decrease by 13% and 23%, respectively.

Although some projections are highly variable between the 25th and 75th percentile values, the overall trend is for warmer annual mean temperatures, increased precipitation as rain, and decreased precipitation as snow.

11.3.1.2 Sea-level Rise

Rising temperatures are contributing to sea-level rise because of thermal expansion of oceans and glacier mass loss (IPCC 2013). Depending on the climate change scenario, global sea level is expected to rise by 0.26 m to 0.82 m by the end of this century, compared with the average sea level between 1986 to 2005 (IPCC 2013). BC and Atlantic Canada plan for an average sea level rise of 1 m by 2100, which is higher than the IPCC projections (Arlington et al. 2013). On a regional scale, based on an extreme high estimate, Thomson et al. (2008) projected a relative sea-level rise for Prince Rupert in the range of 0.95 m to 1.16 m for 2100.

11.3.2 Description of Effect Mechanism

Changing climate variables such as temperature and precipitation can affect working conditions as well as infrastructure. Rising sea level can affect coastal infrastructure, such as marine facilities, and can compromise the ability of the marine terminal to operate if sea level rises above planned design specifications. Effect mechanisms of changing extreme weather events as part of a changing climate are covered separately in Section 11.4.

11.3.3 Mitigation Measures

The design and construction of the individual facilities are regulated by best practices, latest design standards, and codes that aim to limit effects of the environment on infrastructure, including for example:

- Canadian Standards Association (CSA) code for LNG facilities (CSA 2011)
- National Building Code of Canada (NBC 2010), and
- British Standard Code of Practice for Maritime Structures.

The design will incorporate an adequate factor of safety to address changes in temperature or precipitation during the lifetime of the Project. The materials selected for the Project will be consistent with effective design practice, will meet or exceed relevant codes for marine port facilities, and will withstand the marine environment (e.g., high moisture levels, wind, snow) as well as changing ambient temperature levels.

Future extents of projected sea-level rise have been reviewed but will be further incorporated in the front end engineering design (FEED) phase of the Project design. The projected sea-level rise within the 25-year intended service life of the Project will be accommodated in the Project's design. The design will allow for normal operation under the sea-level rise extents expected to occur within the service life of the facility. These design factors will include, but may not be limited to, construction of a bund around the facility site, proactive water management of the site, raising the facility site, and constructing the loading facilities at the marine wharf on an elevated table top.

11.3.4 Potential Effects on the Project

Concerns about potential effects of climate change on the Project are assessed qualitatively as outlined by Canadian Environmental Assessment Agency Guidelines (CEA Agency 2003). Indirect effects of climate change related to changing patterns of extreme weather events are covered separately in Section 11.4.

Climate models and scenarios suggest that the climate in BC will continue to change. The confidence level of future climate-change projections, in particular for temperature, is high (IPCC 2013). This means that the Project's operating environment and operating conditions, ecosystems, and surrounding communities will not be static. Increasing mean temperature and or rainfall and associated decrease in mean snowfall and increase in number of frost-free days will not affect the Project's processes or operation because the Project design will incorporate a safety margin for these future operating-environment anticipated changes. The Project phases' sensitivity are, therefore, ranked nil to low, and this ranking will be confirmed in a design review study or a vulnerability assessment study conducted during formal detailed design. These studies will include a process and operation-focused assessment for identifying conditions or processes and operational upsets that could result in effects on the Project.

The confidence in sea-level rise projections are high in the scientific community (IPCC 2013), which means that this will require mitigation, although only minimally, given the lifetime of the Project. LNG Canada will address and incorporate rising sea levels into the design planning and is planning a more detailed climate-change analysis during the FEED phase. This detailed analysis will assess the potential risk and effect of sea-level rise, changing temperature and precipitation patterns, and will identify potential mitigation measures and design modifications, where possible.

11.4 Extreme Weather Events

Severe weather events include extreme temperatures, precipitation and flooding, and associated high wind and waves.

11.4.1 Environmental Factors

11.4.1.1 Temperature

Data from the National Climate Data and Information Archive of Canada (Government of Canada 2014) show that extreme temperatures, ranging from a low of -25.0°C to a high of +36.1°C, have been recorded (based on climate data from Kitimat [1971 to 2000]). The 100-year extreme high hourly temperature is +38.4°C, and the extreme low is -27.6°C. Atmospheric icing is generally expected anytime between November and March.

11.4.1.2 Precipitation, Flooding

The same data (Government of Canada 2014) also show that maximum daily total rainfall ranges from 46.6 mm in June to above 140 mm in October. Rainfall intensity corresponding to a 1-in-100-year, 24-hour period rainfall event is predicted to be 165 mm based on analysis from LNG Canada. The snow-free period is usually from May to September. Heavy snowfall can be expected during winter months. Maximum snow depth of 1,400 mm was recorded during the month of February.

According to floodplain maps, the Project site is located in an area identified as having a medium to high flood risk (Kerr Wood Leidal 2012) because the LNG processing facility is located in the middle of the flood plain of Kitimat River. A flood study for the Project carried out by LNG Canada estimated that a 1-in-1,000-year flood would result in water levels of 12.7 m above chart datum (CD) at the most upstream section of the Project site, which is 9.5 m above mean sea level. At the most downstream section of the Project site, the water levels of a 1-in-1,000-year flood scenario would result in water levels of 9.2 m above CD (6 m above mean sea level).

11.4.1.3 Wind and Waves

Wind patterns in Kitimat are generally mild and shaped by the local topography of the Kitimat River valley, running from north to south. In the winter, the wind blows generally from the south, and in the summer, it blows from the north. Hourly wind data from Terrace, north of Kitimat, and the Nanakwa Shoal buoy, located in Kitimat Arm (data from 1973 to 2011 for Terrace and 2001 to 2011 for the buoy) show that monthly averages range from 3 m/s to 5 m/s and maximum gust speeds average 20 m/s to 30 m/s (NCDC NOAA 2014, DFO 2014). Once in 100 years, extreme winds are estimated to be in the order of 25 m/s to 35 m/s, depending on the interval.

Located at the end of Kitimat Arm, the Project site will be mostly sheltered from oceanic influence. The annual average wave height at the Nanakwa Shoal buoy is 0.14 m (based on data from 2001 to 2011). Wave heights are usually greater during winter (DFO 2014). The 100-year return wave height is analyzed to be 3.17 m, based on a 25-year data record. The water level at Kitimat is further influenced by a semi-diurnal mixed tide, which means there are two high water and two low water levels a day. The extreme highest high water level is 6.7 m above CD (CHS 2014).

Storm surges occur along the coast of BC. Substantial events occurred in December 1982 and 2003; however, there was no effect at Kitimat (Abeysirigunawardena et al. 2011). Data from the CHS Marine Chart for Douglas Channel and Kitimat Arm show that the water current velocities are very low in the channel. Tidal current velocities are 0.5 knots for flood conditions and 1 knot for ebb conditions (CHS 2014; DFO 2014).

11.4.1.4 Future Projections of Extreme Weather Events

Because extreme events are rare, establishing trends and making future projections is complicated and, so far, is limited to qualitative statements and projections for broad spatial regions only (IPCC 2012). This limitation is mainly attributable to the state of historical records, limited availability of tools to analyze changes in extremes, or deficiencies in understanding the causes of extreme events (Zwiers et al. 2013). However, it has been shown that extreme event patterns have changed over the last few decades and are expected to further change in the future, particularly their intensity, duration, and frequency (IPCC 2012). The following descriptions are high-level projections of possible future changes in extreme weather events on a broad spatial scale.

11.4.1.4.1 Temperature

The future return periods (2045 to 2065) of maximum daily temperature extremes for western North America are decreasing, signifying an increase in their frequency. A 1-in-20-year hot day extreme event (based on extremes from 1981 to 2000) is expected to occur more often, approximately once every 3 to 4 years by mid-21st century, with an uncertainty of occurring between 1.5 years and 6 years, depending on the scenarios. Daily extreme maximum temperatures will likely increase by about 1°C to 3°C (IPCC 2012).

11.4.1.4.2 Precipitation

Projected changes in precipitation intensity and return frequency have been assessed in several studies, with the consensus that extreme precipitation events will be heavier and more frequent in the future. The return frequency of a 1-in-100-year extreme 24-hour precipitation event for North America (25°N to 65°N) is expected to increase to once in 70 years by mid-21st century (Kharin and Zwiers 2000; Lemmen et al.

2008). Specific projections for the west coast of Canada reveal the same picture: the return level of extreme precipitation values is projected to increase by 5% to 12% by mid-21st century. Absolute increases are expected to be around 5 mm to 17 mm (Mladjic et al. 2011). For BC specifically, the Institute for Catastrophic Loss Reduction (ICLR 2012) states that a 10% to 15% increase in heavy rainfall events is expected.

11.4.1.4.3 Wind

Future projections of extreme wind events are less reliable. Global circulation models have not yet been able to precisely predict the changes in regional wind speed and direction. Some global studies, however, concluded that daily winter average wind speeds (10 m above ground) are expected to increase by more than 10% by 2081 to 2100 along the west coast of BC, relative to 1981 to 2000. Summer wind speeds are expected to increase over northwestern parts of Canada as well (McInnes et al. 2011).

11.4.1.4.4 Summary

On average, there will be less time between heavy precipitation and hot-day events and potentially increasing wind speeds (see Table 11.4-1).

Table 11.4-1: Projected Changes of Extreme Weather Phenomena

Weather Phenomenon	Projected Change (by middle to the end of 21st century)
Hot days	Increasing daily maximum temperature and decreasing return period
Precipitation	Increasing intensity of heavy precipitation events and decreasing return period
Winds	Increasing wind speeds

11.4.2 Description of Effect Mechanism

Extreme weather events can affect the Project by limiting the function of specific infrastructure components and compromising facility operations, onshore and offshore. Extreme weather events, such as storms, can also pose hazardous working conditions and delay or temporarily close normal Project operations. Adverse weather, such as heavy precipitation and flooding, could also damage onshore and offshore infrastructure and vessels. Because the Project site is located in a floodplain, flooding is considered a risk and requires mitigation because all Project phases could be affected. Increases in the magnitude of extreme rainfall have potential for effects on the facility’s drainage infrastructure. Wind and sea conditions can affect the Project by dense blowing sea foam, heavy tumbling of the sea, and poor visibility, all of which can make onshore and offshore working conditions, including shipping, hazardous. Elevated temperature extremes may have effects including increased energy demands for cooling, higher potential for heat-related illness for workers, and changes in vegetation in the operating environment.

Potentially cold temperatures could lead to icing on ships (e.g., when water is taken over the bow in spray) or at the marine terminal and the LNG processing and storage site, which could also affect working conditions.

11.4.3 Mitigation Measures

Project onshore and offshore design will comply with criteria for extreme conditions of latest applicable building codes and standards, such as CSA code for LNG facilities, as well as the Shell Design and Engineering Practice Manual.

11.4.3.1 Temperature

- For conditions of elevated extreme high temperatures, established corporate procedures and safety measures intended to protect workers from conditions of heat stress will be implemented at the facility
- All materials selected for use in the facilities will fulfill criteria from applicable building codes and standards for expected temperature ranges. During the design development, design values for temperature will be confirmed and ranges expanded, as required, for expected long-term trends and changes.
- LNG processing design will define actions needed to prevent and control hazardous situations during winter conditions (e.g., anti-plume measures in the cooling towers to prevent local ice build up).
- Appropriate corrosion protection will be applied to structures (e.g., steel elements). Cables are buried under ground where possible. Water pipes that cannot be buried below frost level will be insulated or heat-traced to avoid freezing.
- Potential structural icing on the LNG processing facility or LNG carriers and associated vessels will be addressed by adequate de-icing methods. Icing on LNG carriers could pose a potential risk during mooring processes because it could prevent safely securing the vessel to the quay. In order to address this potential risk, LNG Canada is assessing the application of a de-icing system for specific parts of the LNG carriers. Infrastructure and or operational activities that are at risk of icing will be analyzed in the engineering review phase in more detail.

11.4.3.2 Precipitation and Flooding

- Project design will allow for reliable and safe operation during extreme snow and rain events. Long-term trends of precipitation (as well as the proportion of precipitation as rain or snow) will be evaluated and design values of water levels will be updated as required.
- The Project drainage infrastructure will be designed to manage a storm recurrence of once every 5 years in order to withstand extreme rainfalls of 17 mm/hour.
- Snow cover depth can be as high as 1,400 mm in winter. This snow cover and potential ice events will be considered in the structural design in order to address the potential load that snow and ice can exert on buildings.
- A minimum height of 0.6 m above grade is planned for outdoor equipment to remain accessible during average snowfall depth. The design will accommodate for specific snow-holding areas.
- The overall elevation of the site will be raised with imported structural fill material, which provides safe and durable conditions unaffected by rainwater or snow melt.
- The perimeter of the facility will be protected by a bund wall with a crest height of up to 9.5 m (relative to Geodetic Datum, which can be considered the same as the mean sea level) at its highest point in order to protect the infrastructure against the effect of a 1-in-1,000-year flood event. This translates into an approximately 3.5 m tall wall above existing levels. The exterior of the bund will be impervious, with additional scour protection where the bund is in potential contact with rivers or streams. The bund will have the structural capacity to support an additional wall of 1 m height on top of the bund crest. This measure will allow for additional flood protection in the future, should this be required due to changing environmental conditions.
- Runoff and drainage components will be designed to manage extreme precipitation and sudden snow melt events. During operation, the Project will include stormwater holding basins in the low-lying, southeast area of the Project site. During construction, additional holding basins may be constructed as site preparation advances.
- The LNG loading line corridor from the LNG tanks to the berths will be elevated, roughly 5 m above potential flooding levels. Berths will be protected at a minimum, against 1-in-50-year flood occurrences by constructing the marine terminal above flooding levels.

Adverse conditions, such as rain and snow, are considered typical working conditions for this region and the work schedule will provide allowances for these conditions. In extreme cases, associated delays in operations may occur and, if possible, the work can be halted until conditions improve. The design further incorporates shelter and refuge places for personnel.

11.4.3.3 Wind and Waves

- The marine terminal will be designed to allow LNG carrier approaches during high and low tides. The rock armour for coastal protection around the LNG berths will be designed to withstand a 1-in-100-year storm condition (repairable damage).
- In order to adapt to adverse marine conditions, LNG carriers will be equipped with radar, very high-frequency radios, automated identification systems, and navigational equipment. To further mitigate potential risks associated with LNG carrier traffic, pilotage is mandatory from at or near Triple Island (inwards and outwards), and tugs will escort and assist LNG carriers through the routing, berthing, and navigating in these areas.
- The design plan will incorporate potential extreme wind conditions as outlined in building codes and standards. The CSA codes, for example, consider the typical, as well as the maximum, wind loads. As a consequence, LNG carriers will not dock if weather circumstances exceed the design criteria.

11.4.4 Potential Effects on the Project

With a projected warmer climate, more precipitation is expected to fall as rain rather than as snow (see Section 11.3), which could alter characteristics of the region's hydrological cycle (including the flooding risk) and could lead to an increased risk of landslides. The Project's water supply could be affected if the hydrological regime changes along with a seasonal increase in hot, dry conditions. Sustained dry periods could reduce water availability of Kitimat River and thereby affect operations.

Confidence in predicting future extreme weather events is low; however, Project design will consider potential changes in weather extremes because they could pose a risk to all Project phases. Most existing codes and standards are based on historical climate records and do not consider operating environment characteristics for situations where the future climate contains ranges that extend beyond the historical climate record. To address this, Engineers Canada is currently engaging with governments and other regulatory authorities to review and adjust infrastructure codes and standards, as well as infrastructure climate design, in order to account for both current and future climate in engineering designs (Canadian Council of Professional Engineers, Engineers Canada, PIEVC 2008).

LNG Canada will address this concern by going beyond relying on existing codes and complying with current standards. LNG Canada considered extreme weather conditions, and mitigation measures will effectively withstand these extreme conditions and reduce potential effects associated with them (e.g., see mitigation measures for flood levels).

Based on the planned Project design and mitigation measures, the sensitivity of Project phases to extreme weather events will be nil to low, especially because adaptation strategies for potentially changing future flooding levels are incorporated in the design. More specific studies and analyses are anticipated during the engineering review phase in order to assess detailed Project design to cope with adverse effects of potential weather conditions and future changes. Potential studies include, for example, a winterization analysis and a more detailed flood study. In addition, during the engineering review, a design review and or vulnerability assessment analysis will be conducted. LNG Canada will continue monitoring and assessing environmental key variables that serve as precursors or triggers to extreme weather events in order to understand how to mitigate potential risk and how to adapt Project operations if required.

11.5 Seismic Activity and Tsunamis

Western Canada experiences higher than average seismic activity because of its location near major plate tectonic boundaries. The Juan de Fuca Plate (near Vancouver Island) is currently moving eastward beneath the North American Plate upon which most of Canada rests, while the Pacific Plate is moving northwestward along the edge of the North American Plate near Haida Gwaii. Consequently, Western Canada can experience various plate interactions: transform, divergent, and convergent boundaries. The Queen Charlotte Fault, which lies west of Haida Gwaii, takes up most of the seismic activity, including the largest historic earthquake in Canada, which occurred on August 22, 1949 (magnitude 8.1) (Cassidy et al. 2010), as well as a recent magnitude 7.8 earthquake on October 28, 2012 (Lay et al. 2013).

The simplified seismic hazard map for Canada shows a moderate relative risk for the northern part of the BC coast (Earthquakes Canada 2013a). The national earthquake database lists only one earthquake with magnitude 5.3 east of Masset for the period from 1985 to 2013 in a radius of 200 km around the Project site. All other earthquakes were of smaller magnitude (Earthquakes Canada 2013b).

An associated risk of seismic activity is the possible generation of tsunamis (long surface gravity waves) as well as liquefaction. Liquefaction is a soil phenomenon in which soil loses its integrity and liquefies due to strong earthquakes and ground shaking. Tsunamis can also be triggered by (submarine) landslides, related to slope instability. Landslide-generated tsunamis can produce substantial waves, with consequent run-up on coasts, and it can be amplified if the energy is trapped within inlets or fjords (Skvortsov and Bornhold 2007). Landslides are generally triggered by gradual processes (e.g., weathering) or external factors such as undercutting of a slope, intense rainfall, shock or vibration, or loading on upper slopes (Ministry of Energy and Mines BC 1993). BC's coast is characterized by steep slopes, seasonal extremes in soil moisture and large tidal ranges (DFO 2012). These factors, combined with a high seismic activity, increase the potential for slope failures (Conway et al. 2012). Landslide susceptibility around Kitimat Arm is ranked high according to the landslide susceptibility map of Canada (Bobrowsky and Dominguez 2012).

Kitimat Arm has experienced landslide-generated tsunamis in the recent past, with significant events in 1974 and 1975 and smaller events in 1952, 1968, and 1971 (Skvortsov and Bornhold 2007). The submarine landslide in 1975 occurred because of infrastructure development at the Moon Bay marina. Shoreline and marine works (dredging and fill placement) in Moon Bay led to increased loadings on the fjord sidewalls. This increased loading, together with increased pore water pressure, caused by an extreme low tide before the slide, are thought to have reduced slope stability and triggered the slide. The consequent tsunami reached a record wave height of 8.2 m and “flooded all facilities in the upper delta of Kitimat Arm, damaging the Northland Navigation Wharf, destroying dolphins at the Eurocan Terminal, and carrying away shore installations at the First Nations settlement of Kitamaat Village 4 km across the inlet on the east shore” (Skvortsov and Bornhold 2007).

Larger-volume slides than the two in 1974 and 1975 occurred 5,000 to 10,000 years before present in the southern part of Douglas Channel and are thought to have been triggered by earthquakes (Conway et al. 2012). Thomson et al. (2012) modelled the associated tsunamis and concluded that these submarine landslides would have caused waves with peak amplitudes of up to 30 m to 40 m near the failure region; but for regions farther away, such as Kitimat, the wave amplitude would have been below 1 m.

11.5.1 Description of Effect Mechanism

Project components could be affected by a tsunami or an extreme seismic event and associated risks (i.e., liquefaction) that exceed design capacity. The primary effect mechanism of a seismic event is damage to infrastructure through shaking and vibration. An earthquake of sufficiently large magnitude could lead to permanent lateral ground movement and alter the infrastructure foundation, which could lead to settlement or damage. This could lead to a LNG leak or spill and affect the surrounding environment. Similarly, slope instability leading to landslides and potential tsunamis could result in destructive wave heights, inundation of marine facilities, and damage to infrastructure.

11.5.2 Mitigation Measures

Local and regional seismicity are taken into account in the design and material selection. All facilities are designed in accordance with applicable standards for seismic hazard. Seismic design of LNG tanks in Canada are governed by the CSA Z276-11, which specifies three design levels of seismic ground motions (1) Operating Basis Earthquake (OBE), (2) Safe Shutdown Earthquake (SSE), and (3) Aftershock Level Earthquake (ALE, defined as one-half of SSE ground motions). The Project design will also consider standards such as NFPA-59A (ANSI 2006) in accordance with Natural Resources Canada’s requirements. Preliminary geotechnical site investigation by LNG Canada revealed that piled foundations and vibratory stone columns will be required to provide safe bearing capacities. If slope failure does occur (e.g., at cut and fill slopes onsite), it will be repaired, as much as possible, with material stored onsite to facilitate an immediate response. For the quayside and waterfront facilities, ground improvements will be implemented to prevent liquefaction.

Based on a modelling study by LNG Canada, the berths, the marine infrastructure, and the surrounding area could be inundated (not necessarily damaged) by a tsunami triggered by a landslide, especially if the tidal conditions elevate the sea level. For design purposes, wave heights corresponding to a landslide 10% larger than the worst-case scenario were modelled. Further, the LNG loading line corridor will be elevated to be above potential tsunami height. The facility itself is assumed to be safe from potential tsunamis because it will be located farther inland and protected by a bund that is higher than the maximum modelled tsunami crest elevation. The tsunami design conditions are based on tsunamis occurring during mean water level, which is conservative, because tsunamis from landslides are prone to happen during low tide conditions.

The Project will not be affected by tsunamis occurring outside the Douglas Channel because the fjord is branched and curved at multiple locations, which would dissipate tsunami energy.

11.5.3 Potential Effects on the Project

A liquefaction assessment was conducted for the Project by LNG Canada. The assessment determined that, liquefaction is possible onshore and offshore, as well as in the estuaries, under the conditions of an OBE event and/or a SSE event and could reach depths of about 15 m (up to 35 m in certain areas). The SSE corresponds to the greater of the probabilistic ground motion having a 2% probability of exceedance within a 50-year period (i.e., the 2,475-year return period earthquake) or the deterministic 84th percentile ground motion for the Cascadia subduction earthquake at each period of interest. The LNG tank systems and associated systems must not suffer collapse or loss of containment capability in the event of the SSE. The OBE corresponds to the probabilistic ground motion having a 10% probability of exceedance within a 50-year period (i.e., the 475-year return period earthquake) for each period of interest. The LNG tanks systems and associated systems are required to remain operational during and after the OBE event (CSA 2011).

In the area of the RTA Wharf “B”, the risk of liquefaction is predicted only under the SSE event and not the OBE event. However, liquefaction may occur in either the SSE or OBE event in other offshore areas.

Steep slopes and nested failures along the southeastern part of Douglas Channel could lead to future (submarine) landslides (Conway et al. 2012). Material in the area of Moon Bay that did not slide during the 1975 event poses a potentially greater future risk. Anthropogenic activities, such as construction, are thought to be triggering mechanisms (Ministry of Energy and Mines BC 1993). Potential effects of run-up waves caused by a tsunami could include inundation, erosion, and infrastructure damage. Wave generation can affect both the coastline and marine vessel traffic (Thomson et al. 2012).

The confidence level of predicting earthquakes or landslide-generated tsunamis is low because it is not possible to predict when these events might occur. Studies during the FEED phase will further assess the potential risk of seismic activity and tsunamis (e.g., risk of overtopping at berths) as well as liquefaction scenarios and, where appropriate, propose potential risk reduction measures for the land-based and marine infrastructure design.

11.6 Forest Fires

Forest fires result from human causes (e.g., campfires, all-terrain vehicle use, and other human activities) or from natural causes (e.g., lightning). The BC average, taken from 2002 to 2011, indicates 1,922 fires a year of which approximately 40% were caused by people and approximately 60% were caused by lightning (BC Wildfire Management Branch 2014).

Factors that influence the probability and magnitude of wildfires include fuel (i.e., vegetation type, loading, moisture content), ignition source, and climatic/weather conditions such as relative humidity, temperature, precipitation, wind speed, and wind direction (Price and Rind 1994). Wildfire conditions in BC change continuously according to these factors.

The Project site abuts small patches of mature and young forest stands, primarily between the Project and Kitimat River, which would provide limited fuel for forest fires. However, in general, stands in the Coastal Western Hemlock very wet maritime biogeoclimatic subzone have a very low risk of disturbance by fire due to the cool, wet climate of coastal forests (Dorner and Wond 2003). This is reflected in an analysis of historical wildfire incidents; the area shows low forest fire frequency and small areas burned. The location of all recorded forest fire incidents from 1980 to 2012 (DataBC 2014) were spatially analyzed by defining the spatial assessment area as a 100 km buffer around the Project footprint; there were only 94 fires reported from 1980 to 2012. Of these fires, 82% were caused by human activity and the rest by lightning. The mean area burned was 0.65 ha. Most of the fires occurred during the summer months, but some occurred as early as May or as late as October.

11.6.1 Future Projections of Forest Fires

Climate is a strong top-down driver of forest fires (Flannigan et al. 2000; Wotton et al. 2010) and determines forest fire frequency (Westerling et al. 2006) and size (Skinner et al. 1999; Stephens 2005). Different studies reported an increase in forest fire frequency and area burned over the last few decades (Stocks et al. 2002). A changing climate is expected to result in more frequent forest fires in many boreal forests across Canada (Flannigan et al. 2006). Warming temperatures play a key role for three reasons: they affect the amount of moisture in the atmosphere, they coincide with lightning, and they affect the length of the fire season. Balshi et al. (2009) estimate that the annual area burned in western North America will double by 2041 to 2050 compared with the amount burned during 1991 to 2000. Wotton et al. (2010) evaluated the potential effect of climate change on future forest-fire behaviour in BC, based on different general circulation models (GCM) (GCM from the Hadley Centre and GCM from the Canadian Centre for Climate Modelling). The results vary substantially with the GCM used, but both projections suggest that BC as a whole would experience an increase in fire activity by the end of the 21st century (Wotton et al. 2010).

11.6.2 Description of Effect Mechanism

Forest fires can temporarily suspend activities during all Project phases. In the case of a large fire, infrastructure can be damaged and the ability to operate can be impaired or stopped. Forest fires occurring close to the area surrounding the LNG facility could pose a risk and potentially result in a release of LNG to the environment.

11.6.3 Mitigation Measures

Project design follows strict fire codes such as the National Fire Code of Canada or the more Project-specific fire standards CSA Z-276-11 for LNG facilities. The LNG facility is equipped with an extensive firefighting system (fire water tanks, jockey pumps, fire water pumps and a fire water main grid that runs throughout the processing and storage site and marine terminal including, wharf), which could be used in the case of fires within the facility as well as for external fires.

The LNG processing facility is built from non-combustible materials. In addition, the designated exclusion zone and Project boundary provide sufficient buffers or firebreaks to reduce the risk of being affected by a distant, external forest fire. Kitimat River provides a firebreak to the east; other industrial sites and roads provide a firebreak to the west. The southern half of the Project footprint is non-forested wetlands, which are too wet to support a fire.

In the event of a forest fire during the construction, operation, or decommissioning phases, ongoing activities would be suspended in potentially affected areas if conditions were considered to be unsafe by LNG Canada or if requested by the appropriate authority.

11.6.4 Potential Effects on the Project

The extent of the effects from a forest fire depends on the location and size of the fire event in relationship to the Project site and the prevailing weather conditions. Large fires can result in a loss of resources and damage to property and infrastructure. Forest fire smoke can affect visibility and air quality.

Based on the predicted risk and the implemented mitigation measures, the Project phases are not expected to be affected by forest fires. The confidence level of the predicted low forest-fire risk is medium to high; however, forest fires or wildfires could pose a risk to all Project phases and, therefore, appropriate mitigation measures will be considered in the final Project design.

11.7 Conclusion

This section discussed potential effects of the environment on the Project and mitigation measures planned by LNG Canada to reduce the possible risk.

It is important to note that the relationship between the environment, such as extreme weather events, and effects on the Project, is not straightforward. The level of effect is influenced by exposure and vulnerability to the individual events, and the level of preparedness by LNG Canada. Further, the severity of an effect may be aggravated or alleviated by the season during which the event occurs and its duration or the simultaneous occurrence of another extreme event (Senevirante et al. 2012; Zwiers et al. 2013).

Factors of the environment, as analyzed in this section, could potentially affect Project infrastructure and operations, but these risks are understood and can be managed. The primary method to reduce potential risks of environmental effects is sound planning (including vulnerability assessment) and design, in conjunction with construction methods that are developed with the intent of reducing risks to acceptable levels.

Latest international standards, codes, technical advisor standards specifications, design and engineering practice, publications and standard drawings, and agreed-upon resiliency improvement measures beyond these standards and codes provide the basis for the Project's design. Design specifications for the Project will comply with Canadian and BC legislation and regulations, and LNG Canada policies, standards, and guidelines. In addition, a design review analysis (process and operation-focused assessment), as well as specific risk studies, will be conducted during the FEED stage of the Project design to further adapt the design and to predict, prepare, and appropriately control risks and their potential effects.

Current building codes and standards are usually based on past extreme weather statistics, assuming that the climate remains static. These assumptions become less valid with a changing climate (Auld et al. 2010). Extreme events may happen outside the thresholds of current design codes and standards and could represent a potentially unaddressed risk. Some designs have adequate resilience, but, in some cases, a small change in environmental conditions can result in a critical response and an escalating risk for the operation. The effect from climate change will be felt through changing averages as well as through changes in frequency and intensity of extreme events. Design measures and mitigation approaches will be incorporated into the planning, construction, and operation phases of the Project to reduce these potential risks. LNG Canada goes well beyond complying with codes and standards and hence addresses the risk of potentially changing extreme weather events (e.g., planning for additional future flooding protection). LNG Canada has considered extreme weather events and potential effects associated with them and developed mitigation measures to effectively withstand these conditions.

The Project participants (see Section 2) are leaders in the global LNG industry. Since 1964, they have constructed and operated LNG facilities throughout the world. This depth of experience has been applied to the Project through planning, engineering design, and mitigation measures proposed to address the potential adverse effects of the environment on the Project. Given the various strategies and mitigation measures, it is unlikely that the Project will be severely affected by the environmental factors addressed in this section.