

## **4 ASSESSMENT OF POTENTIAL ENVIRONMENTAL EFFECTS**

---

### **4.10 Marine Mammals**

#### **4.10.1 Introduction**

Marine mammals were selected as a Valued Component (VC) because of their traditional, cultural, ecological, and recreational (including economic) importance and their potential to be affected by the construction, operations and decommissioning of the Aurora liquefied natural gas (LNG) Project (the Project). Protection of marine mammals is regulated under legislation such as the Federal *Fisheries Act* and *Species at Risk Act* (SARA), and marine mammals have been identified as being important to Aurora LNG, regulators, Aboriginal Groups, stakeholders, and the public. The assessment of potential effects on marine mammals was conducted based on the information requirements identified in the Application Information Requirements (AIR).

For the purpose of this assessment, marine mammals are inclusive of all species of whale, dolphin, porpoise, seal, sea lion, and sea otter that may occur in northern British Columbia (BC) and thus may interact with Project activities. Special consideration is given to those marine mammal species designated as *endangered*, *threatened*, or *special concern* under Schedule 1 of SARA (SARA 2002).

The Marine Mammal VC is linked to other VC assessments, either through integration (information from other VCs is incorporated into this assessment) or support (information from this assessment is incorporated into the assessment of other VCs). Components of this assessment integrate information from the following VCs:

- Water Quality (see Section 4.5)
- Marine Fish and Fish Habitat (see Section 4.9).

Other VCs and sections supported by components of this assessment include:

- Marine Use and Navigable Waters (see Section 6.5)
- Summary of Statutory Requirements under CEAA 2012 (see Section 11.0)
- Aboriginal Consultation (see Section 12.0).

The Acoustic Environment assessment (see Section 4.4) relates to potential changes to in-air sound levels only, and effects are considered from a human perspective. Potential changes to underwater sound levels are addressed within this section of the assessment and are also discussed in the assessment of Marine Fish and Fish Habitat (see Section 4.9), as increases in underwater noise from construction and operations may affect marine wildlife. Potential effects associated with accidents or malfunctions, including spills of toxic or hazardous materials during Project construction and operations, are discussed in Accidents or Malfunctions (see Section 9.0).

Additional information on the study methods and results related to this assessment are provided in the Marine Mammals Technical Data Report (TDR) (see Appendix N), the Prince Rupert – Aurora LNG Acoustic Monitoring Study (see Appendix O), and the Aurora LNG Acoustic Study: Modelling of

Underwater Sounds from Pile Driving, Rock Socket Drilling, and LNG Carrier Berthing and Transiting (see Appendix P).

#### **4.10.2 Scope of Assessment**

This section of the Application defines and describes the scope of the assessment of potential effects on marine mammals, including the regulatory and policy setting, influence of consultation on the assessment, and the selection of potential effects and measurable parameters.

##### **4.10.2.1 Regulatory and Policy Setting**

The assessment of potential effects of the Project on issues under federal jurisdiction, which include marine mammals, is mandated under Section 5(1)(a) and (b) of the *Canadian Environmental Assessment Act 2012* (CEAA 2012). Section 5(1)(c) also requires an assessment of potential effects on marine mammals due to their potential to affect Aboriginal peoples.

Regulation of marine mammals in Canada is governed primarily by the Federal *Fisheries Act* (1985) (under which marine mammals are classified as ‘fish’ for regulatory purposes), and the associated Marine Mammal Regulations. Section 7 of the Marine Mammal Regulations prohibits ‘disturbance’ of marine mammals except when fishing for them under the authority of the Regulations.

The SARA is the main federal statute pertaining to the conservation and protection of marine mammal (and other) species at risk. Under Section 32(1) of SARA, no person shall kill, harm, harass, capture or take an individual of a wildlife species [including marine mammal] that is listed as an extirpated species [i.e., locally extinct], an endangered species, or a threatened species. Subsection 58(1) of SARA prohibits the destruction of any part of the designated critical habitat of any listed endangered, threatened, or extirpated species.

Additional legislation, including the BC *Wildlife Act* (1996), the International Convention for the Prevention of Pollution from Ships, the *Canada Shipping Act* (2001), the *Canadian Environmental Protection Act* (1999), and the BC *Environmental Management Act* (2003), provides further guidance for the management and protection of marine mammals. Further details on these acts and policies as they apply to marine species are outlined in the assessment of marine fish and fish habitat (see Section 4.9).

A number of other federal guidance documents are also of relevance to marine mammals. Fisheries and Oceans Canada (DFO) relies on the following best management practices (BMPs) to reduce potential effects on marine mammals associated with marine pile driving and in-water blasting:

- Best Management Practices for Pile Driving and Related Operations (BC Marine and Pile Driving Contractors Association and DFO 2003)
- Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters (Wright and Hopky 1998).

The marine mammal assessment has also been developed in consideration of relevant listed species’ action plans, recovery strategies, or management plans, and in recognition of key threats and recommended mitigation measures identified in such plans.

While the Canadian federal government has not developed guidelines or formally recognized regulatory thresholds for underwater sound levels to protect marine mammals from injury or disturbance, a key component of the assessment of potential effects on marine mammals relates to the introduction of anthropogenic sources of noise into the marine environment. Research continues to progress in this field and suggested noise thresholds are constantly evolving, but there is currently little consensus among bioacousticians as to how to best perform acoustic impact assessments or determine injury and/or disturbance thresholds. In the absence of formal Canadian thresholds, the acoustic modelling conducted in support of this assessment conservatively considered a number of acoustic assessment criteria, based on interim regulatory guidelines historically applied in the United States (US), more recently recommended thresholds published in the peer-reviewed scientific literature, and recent regulatory review of other Canadian projects. Methods and results of underwater noise modelling, and the selection of thresholds is discussed in Section 4.10.5.1 below and in detail in Appendix P (Aurora LNG Acoustic Study: Modelling of Underwater Sounds from Pile Driving, Rock Socket Drilling, and LNG Carrier Berthing and Transiting).

#### **4.10.2.2 Influence of Consultation on the Assessment**

The development of the AIR and this Application was influenced by Aurora LNG's consultation with members of the Working Group, Aboriginal Groups, and the public. This subsection documents and summarizes how the information obtained through consultation completed by Aurora LNG influenced the assessment of marine mammals. Potential sources of this information include, but are not limited to, the EA-related Pre-Application Consultation completed by Aurora LNG, which is provided in more detail in the Aboriginal Consultation Plan, Public Consultation Plan and associated consultation reports.

Table 4.10-1 provides a summary of the topics and key information and concerns that Aurora LNG identified as part of its consultation that relate to the Marine Mammals VC, as well as a summary of the influence that the outcomes of this consultation had on the assessment.

**Aurora LNG**

Environmental Assessment Certificate Application

Section 4.10: Marine Mammals

**Table 4.10-1 Summary of Key Information and Concerns that Influenced the Scope of the Assessment**

Topic	Key Information and Concerns	Influence on the Assessment
Existing information	The Application should incorporate information on listed species, seasonal distribution, abundance, and important areas for marine mammals. Information should be collected through seasonal marine mammal field surveys, ambient acoustic monitoring, and predictive acoustic modelling.	As a result of the comments received, additional field surveys for marine mammals were conducted to expand on seasonally collected data, acoustic monitoring of the marine environment in the Project area was conducted, and modelling of underwater noise for marine construction and operations activities have been undertaken for the Project. Results (see Appendices N, O and P, respectively) were used to inform the assessment of potential residual Project and cumulative effects.
Local Assessment Area (LAA) boundaries	<p>The LAA buffer for assessment of effects on marine mammals should reflect the potential extent of behavioural effects from underwater noise.</p> <p>Fisheries and Oceans Canada has advised Aurora LNG that for the assessment of the Project, the LAA should be set to encompass the area where any Project activity (construction, operations, decommissioning) will exceed 160 decibels (dB).</p>	Results of acoustic modelling showed that the 160 decibel (dB) rms re 1 µPa (micropascal) isopleth was reached at a maximum distance ( $R_{max}$ ) of 4.0 kilometres (km) from the LNG jetty and 7.2 km from the material offloading facility (MOF) during marine construction activities, and 0.1 km during berthing and shipping activities. These distances fall within the range of the original LAA buffer; therefore no modifications to the LAA boundaries were made (see Section 4.10.2.5)
Regional Assessment Area (RAA) boundaries	<p>The RAA buffer should be ecologically relevant and reflect marine traffic contributions from this Project and other projects as part of the cumulative effects assessment. It is also understood that, for the assessment of underwater noise on marine mammals, some behavioural effects will extend beyond the LAA into the RAA.</p> <p>Given that shipping noise may have potential behavioural effects on marine mammals and because the project inclusion list includes Kitimat shipping traffic, the RAA for marine mammal may need to include a larger area to the south of Triple Island for the cumulative effects assessment.</p>	<p>The boundaries of the marine mammal RAA encompass the area within which potential Project-related effects on marine mammals could act cumulatively with effects from other past, present or reasonably foreseeable future projects and encompass all projects and activities in the region (Prince Rupert / Chatham Sound / Triple Island) (see Section 4.10.2.5). Behavioural effects from underwater noise will extend beyond the LAA into the RAA and will be assessed in that context.</p> <p>The boundaries of the originally proposed RAA for marine mammals were revised to include the Archibald Islands to the south and the northwest coastline of Stephens Island.</p>
Effects of noise and vessel strikes	Potential Project effects should assess underwater noise, include potential for exposure to noise above injury thresholds, and include change in mortality risk	As a result of the comments received, change in mortality risk was added to address potential for lethal vessel strikes (see Section 4.10.5.4). The potential for marine mammal auditory injury as a result of Project activities was assessed under change in health (see Section 4.10.5.2).

**Table 4.10-1 Summary of Key Information and Concerns that Influenced the Scope of the Assessment**

Topic	Key Information and Concerns	Influence on the Assessment
Effects on habitat and prey	The Application should identify and assess important areas and potential effects on marine mammal prey species	The assessment of change in behaviour for marine mammals considered potential for changes in localized movement patterns or access to preferred habitats, including foraging areas (see Section 4.10.5.2). It was informed by potential changes in the distribution or availability of prey resources as a result of Project-related activities, as identified in the marine fish and fish habitat assessment (see Section 4.9).
Exclusion zones	Fisheries and Oceans Canada stated that underwater noise levels of 160 dB should be used to define the size of exclusion zones monitored during construction.	Project specific underwater noise modelling has been used to verify the proposed spatial boundaries of the exclusion zones (see Section 4.10.5.2) for marine mammals based on the predicted 160 dB rms re 1 µPa sound contour as per DFO advice.

Detailed information related to the influences of the Working Group (including Aboriginal Groups) and the public on the AIR can be found in the respective Tracking Tables compiled by Aurora LNG, which detail the comments received and Aurora LNG's associated responses and are available on the BC Environmental Assessment Office (BC EAO) website<sup>1</sup>. Additional information on the influences of Aboriginal Groups and the public, related to the AIR and the compilation of this Application, can also be found in the sections related to Aboriginal Consultation (see Section 12.0) and Public Consultation (see Section 13.0) of this Application, respectively.

#### **4.10.2.3 Traditional Knowledge and Traditional Use Incorporation**

Traditional knowledge (TK)/traditional use (TU) information was gathered from Project specific studies submitted to Aurora LNG and from publically available sources. This information was reviewed and considered during the preparation of the Application, and has been incorporated into the assessment, where applicable.

Aurora LNG worked with Aboriginal Groups on the scope of these Project specific studies, generally allowing each of the Aboriginal Groups to focus their specific studies on the topics, data and concerns they believed were the most pertinent to the Project. At the time of writing of this assessment, Project specific studies had been received from Metlakatla First Nation, Gitxaala Nation, Kitsumkalum First Nation, Kitselas First Nation and Gitga'at First Nation.

Furthermore, Aurora LNG anticipates receiving an Aboriginal Interest and Use Study (AIUS) and socio-economic study from Lax Kw'alaams Band during Application review. Aurora LNG is committed to working with Lax Kw'alaams Band to incorporate this additional information in the environmental assessment.

Details related to the incorporation of Project specific TK/TU and other available information relevant to marine mammals are outlined in Section 4.10.3.1 (Existing Conditions for Marine Mammals).

#### **4.10.2.4 Selection of Potential Effects and Measurable Parameters**

Table 4.10-2 lists the potential Project effects on marine mammals and provides a summary of the Project effect mechanisms and measurable parameters used to assess the potential effects. Project effect mechanisms are shown in this table to show the linkage between the potential Project effect and the Project mechanism that could result in that effect; these mechanisms are described in more detail in the assessment of residual effects section. Measurable parameters facilitate qualitative or quantitative measurement of potential Project and cumulative effects, and provide a means to characterize the change in health (with respect to the potential injury from underwater noise or in-water blasting), behaviour (particularly as a response to increases in underwater noise), and mortality risk (given increased potential for vessel strikes). Measurable parameters are qualitative in the absence of metrics or standards to support quantitative analyses.

---

<sup>1</sup> [http://a100.gov.bc.ca/appsdata/epic/documents/p416/1448316686253\\_JvGzWTNTrbXHdlMx4vyDqW8DV3jBflkTwl8y9d2yp1sDnt1V0I3W!-1807974911!1448316206814.pdf](http://a100.gov.bc.ca/appsdata/epic/documents/p416/1448316686253_JvGzWTNTrbXHdlMx4vyDqW8DV3jBflkTwl8y9d2yp1sDnt1V0I3W!-1807974911!1448316206814.pdf)

Potential effects of the Project on marine mammals identified in the AIR were selected based on: the anticipated nature of Project activities and works during construction, operations, and decommissioning; legislative and regulatory requirements (e.g., compliance with SARA and the *Fisheries Act*); issues and concerns identified during consultation with government agencies, Aboriginal Groups, stakeholders, and community members (see Section 4.10.2.2); and, the professional judgment and experience of the environmental assessment team on similar projects along the Pacific north coast of BC.

Marine mammals and marine birds have been split into separate VCs (originally combined as the Marine Wildlife VC in the AIR) to better focus the assessment. The assessment of the potential effects on marine birds can be found in Section 4.11.

As part of the process of compiling the Application, measurable parameters were modified from those appearing in the AIR. Edits were as follows:

- The metric for expressing extent (in change in health and change in behaviour) was changed from square metres to kilometres (km) to better reflect the way in which sound level threshold exceedances are measured. Results of acoustic modelling are presented using the  $R_{95\%}$  radius (in km), which is the predicted range encompassing at least 95% of the area (in the horizontal plane) that would include sound at or above a set level (e.g., marine mammal injury or behavioural disturbance thresholds) (further explanation of  $R_{95\%}$  is provided in Section 4.10.2.5 and in Aurora LNG Acoustic Study: Modelling of Underwater Sounds from Pile Driving, Rock Socket Drilling, and LNG Carrier Berthing and Transiting, Appendix P).
- The term 'qualitative' was added to qualify likelihood under the measurable parameter for change in mortality risk to better reflect the style of assessment (i.e., a qualitative assessment of mortality risk was undertaken; no quantitative assessment of vessel strike likelihood was performed). The text in parentheses was also added to clarify that with the implementation of mitigation measures, the only anticipated potential for a Project change in mortality risk is from an increased potential for vessel strikes. Further details are provided in Section 4.10.5.4. Potential for injury from marine construction activities such as in-water impact pile driving and in-water blasting is assessed in Section 4.10.5.2.

**Table 4.10-2 Potential Effects and Measurable Parameters for Marine Mammals**

Potential Project Effects	Project Effect Mechanism	Measurable Parameters	Rationale for Selection of Measurable Parameter
Change in health	Project-related construction (i.e., LNG jetty, MOF, and pioneer facility), operations (i.e., shipping activities), and decommissioning will introduce new sources of underwater noise to the marine environment	Timing, duration (hr), intensity (dB) and extent (km) of underwater noise, relative to published and/or industry standards for the onset of auditory injury (i.e., permanent threshold shifts) to marine mammals from underwater noise	Exposure to underwater noise above recognized thresholds has the potential to cause auditory injury in marine mammals
Change in behaviour	Project-related construction (i.e., LNG jetty, MOF, and pioneer facility), operations (i.e., shipping activities), and decommissioning will introduce new sources of underwater noise to the marine environment	Timing, duration (hr), intensity (dB) and extent (km) of underwater noise, relative to published and/or industry standard thresholds for marine mammal behavioural responses to underwater noise	Exposure to underwater noise above recognized thresholds has the potential to alter marine mammal behaviour
Change in mortality risk	Project-related activities will increase the amount of marine traffic during construction and decommissioning (e.g., support vessels), and operations (e.g., LNG carriers, escort and harbour tugs)	Estimated change in likelihood (qualitative) of mortality or injury to marine mammals resulting from Project-related increases in marine traffic (i.e., increased potential for vessel strike)	Project-related vessels have the potential to strike and injure or kill marine mammals

**4.10.2.5 Boundaries**

The spatial, temporal, administrative, and technical boundaries for the assessment of effects on marine mammals are discussed below.

**SPATIAL BOUNDARIES**

The local assessment area (LAA) and regional assessment area (RAA) boundaries for the assessment of marine mammals are described in Table 4.10-3 and are generally consistent with the boundaries identified in Section 3.3 (Assessment Boundaries of the AIR), except the following changes:

- The size of the LAA was originally determined by applying a 6 km buffer around the LNG jetty and MOF and on either side of the shipping route; the buffer diameter was selected based on the results of previous underwater noise modeling studies conducted for other recent environmental assessments of BC North Coast projects. During review of the AIR, DFO advised that: “The LAA should encompass the area where any project activity (construction, operations, decommissioning) will exceed 160 dB” (BC EAO 2015). Project specific underwater noise modeling was later undertaken to determine the distance over which sound pressure levels (SPLs) of 160 decibels (dB) re 1 micropascal (µPa) root-mean-squared (rms) were exceeded. Results of underwater noise modeling work confirm that a buffer of 6 km captures the area over which both the predicted  $R_{max}$  and

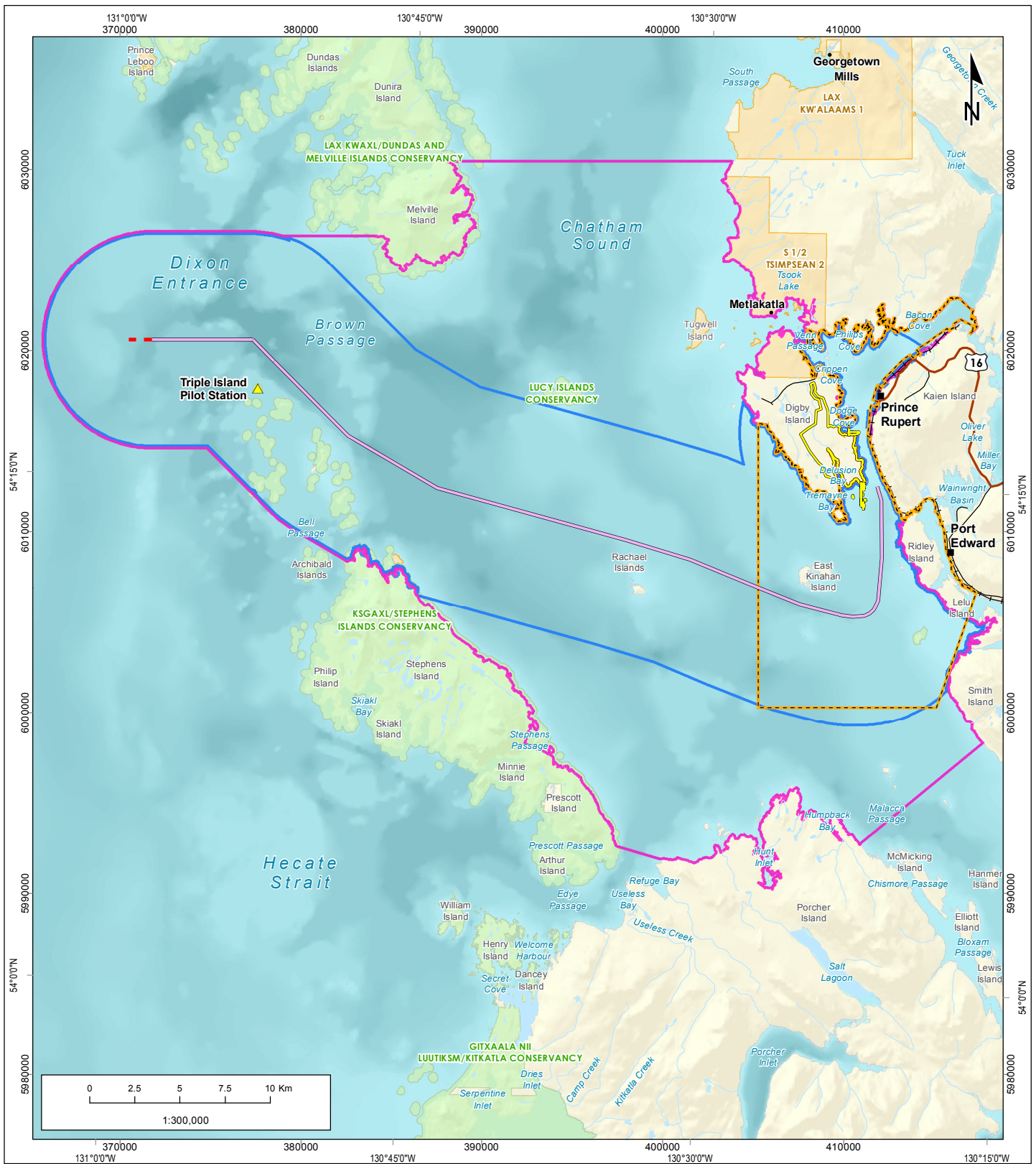
$R_{95\%}$  SPLs exceed the 160 dB re 1  $\mu$ Pa rms thresholds during Project-related activities.  $R_{95\%}$  is the predicted range encompassing at least 95% of the area (in the horizontal plane) that would include sound at or above that level. Full results of the acoustic modelling are presented in the Aurora LNG Acoustic Study: Modelling of Underwater Sounds from Pile Driving, Rock Socket Drilling, and LNG Carrier Berthing and Transiting (see Appendix P). Note that while the maximum distance ( $R_{max}$ ) to the 160 dB re 1  $\mu$ Pa rms contour at the MOF was predicted to be 7.2 km during marine construction activities, because of the confined nature of the marine waters at this location and the fact that the 6 km boundary also extended outwards from the marine shipping routes to the south, these isopleths still fell within the boundaries of the original LAA.

- The RAA for marine mammals has been developed to encompass the area within which potential Project-related effects on marine mammals could act cumulatively with effects from other past, present and reasonably foreseeable future projects and activities. Based on feedback received during consultation, the boundaries of the originally proposed RAA for marine mammals were revised to include the Archibald Islands to the south and the northwest coastline of Stephens Island. The cumulative effects assessment for marine mammals will consider vessel traffic from Kitimat and Prince Rupert that overlaps with the RAA and is associated with past, present and reasonably foreseeable future projects.
- It is also understood that, for the assessment of underwater noise on marine mammals, some behavioural effects will extend beyond the LAA into the RAA. These effects are considered in this assessment.

These boundaries are illustrated in Figure 4.10-1.

**Table 4.10-3 Spatial Boundaries for Marine Mammals**


Boundary	Description and Rationale for Selection
LAA	The LAA is based on a 6 km buffer around the marine terminal and a 6 km buffer extending on either side of the shipping route, which extends from the marine terminal to the Triple Island pilot boarding station. Fisheries and Oceans Canada advised that the LAA should encompass the area where any Project activity (construction, operations, decommissioning) will exceed 160 dB re 1 $\mu$ Pa root-mean-squared (rms). Results of Project specific underwater noise modelling studies confirmed that this area was encompassed in the original buffer applied in the AIR.
RAA	The RAA extends from the marine terminal to west of the Triple Island pilot boarding station and encompasses Prince Rupert Harbour and most of Chatham Sound. The use of the Triple Island boarding station as a westward boundary is based on professional judgment and is consistent with other recent environmental assessments for projects in the Prince Rupert Area.



- |  |   |  |
|--|---|--|
| <ul style="list-style-type: none"> <li>■ City, Municipality, or Town</li> <li>• Community, Locality, or Village</li> <li>▲ Triple Island Pilot Station</li> <li>— Highway</li> <li>— Road</li> <li>— Railway</li> <li>— Watercourse</li> </ul> | <ul style="list-style-type: none"> <li>■ Park, Protected Area, Ecological Reserve, or Conservancy</li> <li>■ First Nation Reserve</li> <li>■ Waterbody</li> <li>■ Prince Rupert Port Authority Boundary</li> <li>■ Shipping Route</li> <li>■ Pilot Boarding Zone</li> </ul> | <ul style="list-style-type: none"> <li>■ Project Development Area</li> <li>■ Local Assessment Area</li> <li>■ Regional Assessment Area</li> </ul> <p><b>Bathymetry (m)</b></p> <p>High : 1</p> <p>Low : -500</p> |
|--|---|--|

**Data Sources:** Government of British Columbia: DataBC, Terrain Resource Information Management, National Topographic System, BC Stats, BC Oil & Gas Commission, Government of Canada: CanVec v12, National Hydrology Network, Atlas of Canada National Framework, Fisheries and Oceans Canada, Environment Canada, Natural Resources Canada, BC Marine Conservation Analysis, INPEX Gas British Columbia Ltd, Nexen Energy ULC, Service Layer Credits, Copyright © 2014 Esri

**Disclaimer:** Contains information licensed under the Open Government License – British Columbia, Canada. Although there is no reason to believe that there are any errors associated with the data used to generate this product or in the product itself, users of these data are advised that errors in the data may be present. Use of this map is strictly at user's own risk. Nexen Energy ULC (Nexen) and INPEX Gas British Columbia Ltd. (IGBC) and each of their affiliates make no representation, warranty or guaranty about this map or its contents, including, without limitation, accuracy, completeness, or fitness for any purpose. Nexen and IGBC shall have no liability for any errors, omissions, or inaccuracies in the information provided. Nexen and IGBC assumes no liability for any decisions made or actions taken or not taken in reliance upon the data furnished on this map. Usage, manipulation, or reproduction, in any form, of the data and information contained herein is prohibited without permission of Nexen and IGBC.



**ENVIRONMENTAL ASSESSMENT  
CERTIFICATE APPLICATION**

**LOCAL AND REGIONAL ASSESSMENT  
BOUNDARIES FOR MARINE MAMMALS**

Projection: UTM Zone 9 Datum: NAD 83	Fig. ID: 123220054 Date: Oct 21, 2016	Drawn By: RC Checked By: AA	FIGURE NO: <b>4.10-1</b>
---	--	--------------------------------	--------------------------

### ***TEMPORAL BOUNDARIES***

The temporal boundaries for the assessment are:

- Construction: Phase 1 (trains 1 and 2) is anticipated to commence in 2020 and will be completed within approximately five to six years; Phase 2 (trains 3 and 4) will commence based on market demand.
- Operations: Minimum 25 years after commissioning.
- Decommissioning: Is anticipated to commence approximately 12 months after the end of the Project life and continue for approximately two to five years.

### ***ADMINISTRATIVE BOUNDARIES***

The following administrative boundaries are applicable to the marine mammal assessment:

- Legislative and regulatory requirements – legislation applicable to the conservation and management of marine mammals, such as the *Fisheries Act*, SARA, and critical habitat orders. There is no designated critical habitat for marine mammals in the RAA.
- Prince Rupert Port Authority (PRPA) – the marine components of the Project as well as a portion of the shipping route lie within the jurisdictional boundary of the PRPA. The PRPA manages port activities within the Prince Rupert harbour and may implement certain restrictions, such as speed limits, on Project activities.
- Chatham Sound Ecologically and Biologically Significant Area (EBSA) and DFO Important Areas (IAs) for marine mammals – the Project lies within the Chatham Sound EBSA, established as one of 15 EBSAs identified within the Pacific North Coast Integrated Management Area (PNCIMA). Ecologically and Biologically Significant Areas are defined as areas worthy of enhanced management or risk aversion (DFO 2004). Regional experts also identified IAs for a variety of species, including marine mammals, based on an evaluation of five criteria (i.e., Uniqueness, Aggregation, Fitness Consequences, Naturalness, and Resilience) (Clarke and Jamieson 2006a). The IAs were then ranked as low, medium, or high importance. The Chatham Sound EBSA makes up part of a high importance IA for northern resident killer whales, a high importance IA for humpback whales, and a moderate importance IA for Steller sea lion (Clarke and Jamieson 2006b; PNCIMA 2011; Ford 2014) (see Figure 4.10-2).
- Conservancies are established under the BC *Park Act* and often encompass a portion of the marine environment. Conservancies have been established for (a) the protection and maintenance of their biological diversity and natural environments; (b) the preservation and maintenance of social, ceremonial and cultural uses of First Nations; (c) the protection and maintenance of their recreational values; and (d) development or use of natural resources in a manner consistent with the purposes of (a), (b) and (c) above. There are three conservancies that overlap with the RAA (see Figure 4.10-2):
  - Ksgaxl/Stephens Islands Conservancy
  - Lax Kwaxl/Dundas and Melville Islands Conservancy
  - Lucy Islands Conservancy.

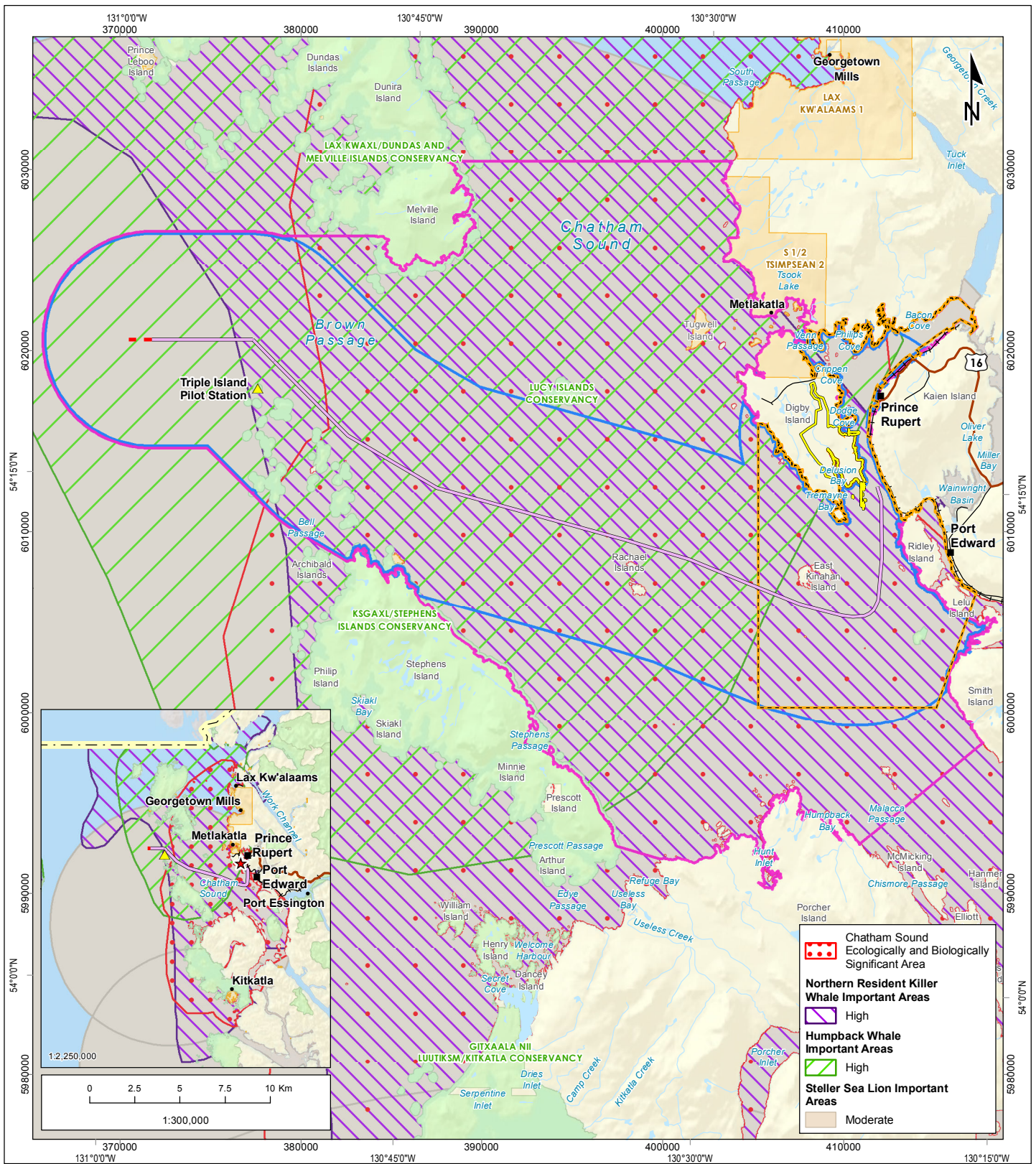
## **Aurora LNG**

Environmental Assessment Certificate Application

Section 4.10: Marine Mammals

---


According to BC Parks (2016), marine mammals that use these areas include killer whales, humpback whales, Steller sea lions, Pacific white-sided dolphins, harbour seals, and porpoises. While sea otters have recently been sighted around Triple Island and nearby Rachael Island in the northern part of the Ksgaxl/Stephens Islands conservancy (BC Parks 2016), sightings are typically of lone males, as such this area is not yet considered part of their occupied range (Ford 2014).



<ul style="list-style-type: none"> <li>City, Municipality, or Town</li> <li>Community, Locality, or Village</li> <li>Triple Island Pilot Station</li> <li>Highway</li> <li>Road</li> <li>Railway</li> <li>Watercourse</li> </ul>	<ul style="list-style-type: none"> <li>Park, Protected Area, Ecological Reserve, or Conservancy</li> <li>First Nation Reserve</li> <li>Waterbody</li> <li>Prince Rupert Port Authority Boundary</li> </ul>	<ul style="list-style-type: none"> <li>Project Location</li> <li>Shipping Route</li> <li>Pilot Boarding Zone</li> <li>Project Development</li> <li>Local Assessment Area</li> <li>Regional Assessment Area</li> </ul>
--	--	---

**Data Sources:** Government of British Columbia: DataBC, Terrain Resource Information Management, National Topographic System, BC Stats, BC Oil & Gas Commission, Government of Canada: CanVec v12, National Hydrology Network, Atlas of Canada National Framework, Fisheries and Oceans Canada, Environment Canada, Natural Resources Canada, BC Marine Conservation Analysis, INPEX Gas British Columbia Ltd, Nexen Energy ULC, Service Layer Credits, Copyright © 2014 Esri

**Disclaimer:** Contains information licensed under the Open Government License – British Columbia, Canada. Although there is no reason to believe that there are any errors associated with the data used to generate this product or in the product itself, users of these data are advised that errors in the data may be present. Use of this map is strictly at user's own risk. Nexen Energy ULC (Nexen) and INPEX Gas British Columbia Ltd. (IGBC) and each of their affiliates make no representation, warranty or guaranty about this map or its contents, including, without limitation, accuracy, completeness, or fitness for any purpose. Nexen and IGBC shall have no liability for any errors, omissions, or inaccuracies in the information provided. Nexen and IGBC assumes no liability for any decisions made or actions taken or not taken in reliance upon the data furnished on this map. Usage, manipulation, or reproduction, in any form, of the data and information contained herein is prohibited without permission of Nexen and IGBC.



**ENVIRONMENTAL ASSESSMENT  
CERTIFICATE APPLICATION**

**MARINE MAMMAL  
ADMINISTRATIVE BOUNDARIES**

Projection: UTM Zone 9 Datum: NAD 83	Fig. ID: 123220054 Date: Oct 21, 2016	Drawn By: RC Checked By:	FIGURE NO: <b>4.10-2</b>
---	--	-----------------------------	--------------------------

### ***TECHNICAL BOUNDARIES***

The technical boundaries summarized below did not limit the ability to fully assess the potential effects of Project activities on marine mammals:

- Spatial and temporal – field programs (marine mammal surveys and underwater acoustic monitoring) were conducted to collect information on marine mammal occurrence within the RAA to better understand their distribution and seasonal presence (see the Marine Mammals TDR, Appendix N). Project specific data are limited to specific periods of time between 2014 and 2015 and the specific areas surveyed/monitored within the RAA; however, these data are supplemented by data from the scientific literature (e.g., Ford et al. 2010; Best and Halpin 2015; Ford 2014), from voluntary sightings databases (British Columbia Cetacean Sightings Network [BCCSN] 2014), and from surveys conducted by other proponents in the RAA (e.g., LNG Canada 2014; Stantec 2016 [Pacific NorthWest LNG Project Marine Mammal Program Final Report]). Absence of sightings or acoustic detections cannot be interpreted to represent an absence of species occurrence in the area. Likewise, Project specific estimates of species densities and relative abundance were only possible for marine mammal species with a sufficient number of sightings recorded (i.e., humpback whales and harbour porpoise).
- Project construction and design parameters – the marine mammal assessment has been prepared based on the understanding of the preferred construction methods and Project design at the time of filing. Detailed engineering studies and geotechnical investigations are still underway, and the results of these studies may change or refine the construction methods and/or Project design.
- Acoustic modelling – the marine mammal assessment relies on the results of underwater modelling to predict Project-related changes in underwater noise. Model input parameters specific to the engineering and design of the marine components and activities are based on the best available information or conservative assumptions at the time of the modeling. Source levels are likewise based on best available surrogate measurements from comparable activities/sources.
- Scientific knowledge – scientific understanding of the levels of underwater noise capable and likely to cause effects on marine mammals continues to progress at a rapid pace; however, some of the current thresholds in use at the time of assessment exist only in interim or draft form, and scientific consensus or formal regulatory guidance is often lacking. Also, the scientific/acoustic community has questioned the application of a singular numeric threshold to predict behavioural effects, since situational context for noise exposure is recognized as being a key factor in predicting outcome. Available sound thresholds to predict behavioural response are therefore considered herein as a guide to informing the assessment of potential effects of sound on marine mammals rather than as an absolute measure of such effects occurring.

The limitations associated with baseline data (as noted above) were accounted for in the assessment by:

- Conducting Project-related surveys during appropriate time periods (e.g., eight marine mammal surveys across a one-year period to attempt to capture seasonal variations in density) and considering results from surveys conducted for other projects in the RAA (e.g., Pacific NorthWest [PNW] LNG project, LNG Canada Export Terminal project)
- Using a statistically rigorous survey design, with appropriate coverage of the different types of habitats considered representative of conditions in the RAA

- Supplementing visual observations with acoustic detections collected during a dedicated acoustic monitoring program
- Undertaking extensive literature reviews to complement baseline data collected during field studies.

Limitations associated with Project construction/design and underwater acoustic modeling were accounted for by using conservative estimates for model parameters and scenarios (e.g., by modeling scenarios that would result in Project effects of greater magnitude or duration), so that in the event that Project construction or design are refined, the assessment of potential effects on marine mammals remains representative. Limitations on understanding of how and what levels of sound might affect marine mammals is accounted for by considering a variety of acoustic thresholds, and by using modelling results as only one tool to inform the assessment, in combination with a review of other current scientific literature (e.g., wherein situational examples lacking in numeric thresholds can still provide context to the assessment).

Assumptions and technical limitations pertaining to scientific information, field programs, data analyses, and data interpretation are discussed in detail within the associated TDRs (see Appendices N, O and P; see Section 4.10.3.1 for a breakdown of content in the TDRs).

#### **4.10.2.6 Residual Effects Description Criteria**

The criteria and definitions described in Table 4.10-4 are used to characterize the residual effects on marine mammals.

**Aurora LNG**

Environmental Assessment Certificate Application

Section 4.10: Marine Mammals

**Table 4.10-4 Characterization of Residual Effects on Marine Mammals**

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories	
Magnitude	The amount of change to the VC relative to existing conditions	Negligible	No measurable change from existing conditions
		Low	A measurable change from existing conditions, that is below environmental and/or regulatory guidelines, and does not affect the long-term persistence of any marine mammal population in the assessment area
		Moderate	A measurable change from existing conditions, that is above environmental and/or regulatory guidelines, but does not affect the long-term persistence of any marine mammal population in the assessment area
		High	A measurable change from existing conditions, that is above environmental and/or regulatory guidelines, and has potential to affect the long-term persistence of any marine mammal population in the assessment area
Geographic Extent	The geographic area in which an effect occurs	PDA	Residual effect is restricted to the PDA
		LAA	Residual effect extends into the LAA
		RAA	Residual effects may interact with similar effects from other projects and activities in the RAA
Frequency	Identifies when the residual effect occurs and how often during the proposed Project or in a specific phase	Single event	Effect occurs once
		Multiple irregular events	Effect occurs more than once but at no set schedule
		Multiple regular events	Effect occurs at regular intervals
		Continuous	Effect occurs continuously
Duration	The period of time required until the measurable parameter or the VC returns to its existing condition, or the effect can no longer be measured or otherwise perceived	Short-term	Residual effect is measurable for a few hours to a few months
		Medium-term	Residual effect is measurable for many months to a few years
		Long-term	Residual effect is measurable for multiple years but is not permanent relative to the average lifespan of relevant marine mammal species
		Permanent	Residual effect is deemed permanent over the average lifespan of relevant marine mammal species

**Table 4.10-4 Characterization of Residual Effects on Marine Mammals**

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories	
Reversibility	Whether or not the residual effect on the measurable parameter or the VC can return to its existing condition once the physical work or activity causing the disturbance ceases	Reversible	The residual effect is likely to be reversed after activity completion
		Irreversible	The residual effect is unlikely to be reversed
Context	Existing condition and sensitivity of the VC in the area where effects occur	Undisturbed	Residual effect takes place in an area that is relatively undisturbed or not adversely affected by human activity
		Disturbed	Residual effect takes place in an area that has been substantially previously disturbed by human development or human development is still present

#### **4.10.2.7 Likelihood of Residual Effects**

Likelihood is the relative probability (qualitative) of an adverse residual effect occurring on marine mammals. Likelihood is determined based on an understanding of the mechanism of the potential effect and the available mitigation measures to reduce or avoid the residual effect. The categories and definitions for the probability of a residual effect occurring on marine mammals are presented as follows.

- **Low**—Adverse interactions between the Project and marine mammals can largely be avoided or mitigated, and adverse residual effects are unlikely
- **Medium**—Adverse interactions between the Project and marine mammals may be difficult to avoid or mitigate, and adverse residual effects are likely
- **High**—Adverse interactions between the Project and marine mammals cannot be practically avoided or mitigated, and adverse residual effects are highly likely.

#### **4.10.2.8 Significance Threshold for Residual Effects**

This section describes the threshold for each potential effect, beyond which a residual effect is considered significant. The thresholds present the limits of an acceptable change in a measurable parameter or state of the VC, based on applicable legislation, regulatory guidance documents or other management standards. Where thresholds are not set by legislation, guidance documents or standards, a threshold has been developed based on scientific literature and professional judgment.

A significant adverse residual effect is defined as one that threatens the long-term persistence of a marine mammal species or local population in the RAA.

#### **4.10.3 Existing Conditions for Marine Mammals**

This section first describes methods used to identify the existing conditions, and then provides an overview of the existing conditions for marine mammals. Additional detailed information is provided in the Marine Mammals TDR, Appendix N.

##### **4.10.3.1 Methods**

A brief summary of desktop and field-based studies is provided below; full details are presented in the associated appendices (outlined below).

#### ***LITERATURE REVIEW AND PREVIOUS INVESTIGATIONS***

A review of available scientific literature and technical reports was used to gather information on existing conditions for marine mammals and to develop a list of those species likely to be present in the marine mammal RAA. The conservation status listings according to the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), SARA and the BC Conservation Data Centre (BC CDC) were also collected. Literature review resources included: peer-reviewed literature (e.g., *Marine Mammal Science*), grey literature (e.g., *Canadian Science Advisory Secretariat Science Advisory* reports, Raincoast Conservation Foundation reports, COSEWIC update status reports, DFO Recovery Strategies and

Management Plans), opportunistic data from the BCCSN (BCCSN 2014), and reports from marine mammal field programs conducted by other proponents in the RAA (e.g., LNG Canada 2014; Stantec 2016 [PNW LNG Project Marine Mammal Program Final Report]). The review of available scientific literature and technical reports was used to help characterize the regional presence, abundance, and distribution of marine mammals likely present in the marine mammal RAA. Recommended underwater noise thresholds for marine mammals (for harm and sensory disturbance) and associated scientific literature on the topic were reviewed. Further details on marine mammals anticipated to be present within the RAA are provided in Section 3 of the Marine Mammals TDR (see Appendix N) and additional information on marine mammal acoustics and noise thresholds is provided in the Prince Rupert – Aurora LNG Acoustic Monitoring Study (see Appendix O) and the Aurora LNG Acoustic Study: Modelling of Underwater Sounds from Pile Driving, Rock Socket Drilling, and LNG Carrier Berthing and Transiting (see Appendix P).

### ***MARINE MAMMAL SURVEYS***

Project specific information on the presence, distribution, seasonal timing, and abundance of marine mammals in the RAA, was collected during field-based studies. Data collected on marine mammals with a sufficient number of sightings (~40 sightings over all surveys; Buckland et al. 2001) were used to estimate species densities and relative abundance within the study area (see 'Relative Abundance Estimates' below). Eight vessel-based marine mammal line transect surveys were completed over a period of one year between July 2014 and June 2015 using distance sampling methods (Buckland et al. 2001). The purpose of the vessel-based surveys was to collect more detailed information on the distribution and seasonal timing of marine mammals in the RAA, and to estimate the relative abundance of species in the RAA. The survey design consisted of 15 parallel, equally-spaced transect lines orientated perpendicular to the coastline to reduce edge effects and to provide a uniform coverage of the region (Buckland et al. 2001; Thomas et al. 2007; Dawson et al. 2008). The first six surveys were conducted within a survey area that extended north to Grassy Point because both Grassy Point and Digby Island were being considered as potential Project sites. Once the Grassy Point site was formally withdrawn by Aurora LNG, the remaining surveys were conducted within a smaller survey area that represents the current marine mammal RAA. Surveys were conducted onboard the *MV Freeport* by a crew of five marine mammal observers (MMOs), including up to two First Nations technicians and three Stantec biologists. Prior to the surveys, formal training on survey protocols and marine mammal observer duties was conducted.

The eight surveys were undertaken beginning in the summer of 2014 (1 survey), followed by the fall (2), winter (3), spring (1), and again in the summer of 2015 (1). These periods were selected to represent peak, transitional and low-density periods for marine mammals in the RAA. To the extent possible, surveys were also scheduled to overlap with biologically important times (e.g., foraging) for certain species within the study region. Further methodological details on survey design and sampling protocols, as well as results, are provided in Section 4 of the Marine Mammals TDR (see Appendix N).

***RELATIVE ABUNDANCE ESTIMATES***

Distance sampling (Buckland et al. 2001) was used to estimate marine mammal species relative abundance within the RAA. This method uses the sightings data collected during field studies to estimate the proportion of animals that were present but not observed and uses this information to predict the total number of animals potentially within the study area. The software R 3.2.2 (R Core Team 2015) was used to analyze marine mammal sightings data, employing the package ‘mrds’ (i.e., mark-recapture distance sampling) (Laake et al. 2015). The number of sightings collected by species, pooled over all of the surveys, was calculated to assess if there were sufficient numbers of sightings to estimate abundance using distance sampling methods. A minimum of 40 sightings is suggested for line transects surveys (Buckland et al. 2001). The relative abundance of marine mammal species was modeled for humpback whales and harbour porpoise based on the sightings data collected during the eight field surveys. The detection function was modelled using conventional distance sampling and multiple covariate distance sampling methods. It was not possible to predict the abundance or densities of other species observed in the RAA because there were too few sightings. Further methodological details on the modelling methods employed, including fitting of detection functions, and results are provided in Section 5 of the Marine Mammals TDR (see Appendix N).

***ACOUSTIC MONITORING***

An underwater noise monitoring field study was undertaken to establish existing sound levels near the LNG jetty and shipping lanes, thereby providing a characterization of existing conditions to establish whether underwater noise generated by the construction and operations of the LNG facility might adversely affect marine fish and marine mammals. JASCO Applied Sciences (JASCO) was engaged to undertake this study, which involved two Autonomous Multichannel Acoustic Recorders deployed on the seabed to measure ambient underwater noise levels and anthropogenic noise due to existing vessel traffic. One hydrophone was deployed near the proposed site, off the southern tip of Digby Island, approximately 9 km west-southwest of Prince Rupert (see Figure 1 of the Prince Rupert – Aurora LNG Acoustic Monitoring Study, Appendix O) (operational July 11 – Nov 19, 2014). The other unit was located approximately 30 km from the Project site, by the ferry and container traffic lanes near Triple Islands (operational July 11 – Oct 31, 2014). The data was analyzed for ambient sound, vessel noise, and marine mammal vocalizations. Recordings of whale and seal calls and porpoise clicks provide information on the presence of species of marine mammals that are vocalizing in the area. The results of this monitoring contributed to the assessment of potential effects of underwater noise on marine mammals. Further details and results on the acoustic field monitoring program are provided in the Prince Rupert – Aurora LNG Acoustic Monitoring Study (see Appendix O).

***TRADITIONAL KNOWLEDGE AND TRADITIONAL USE STUDIES***

Marine mammals appear in both the past and current history and traditions of the local Aboriginal Groups that use marine resources in the marine mammal RAA. Seals, sea lions and sea otters serve a food, social and ceremonial function within the communities, both currently and in the past. Killer whale, humpback whale and other marine mammal species have high cultural importance in local Aboriginal communities. As a result of the past and present traditional importance of marine mammals, the Project’s

potential effects on this VC are of interest to Aboriginal Groups. Information provided by Aboriginal Groups and available TK and TU studies were reviewed to identify marine mammal species considered important to Aboriginal Groups. This information was also used to support understanding of marine mammal presence, distribution, seasonality, and abundance in the RAA.

Traditional Knowledge and TU information was acquired from Project specific traditional land use (TLU) studies, Aboriginal Groups' publicly released documents, Environmental Assessment Applications and Reports (from PNW LNG and LNG Canada), and additional publicly-available background information sources on current use by Aboriginal Groups that have been identified as having potential or established Aboriginal rights and related interests in areas that overlap with the RAA. This information is presented in Appendix S.1 (Aboriginal Consultation Report) and Appendix S.2 (Aboriginal Consultation TDR) and is considered in the Application in both Section 11.3 (Requirements under CEAA 2012 Section 5(1)(c)) and Section 12.0 (Aboriginal Consultation), as well as the Marine Mammals TDR (see Section 2, Appendix N).

Five Project specific TLU studies were received that address marine mammals:

- Metlakatla First Nation Traditional Land Use and Ecological Knowledge of Aurora LNG Ltd.'s Proposed Project – Interim Baseline Report (Feb 2016).
- Gitxaala Use Study – Aurora LNG Project Environmental Assessment Certification Application (June 2016)
- Kitsumkalum Traditional Use Study and Socioeconomic Impact Assessment – Aurora Liquefied Natural Gas Project (June 2016)
- Kitselas First Nation Traditional Use Study Analysis: Nexen's Aurora LNG Project – Final Report (March 2015)
- Preliminary Report: Gitga'at First Nation Traditional Use and Occupancy Study for the Aurora LNG Project, Prince Rupert Harbour Region (August 2016).

All five TLU studies contain extensive information, including species lists and geographical sighting or harvesting details, on marine species that were (some continue to be) traditionally harvested in and around Chatham Sound. This information was used within this VC to support Project understanding of marine mammal presence, distribution, seasonality, and abundance in the RAA.

#### **4.10.3.2 Overview**

##### ***CONTEXT***

The Project Development Area (PDA) occurs within the boundaries of the Port of Prince Rupert. This busy industrial port handles large volumes of shipping traffic, with over 450 seagoing vessels and 1,238 harbour movements in 2014 handling over 20 million tonnes of goods (PRPA 2015). These numbers are in addition to the large amount of smaller commercial, fishing, and recreational traffic that currently frequents this area. Existing marine traffic in the RAA is estimated at 10,000 vessel transits per year (equivalent to approximately 27 vessel transits per day) from a combination of shipping traffic, ferries, cruise ships, commercial and recreational fishing vessels, and other recreational watercraft. These vessel movements, in addition to large-scale marine development projects, contribute anthropogenic sources of noise to the ambient marine environment. For the purposes of assessing context, this area is

## Aurora LNG

Environmental Assessment Certificate Application

Section 4.10: Marine Mammals

therefore considered a disturbed area of active human development. Further details on marine traffic conditions in the RAA are discussed in the marine use and navigable waters assessment (see Section 6.5).

### LITERATURE REVIEW AND PREVIOUS INVESTIGATIONS

The RAA overlaps with DFO IAs for humpback whale, northern resident killer whale, and Steller sea lion (see Section 4.10.2.5) (Clarke and Jamieson 2006b; PNCIMA 2011); however, there is no designated critical habitat for marine mammals in the RAA. Twelve species of marine mammals regularly occur within the RAA on either a seasonal or year-round basis: fin, grey, humpback, and minke whales; Dall's and harbour porpoise, killer whales (northern resident and Bigg's [transient] ecotypes), Pacific white-sided dolphins, harbour seals, Steller sea lions, and sea otters. The conservation status of all 12 species is summarized in Table 4.10-5 (i.e., federal listing under SARA, recommended status of COSEWIC, and provincial status as maintained by the BC CDC).

**Table 4.10-5 Conservation Status of Marine Mammal Species in the Marine Mammal RAA**

Common Name	Scientific Name	COSEWIC Status <sup>a</sup>	SARA Status <sup>b</sup>	Provincial Status <sup>c</sup>
Fin whale	<i>Balaenoptera physalus</i>	Threatened	Schedule 1, Threatened	Red
Grey whale	<i>Eschrichtius robustus</i>	Special concern	Schedule 1, Special concern	Blue
Humpback whale	<i>Megaptera novaeangliae</i>	Special concern	Schedule 1, Threatened	Blue
Minke whale	<i>Balaenoptera acutorostrata</i>	Not at risk	No status	Yellow
Dall's porpoise	<i>Phocoenoides dalli</i>	Not at risk	No status	Yellow
Harbour porpoise	<i>Phocoena phocoena</i>	Special concern	Schedule 1, Special concern	Blue
Bigg's (transient) killer whale	<i>Orcinus orca</i>	Threatened	Schedule 1, Threatened	Red
Northern resident killer whale	<i>Orcinus orca</i>	Threatened	Schedule 1, Threatened	Red
Pacific white-sided dolphin	<i>Lagenorhynchus obliquidens</i>	Not at risk	No status	Yellow
Harbour seal	<i>Phoca vitulina richardii</i>	Not at risk	No status	Yellow
Steller sea lion	<i>Eumetopias jubatus monteriensis</i>	Special concern	Schedule 1, Special concern	Blue
Sea Otter	<i>Enhydra lutris</i>	Special concern	Schedule 1, Special concern	Blue

#### NOTES:

Many species of marine mammal are migratory and/or wide-ranging, and the inclusion of a marine mammal in this table is meant to qualitatively reflect the standard distribution of these species. Specific occurrence of a particular species within the RAA at any given time fluctuates, and is therefore uncertain. Other species, not included in this table, may also be infrequently sighted within the RAA.

**Provincial Status Definitions:** **Red:** List of ecological communities, indigenous species and subspecies in BC that are at the greatest risk of being lost. **Blue:** List of ecological communities, indigenous species and subspecies in BC that are of special concern (formerly vulnerable). **Yellow:** List of ecological communities and indigenous species in B.C. that are at the least risk of being lost.

#### SOURCES:

<sup>a</sup> COSEWIC (2016), <sup>b</sup> Government of Canada (2016), <sup>c</sup> BC CDC (2016)

While timing of peak marine mammal occurrence in the RAA is likely to coincide with other peak periods of biological activity in the region (e.g., northern resident killer whales following the migration of the Skeena and Nass rivers Chinook salmon [Ford 2006; Ford and Ellis 2006]), this assessment is based on the assumption that marine mammals may be present in the LAA and RAA at any time of the year, and thus may interact with Project activities regardless of the construction schedule or timing of such activities.

Marine mammals rely heavily on the underwater acoustic environment, as they use sounds both passively and actively, to navigate, communicate, locate prey, avoid predators, and gather information about their surroundings (Richardson et al. 1995; Nowacek et al. 2007; Tyack 2008; Shannon et al. 2015). Exposure to anthropogenic sources of underwater noise therefore has the potential to result in adverse effects on marine life. These effects may range from interference with life functions (e.g., through communication masking [i.e., interference with communication] and impaired detection of conspecifics and/or prey), 'behavioural effects' (used here in the broadest possible context, and including everything from subtle disturbance responses such as changes in diving/breathing rate or foraging efficiency, to overt responses such as habitat avoidance), to temporary changes in hearing sensitivity (i.e., temporary threshold shifts [TTS]) or at high source levels, the possibility of permanent auditory injury (i.e., permanent threshold shift [PTS]). Also likely, although more difficult to observe in a field setting, are primary and secondary stress responses (e.g., through observed changes in stress-related faecal hormone metabolites [glucocorticoids]) (Romano et al. 2004; Wright et al. 2007; Rolland et al. 2012).

### **MARINE MAMMAL SURVEYS**

The eight marine mammal vessel surveys provided a seasonal snapshot of marine mammal presence and distribution within the RAA. The survey schedule was designed to capture high and low-use periods of marine mammal presence within the RAA, and to overlap with biologically important times within the region (e.g., northern resident killer whales in the area to forage on salmon runs). At least nine of the twelve species of marine mammal that regularly occur within the RAA were observed during the vessel-based field surveys (the exceptions were sea otter and grey whale, and one of the killer whale sightings was not distinguished to ecotype). The humpback whale was the most frequently observed marine mammal species and was sighted year-round. There were three sightings of individual minke whales during the February survey, and a pair of fin whales was sighted in the November survey. Four species of toothed whale were observed: northern resident killer whale, Pacific white-sided dolphin, Dall's porpoise, and harbour porpoise. The two porpoise species (harbour and Dall's) were the predominant toothed whales sighted. Both species of pinnipeds (harbour seal and Steller sea lion) were observed year-round.

Results of Project specific marine mammal vessel surveys were also supported by a review of surveys conducted by other project proponents in the region. During the 25 vessel-based line transect surveys undertaken for the PNW LNG project between November 2014 and December 2015, the following marine mammal species were recorded in 'Area A' (an area roughly comparable to the Aurora RAA): harbour seal, Steller sea lion, humpback whale, Dall's porpoise, harbour porpoise, killer whale, Pacific white-sided dolphin, and sea otter (Stantec 2016). Humpback whales were the only species of baleen whale observed during the PNW LNG surveys, and similar to results of the Aurora LNG surveys, these were the most frequently-sighted species of marine mammal in the survey area (comparable to RAA). Humpback whales were observed year-round, with the highest numbers of sightings and individuals in the winter months

## Aurora LNG

Environmental Assessment Certificate Application

Section 4.10: Marine Mammals

---

(November-January). In the area around the proposed Aurora LNG jetty, harbour porpoise were the most frequently seen and abundant marine mammal, and were observed in this area year-round.

LNG Canada undertook eight vessel-based marine mammal line-transect surveys that overlapped with the northwestern-most portion of the RAA, around Triple Islands, between March and October 2013 (LNG Canada 2014). Steller sea lion, humpback whale, harbour seal, killer whale, and Dall's porpoise were observed in this region. A few sightings of fin whale, minke whale, Pacific white-sided dolphin, and harbour porpoise, were reported just outside and to the southwest of the RAA, to the west of Stephens Island.

Detailed results of Project specific surveys and a high level summary of other project survey results are presented in the Marine Mammals TDR (see Appendix N).

### **RELATIVE ABUNDANCE ESTIMATES**

Mean relative abundance estimates ( $\hat{N}$ ) for humpback whales and harbour porpoises are presented, by month, alongside their respective 95% confidence intervals (CI) and coefficient of variation (%CV) in Table 4.10-6. Relative abundance estimates for humpback whales in the RAA suggest there is a peak in presence in the fall (predicted September mean of 249 individuals; 95% CI: 131 – 473); showing a large increase over July numbers (predicted mean of 18; 95% CI of 7 – 43). Estimates then suggest a drop later in the fall (November mean of 99; 95% CI: 43 – 228; December mean: 56; 95% CI: 17 – 190), however, winter abundance estimates suggest that sightings of humpback whales within the RAA could average 100 individuals or more (January prediction; mean of 103; 95% CI: 37 – 290). Relative abundance could not be calculated for the February, April, or June surveys due to the low number of sightings in the RAA. While individual humpback whales may still be present in the RAA in spring and early summer, the lack of sightings is reflective of the fact that most humpback whales migrate to tropical breeding grounds at this time of year. Harbour porpoise relative abundance estimates suggest mean abundance is highest in the fall (predicted September mean of 87 individuals; 95% CI: 25 – 298), although summer (June and July) sightings are not dramatically lower (June mean of 51; 95% CI: 16 – 165; July mean of 62; 95% CI: 22 – 176). There were too few sightings to estimate harbour porpoise abundance in the winter and spring, suggesting fewer animals are present during that time. It was not possible to predict the relative abundance or densities of other species observed in the RAA because there were too few sightings (see the Marine Mammals TDR, Appendix N).

**Table 4.10-6 Marine Mammal Estimated Abundance within the RAA from Conventional Distance Sampling**

	July 2014	Sept. 2014	Nov. 2014	Dec. 2014	Jan. 2015	Feb. 2015	April 2015	June 2015
<b>Humpback whale</b>								
$\hat{N}$	18	249	99	56	103	-	-	-
<b>95% CI (<math>\hat{N}</math>)</b>	7-43	131-473	43-228	17-190	37-290	-	-	-
<b>%CV</b>	45.27	30.15	40.89	62.14	51.44	-	-	-
<b>Harbour porpoise</b>								
$\hat{N}$	62	87	-	-	-	-	-	51
<b>95% CI (<math>\hat{N}</math>)</b>	22-176	25-298	-	-	-	-	-	16-165
<b>%CV</b>	52.28	63.45	-	-	-	-	-	72.19

**NOTES:**

Includes possible repeat sightings  
- not calculated because less than 3 sightings while on effort in the RAA

The PNW LNG project also used density surface modelling to predict relative abundance estimates and higher density areas in 'Area A' (roughly comparable to the RAA) for species and months with a sufficient number of sightings (Stantec 2016). Relative abundance estimates in this area were highest for humpback whales in November 2014 (predicted mean of 312 individuals, 95% CI: 192-508), which was later in the season than results from the Aurora LNG surveys (peak in September). However, PNW LNG results showed annual as well as seasonal variation (e.g., a far lower number of individuals (55) was observed the following November [2015], 95% CI: 27-111). Areas of high abundance for humpback whales (relative to the remaining study area) were predicted in the coastal waters around Kinahan Islands and between Triple and Melville Islands. Harbour porpoise relative abundance estimates peaked in Area A in July (mean of 265 individuals; 95% CI: 110-641). Highest density areas were consistently observed in the waters south of Digby Island, in Porpoise Channel, around Ridley Island, Lelu Island and the northeast coast of Stephens Island. Estimates for harbour seals were highest in June [in-water estimates; 335 individuals, 95% CI: 113-994] and July [hauled out; 356 individuals, 95% CI: 159-798]. Higher density areas included Rachael Islands, the north and east of Stephens Island, and the coastal waters and islands between Porcher and Smith islands, and from Smith up to and including Digby Island.

**ACOUSTIC MONITORING**

Based on the results of ambient underwater sound monitoring (July – Oct/Nov, 2014) conducted for the Project, vessel activity (i.e., transits of large ships, and small vessels like fishing boats, zodiacs and pleasure craft) is the primary source of underwater noise in the LAA and RAA, and these sound events dominated over sounds from weather events (such as heavy rainfall). Data was collected for 132 days at Station 1 (near the proposed LNG jetty) and 113 days at Station 2 (near Triple Islands).

## Aurora LNG

### Environmental Assessment Certificate Application

#### Section 4.10: Marine Mammals

---

At Station 1, the maximum recorded sound level was 150 dB re 1  $\mu$ Pa and median ambient sound level was 99 dB re 1  $\mu$ Pa (1-minute broadband rms SPL). Recorded sound levels exceeded the US National Oceanic and Atmospheric Administration (NOAA)'s interim regulatory threshold (NOAA n.d.) for marine mammal disturbance from non-impulsive noise sources (120 dB re 1  $\mu$ Pa rms SPL) for 8.2% of the time (disturbance thresholds are discussed further in Section 4.10.5.1 and in the Aurora LNG Acoustic Study: Modelling of Underwater Sounds from Pile Driving, Rock Socket Drilling, and LNG Carrier Berthing and Transiting, Appendix P). Recorded daily sound exposure levels (SELs) were almost entirely due to vessel noise. Station 1 had an average of 16 vessels recorded per day (range: 3 – 25), and vessel noise was detected for an average of 14.4 hours per day (range: 7 – 20 hours). Porpoise clicks (species not distinguished) were detected every day at Station 1 (132 days) while killer whale calls (ecotype not distinguished) were detected sporadically (3 days). Harbour seal calls were detected only at Station 1 (36 days) and occurred mainly from mid-July to mid-August.

Maximum and median broadband SPLs at Station 2 were similar to Station 1, at 148 and 100 dB re 1  $\mu$ Pa rms, respectively. The NOAA interim disturbance threshold was exceeded 2.5% of the time. An average of 7.5 vessels was recorded per day (range: 1 – 15), and vessel noise was detected for an average of 8.8 hours per day (range: 1 – 17) at Station 2. Porpoise clicks were detected almost daily at Station 2 (100 out of 113 days), and killer whale calls were detected more frequently than at Station 1 (32 days). Species detected only at Station 2 included: humpback whales (67 detection days from mid-July to late October), fin whales (twice in October), and Pacific white-sided dolphins (once in July) (see Prince Rupert – Aurora LNG Acoustic Monitoring Study, Appendix O).

#### ***TRADITIONAL KNOWLEDGE AND TRADITIONAL USE STUDIES***

The Coast Tsimshian actively hunted a wide variety of species of game, waterfowl, and marine mammals that included sea otters, sea lions, and seals. Some marine mammal harvest occurred year-round.

Sea otters were historically hunted and trapped by Metlakatla First Nation, Kitselas First Nation and Kitsumkalum First Nation, though with the decline of sea otter numbers following commercial over-harvesting, trading in inland furs such as beaver pelts largely replaced use of this species.

Seals and sea lions were some of the main resources used by all five Aboriginal Groups who provided Project specific TLU studies. These species were used for trade, consumptive (food and material) purposes, and ceremonial purposes. Seal and sea lion meat was often smoked, although it was also eaten half dried and fresh, and this formed a staple food source that was very important to sustain long journeys on the water and while preparing eulachon during this traditional fishery. Gitxaala Nation also reported that seal grease was a good source of iron, and was often used to prepare various meals, such as bannock and herring eggs. Kitsumkalum First Nation reported occasional harvesting of whales.

While many species of marine mammal are recognized as important to Aboriginal Groups, the cultural and social importance of both humpback whales and killer whales, as well as the strong hunting traditions connected to sea lion and seal, were explicitly referenced. Many traditional marine and terrestrial hunting areas exist throughout Chatham Sound, with the areas around Stephens, Melville, Porcher and Digby islands identified as important marine resource harvesting and fishing areas. Gitxaala Nation identified the regular occurrence of porpoise in the waters near Digby and Kinahan islands (amongst other locations). With respect to potential Project activity areas, the waters around Digby Island, the marine

shipping route, and the pilot boarding station at Triple Island have been identified as marine mammal hunting areas.

Construction and development of an LNG facility and ancillary infrastructure have been identified as major concerns by Aboriginal Groups, as these activities may have adverse effects on marine life, including marine mammals (e.g., through the introduction of underwater noise, vessel strikes, or potential effects on prey). There are also concerns that increased vessel traffic through important marine resource harvesting areas may adversely affect marine life populations and fish migration routes (see Section 4.9). These potential effects (i.e., Project construction and increased vessel traffic) on marine mammals are addressed in the following sections.

### **SUMMARY**

The RAA is an area of active human development that includes a busy industrial port, large volumes of shipping traffic, and numerous current and proposed marine development projects, all of which contribute anthropogenic sources of noise to the ambient marine environment. Twelve species of marine mammals regularly occur in the RAA on either a seasonal or year-round basis. The majority of these were observed during Project-specific marine mammal field surveys, or surveys undertaken in this area for other projects. The humpback whale was the most frequently observed marine mammal species and was sighted year-round. Relative abundance estimates were highest for humpback whales, harbour porpoise, and harbour seals. A number of marine mammal species are and have been used for trade, consumptive (food and material) purposes, and ceremonial purposes and continue to be important to Aboriginal Groups. The RAA area is also recognized to overlap with DFO IAs for humpback whale, northern resident killer whale, and Steller sea lion, although there is no designated critical habitat for marine mammals in this area.

#### **4.10.4 Project Interactions with Marine Mammals**

Project components and physical activities that may interact with the VC through the identified potential effects are described in Table 4.10-7. Potential interactions are indicated by check marks, and are discussed in detail in Section 4.10.5 in the context of effects mechanisms, standard and Project specific mitigation, and residual effects. Justifications for non-interactions are described after the table and are not assessed further.

**Table 4.10-7 Potential Project Interactions and Effects on Marine Mammals**

Project Components and Physical Activities	Potential Effects		
	Change in Health	Change in Behaviour	Change in Mortality Risk
<b>Construction</b>			
Site preparation (clearing, grubbing, grading, levelling, on-land disposal, and construction, operations and decommissioning of temporary facilities)	-	-	-
Onshore construction (installation of LNG facility, cryogenic rundown line and vapour return line, utilities, ancillary support facilities and access roads)	-	-	-
Employment and Expenditures*	-	-	-
Dredging and disposal at sea	✓	✓	✓
Marine construction (marine transport, material offloading and laydown areas, transfer piping and electrical infrastructure, infilling, pile installation and underwater blasting)	✓	✓	✓
Waste management (waste collection and treatment)	-	-	-
Vehicle traffic (road use, vehicle traffic)	-	-	-
Commissioning and start-up (includes hydro-testing and discharge to the marine environment)	-	-	-
<b>Operations</b>			
Natural gas pre-treatment and natural gas liquids extraction	-	-	-
LNG production (including transfer to storage tanks, and loading on LNG carriers and routine flaring)	-	-	-
Employment and Expenditures*	-	-	-
LNG shipping (inclusive of LNG carriers and other supporting marine traffic such as tugs)	✓	✓	✓
Waste management (collection, treatment if needed, and disposal of solid waste and wastewater, including stormwater and cooling water from the power generation facility)	-	-	-
<b>Decommissioning</b>			
Dismantling of land-based and marine infrastructure, including related vessel traffic	✓	✓	✓
Remediation and reclamation of the site	-	-	-
Employment and Expenditures*	-	-	-
Waste management	-	-	-

**NOTES:**

- ✓ Potential interactions that may cause an effect
- Not applicable
- \* All Project activities requiring the presence of workers and/or expenditures

The only anticipated potential for a Project change in mortality risk is from an increased potential for vessel strikes; check marks under this heading in Table 4.10-7 denote Project activities for which there are associated vessels (e.g., construction support vessels, dredging or disposal at sea barges, LNG carriers and tugs etc.). Potential for non-strike-related marine mammal mortality is not expected during any Project activity, particularly following the implementation of standard BMPs and mitigation measures to reduce the potential for changes in health (discussed further in Section 4.10.5.2). Potential for injury from marine construction activities such as in-water impact pile driving and in-water blasting (whether due to auditory or blast injury) is assessed under the change in health effect (see Section 4.10.5.2). All mention of impact pile driving and blasting in this VC relate to activities that occur within the marine environment (i.e., do not include any terrestrial blasting or pile installation activities).

A number of Project components and activities are terrestrially-based and will have no measurable interaction with the marine environment and marine mammals, particularly following the implementation of standard mitigation measures and BMPs; the following terrestrially-based activities are therefore not carried forward in the residual effects assessment (i.e., no check mark):

- Site preparation (terrestrial)
- Onshore construction activities
- Vehicle traffic (road use)
- Natural gas treatment and natural gas liquids extraction
- LNG production
- Remediation and reclamation of the site.

Employment and expenditures is identified as a unique Project activity related to the number of workers and Project costs associated with construction, operations and decommissioning, and is used to assess socio-economic effects only. This activity is not expected to result in a change in health, behaviour or mortality risk of marine mammals throughout all Project phases.

Assessment of temporary marine facilities (i.e., the pioneer facility) is assessed under marine construction. A detailed description of the Project's marine components and different design options (e.g., pile-and-deck versus concrete caisson at the MOF) is presented in Section 1.2 (Proposed Project Description).

Project-related discharges to the marine environment may occur during construction, operations, or decommissioning (e.g., wastewater and stormwater) or during release of hydrostatic test water during commissioning and start-up. However, based on experience on similar projects, and professional judgement, potential changes to water quality, and subsequently, marine mammal health, are not anticipated as discharges will be appropriately managed and treated prior to release, and guidelines and regulatory requirements will be followed. This topic is addressed in greater detail in the Water Quality VC (see Section 4.5) and the Marine Fish and Fish Habitat VC (see Section 4.9). Accidental releases of material to the marine environment are discussed in Accidents or Malfunctions (see Section 9.0). Considering the above, no further assessment of marine mammal change in health due to waste management or commissioning and start-up is warranted.

#### **4.10.5 Assessment of Residual Effects on Marine Mammals**

The assessment of potential effects on marine mammals considers changes in health, behaviour, and mortality risk as a result of Project effects mechanisms. This section first describes the analytical methods and assumptions used in the assessment, and then describes the Project effect mechanisms, applicable mitigation measures, and characterization and likelihood of residual effects for each Project effect.

##### **4.10.5.1 Analytical Methods**

This section describes the analytical techniques applied in the assessment of Project effects and the conservative assumptions applied to this assessment.

##### ***ANALYTICAL ASSESSMENT TECHNIQUES FOR MARINE MAMMALS***

Potential Project-related effects on marine mammals were assessed by first describing the effect mechanism(s) for all Project components or activities identified in Section 4.10.4 with potential to interact with marine mammals. Each potential effect was evaluated according to the measurable parameter(s), using information collected during field studies, literature review, and acoustic modeling, assuming implementation of BMPs and mitigation measures. Each residual effect (i.e., following the implementation of mitigation measures) was then characterized based on the criteria listed in Table 4.10-4 and a relative likelihood (qualitative) of occurrence was provided.

The primary Project components and physical activities with potential to cause adverse residual effects on marine mammals are marine construction activities (most notably, pile installation and in-water blasting) and increases in vessel traffic associated with LNG shipping (and associated escort tugs) during operations. There are two major effects pathways through which these activities may lead to residual effects on marine mammals. The first is through the introduction of underwater noise to the marine environment. This pathway will occur during both the construction phase (during development of marine infrastructure) and the operations phase (during vessel transit and berthing events). The second pathway of effects is through direct physical interaction between Project-related vessels and marine mammals (i.e., marine mammal-vessel strikes).

The assessment of change in health will address the potential for marine mammals to be exposed to sound levels that are capable of causing permanent auditory injury (i.e., PTS onset). Potential for injury during in-water blasting will also be assessed under this heading. The assessment of change in behaviour will address the potential for marine mammals to alter their activity (including communication), alter their location (e.g., an avoidance response), or respond in some other manner to Project-related underwater noise. Change in mortality risk focuses exclusively on increased risk of vessel strikes.

Marine mammal change in health and change in behaviour share the same effects pathway (i.e., both may occur as a result of marine mammal exposure to increased levels of underwater noise). While sound levels capable of causing injury are also likely to cause behavioural effects, these responses are discussed separately. These two categories of effects were selected because they represent the current groupings under which scientific and US regulatory thresholds for underwater noise levels exist and are partitioned.

It is also recognized that there is a broad spectrum of other potential effects of underwater noise on marine mammals. For example, TTS, a temporary loss of hearing sensitivity, may occur upon exposure to sound levels somewhere below those capable of causing permanent auditory injury but above those expected to cause behavioural responses alone (i.e., without affecting hearing sensitivity). The onset of TTS is dependent on the sound level and frequency, as well as the duration of exposure, similar to PTS. Communication masking and increased stress levels may also occur across the spectrum of noise exposure, but are expected to start at levels below those for which overt behavioural responses may be observed. The Application discusses these additional effects (e.g., TTS, masking, stress) under the heading of change in behaviour (see Section 4.10.5.3), while recognizing that overt behavioural changes, such as avoidance of an area, may or may not accompany these effects.

### *ACOUSTIC MODELLING SCENARIOS AND ASSUMPTIONS*

A large component of the assessment of potential residual effects for marine mammals is based on consideration of predicted underwater sound levels associated with Project-related activities. JASCO was engaged to perform an underwater acoustic modelling study to predict the underwater sound levels generated by impact pile driving and/or rock socket drilling at the LNG jetty and MOF locations, and by LNG carrier and escort tug activities during transiting and berthing. The goal of the modeling study was to predict the extent of ensonification from these activities and to define zones of potential effects on marine mammals based on sound level thresholds for auditory injury and behavioural disturbance.

The following acoustic scenarios were modelled:

1. Impact pile driving with 60-inch (1.5 m) steel pipe piles at the MOF in Casey Cove, Digby Island
2. Impact pile driving with 60-inch (1.5 m) steel pipe piles at the LNG jetty on Frederick Point, Digby Island
3. Rock socket pile drilling for 60-inch (1.5 m) steel pipe piles at the LNG jetty
4. Berthing of an LNG carrier approaching the LNG jetty, assisted by four tugs, at 11 km/h (6 knots [kts])
5. Transiting of an LNG carrier along the ocean-bound shipping route through southern Chatham Sound, assisted by two tugs, travelling at the proposed upper-end LNG carrier transit speed of 30 km/h (16 kts)
6. Transiting of an LNG carrier along the ocean-bound shipping route past the Triple Island pilot station, assisted by two tugs, travelling at the proposed upper-end LNG carrier transit speed of 30 km/h (16 kts).

Since completion of modelling, results from preliminary marine geotechnical investigations have helped to refine the understanding of Project activities, resulting in updates to three of the scenarios discussed above, as follows:

- Scenario 3:
  - While rock socket drilling is still planned for the LNG jetty, it will now also be used at the MOF and possibly pioneer facility; modelling has not been undertaken at this location. Results of rock socket drilling sound levels at the MOF are predicted to be broadly comparable to those at the LNG jetty, although potentially somewhat larger (inferred from larger predicted extents of impact pile driving at the same location).

- Scenarios 5 and 6:
  - For acoustic modelling, it was assumed that LNG carriers would be accompanied by two escort tugs between the LNG jetty and the Triple Island pilot station. It is proposed that escort tugs will only accompany the LNG carriers within the confines of the PRPA boundaries (i.e., modelling results account for noise from three transiting vessels instead of one). Modelled broadband source levels for the LNG carrier and two tugs can be considered a single source when a receptor is several kilometers away from the sound sources; the broadband source levels for this three vessel combination are 20 dB higher than they would be for a single LNG carrier transiting alone. Acoustic modelling for Scenarios 5 and 6 therefore overestimates potential extents of noise above acoustic thresholds based on vessel numbers and is considered conservative.
  - Only the maximum speed expected at any point along the shipping lane was considered in acoustic modelling. In-bound LNG carriers will reduce speeds to 6 kts (11 kilometres per hour [km/hr]) when approaching Triple Island pilot station, and increase to between 12 and 16 kts (22 – 30 km/hr) until the PRPA boundary, where they slow to 10 kts (19 km/hr) and are joined by two escort tugs. They will then proceed at 10 to 12 kts until Coast Island (west of Ridley Island), where they will reduce speed again to 6 kts and carry on to the LNG jetty to berth (see Figure 4.10-1 for place names). While 16 kts is the maximum transit speed, the average speed throughout the RAA will be 12 kts. Acoustic modelling for Scenarios 5 and 6 therefore overestimates potential extents of noise above the acoustic thresholds based on modelled speeds and is considered conservative.

The timing of marine construction activities can also have an effect on the extent of predicted sound levels, extent of possible effect, and duration of exposure, when considering operating pile installation equipment concurrently versus sequentially. While installing multiple piles simultaneously will increase the sound levels produced (and associated extent of ensonification), it will also reduce the duration of this activity. The tradeoff is producing a larger ensonified area that may result in behavioural effects over a short duration, against a smaller area that persists over a longer period. The acoustic modelling study applied conservative assumptions (i.e., overestimates) regarding potential for overlap of concurrent pile driving events; scenarios were selected to maximize potential source levels and extents of ensonification.

Based on the construction concept layouts, the assumptions for timing of marine construction activities were as follows:

- At the MOF, under the pile-and-deck option (concrete caisson design option was not modelled):
  - Installation of 496 steel pipe piles (1.5 m diameter, 55 m length)
  - 40 blows per minute, 60 minutes (uninterrupted) per pile
  - Two 10-hour shifts per day; 2 piles per shift per pile driver
  - 2 piles installed at the same time (i.e., 2 sets of pile driving equipment active at once at a single pile location).

- At the LNG jetty:
  - Installation of 293 steel pipe piles (1.5 m diameter, 45 m length)
  - 40 blows per minute, 40 minutes (uninterrupted) per pile
  - One 10-hour shift per day; 1 pile per shift per pile driver
    - 4 piles installed at the same time (i.e., 2 sets of equipment active at berth 1, concurrently to 2 sets of equipment active at berth 2; separation distance of 1 km).

The MOF concrete caisson design option was not modelled, but it is assumed that this design option will include installation of 15 subtidal piles. Similarly, predicted sound levels during construction of the pioneer facility were not modelled, but this activity is expected to include installation of 8 piles of lesser diameter than those required for the MOF. The modelled pile-and-deck option at the MOF is therefore assumed to conservatively represent the maximum levels and duration of underwater noise that might be expected during any impact pile driving activity required at the MOF.

Timing details and assumptions are discussed in more detail in the later characterization of residual effects. A pile driving event may be as short as 1 minute, or as long as 1 hour, depending on factors such as the size of the pile, the hammer used, the sediment type, and the depth driven (Illingworth and Rodkin Inc. 2007). It was conservatively assumed that each pile at the MOF will take 60 minutes of uninterrupted impact pile driving to be set into place. This duration was reduced to 40 minutes at the LNG jetty to reflect the shallower depth of overburden. Assumptions regarding operation of multiple simultaneous pile drivers result in predicted sound levels and extents to threshold exceedances that are considered to be overestimates and may not be realized on a standard operating day.

#### *ACOUSTIC INJURY AND DISTURBANCE THRESHOLDS*

Threshold criteria are commonly used to assess potential effects of underwater noise on marine mammals. As discussed in Section 4.10.2.1, in the absence of formal Canadian thresholds for levels of underwater noise capable of causing auditory injury or disturbance to marine mammals, underwater noise modelling outputs were developed and considered against a variety of scientific literature-based and regulatory thresholds to guide the assessment of potential injury or disturbance of marine mammals. These criteria are constantly changing; those selected are considered the best available at the time modelling and assessment were completed.

The following three approaches were considered in the acoustic modelling and assessment of injury:

- Interim rms SPL criteria from the US NOAA National Marine Fisheries Service (NMFS) (NOAA n.d.);
- Peak SPL criteria from Southall et al. (2007); and
- SEL<sub>24h</sub> – criteria from Wood et al. (2012), based on refinement of Southall et al. (2007)'s thresholds and calculated as cumulative exposure over a period of 24 hours (see Aurora LNG Acoustic Study: Modelling of Underwater Sounds from Pile Driving, Rock Socket Drilling, and LNG Carrier Berthing and Transiting, Appendix P).

In July 2016, NOAA released technical guidance and updated thresholds, recommending the joint use of new peak SPL and SEL<sub>24h</sub> metrics to replace their previous interim rms SPL criteria for injury (NMFS 2016). This guidance was not formally released at the time of modelling and inclusion of the previous interim rms SPL metrics is still considered of value for comparison with results presented in earlier studies

and environmental assessments. The methods used by Southall et al. (2007) and Wood et al. (2012) differ somewhat from the new NOAA guidance in terms of how the peak SPL and SEL<sub>24h</sub> metrics are weighted for different marine mammal hearing groups, and therefore are not directly comparable.

In the last 10 – 15 years, there has been a substantial increase in the number of studies investigating the level of potential behavioural disturbance to marine animals from underwater noise. In comparison to potential for injury, however, behavioural responses of marine mammals are generally less predictable, more variable, and more context-dependent (Southall et al. 2007; Ellison et al. 2012). Development of thresholds for behaviour are therefore also less straightforward and NOAA continues to rely on its interim guidance (NOAA n.d.), until such time as these regulatory thresholds can be updated (NMFS 2015). This assessment therefore uses the available interim rms sound thresholds for behavioural disturbance as a guide to informing the assessment of potential effects of sound on marine mammals rather than as an absolute measure of such effects occurring. Consideration is also given to modelling results based on species-specific thresholds for disturbance based on literature values for a number of representative marine mammal species:

- Killer whales (Williams et al. 2002a; Williams et al. 2002b);
- Humpback whales (McCauley et al. 2000);
- Harbour seals (Bailey et al. 2010); and
- Harbour porpoise (Tougaard et al. 2015).

Zones of audibility (Richardson et al. 1995) were also calculated for the aforementioned species to determine the maximum zone over which Project-related sounds might be detectable. These areas are calculated as the regions where sound levels are predicted to be both greater than ambient noise (as determined from acoustic monitoring; see Prince Rupert – Aurora LNG Acoustic Monitoring Study, Appendix O) and above an animal's hearing threshold (see the Aurora LNG Acoustic Study: Modelling of Underwater Sounds from Pile Driving, Rock Socket Drilling, and LNG Carrier Berthing and Transiting, Appendix P).

Further details on JASCO's acoustic model, scenarios, thresholds considered, predicted areas of ensonification, and a brief review of relevant publications on the topic are provided in the Aurora LNG Acoustic Study: Modelling of Underwater Sounds from Pile Driving, Rock Socket Drilling, and LNG Carrier Berthing and Transiting (see Appendix P).

### **ASSUMPTIONS**

The following assumptions were used in the effects assessment, facilitating a conservative approach:

- Marine mammals are present in the LAA and RAA throughout the year and occur within the zone of influence of Project activities.
- Assessment of potential effects of vessel traffic during operations (i.e., LNG carrier transit) is representative of the maximum likely potential for adverse effects on marine mammals resulting from Project-related vessels during all Project phases.

While some individual marine mammals may be considered local to the RAA, many species are also migratory, appearing in the RAA seasonally, following prey movements, or simply passing through. The assessment conservatively assumes that the species likely observed in the RAA are continuously

present, and thus are always 'available' for a Project-related interaction. The predicted potential for exposure therefore represents the maximum potential duration of effect, and exposures are likely to be more transient.

For the purpose of the assessment, potential residual effects associated with vessel traffic are discussed primarily in the context of LNG carriers and tugs. Lesser volumes of Project-related traffic will also be operational during other phases (e.g., disposal at sea vessels, construction vessels and barges, decommissioning support vessels); however, these are primarily smaller-sized vessels, and most will have slower operating speeds than LNG carriers. For simplicity, the discussion focuses on LNG carriers and tugs, as these are expected to represent the greatest source for potential effects on marine mammals from vessel traffic (i.e., in terms of both extent of underwater ensonification and increase in mortality risk from strikes). However, the mechanisms for effect (i.e., underwater noise production and physical presence) and conclusions of the assessment apply to any Project-related vessel, operating at any point during the Project. In the following sections, all discussions of noise levels produced by LNG carriers are inclusive of sound output from the associated tugs (two during transit and four during berthing) even if not expressly stated. Sound levels of LNG carriers without their escort or berthing tugs were not modelled; however, it has since been proposed that LNG carriers will travel without accompanying tugs during all transits beyond the PRPA boundaries. Predicted extents of underwater noise during operations are therefore expected to overestimate potential effects.

Underwater noise modeling also used conservative estimates in developing source levels, scenarios and input parameters. For example:

- Pile driving was modelled in deep water sites where sound typically propagates furthest
- The calculated sound isopleths and noise level contour maps represent the maximum sound levels over all depths.
- Although operations will occur throughout the year, the most conservative sound speed profile (December) was used, resulting in prediction of the largest distances to sound level thresholds.
- Use of a confined bubble curtain during impact pile driving was assumed to result in a broadband sound level reduction of 10 dB, which is a realistic target assumption. Well-designed site-specific confined bubble curtains could result in greater reductions.
- Since sound levels generally increase with vessel speed, the LNG carrier and escort tugs were modelled at the maximum expected speed (16 kts; 30 km/hr) along the route between Triple Island pilot station and Digby Island. Vessel speeds will range from 6 – 16 kts, and the average vessel speed in the RAA is expected to be 12 kts (22 km/hr).

All acoustic distance-to-threshold values presented in the assessment below are  $R_{95\%}$  values (i.e., the predicted range encompassing at least 95% of the area in the horizontal plane that would be exposed to sound at or above that threshold level) unless noted otherwise. Further details specific to assumptions used in underwater noise modelling are detailed in the Aurora LNG Acoustic Study: Modelling of Underwater Sounds from Pile Driving, Rock Socket Drilling, and LNG Carrier Berthing and Transiting (see Appendix P).

**4.10.5.2 Assessment of Change in Health*****PROJECT MECHANISMS FOR CHANGE IN HEALTH***

Project components and physical activities have the potential to result in changes to marine mammal health during construction (i.e., dredging and disposal at sea, in-water blasting, and marine construction activities [rock socket drilling and/or impact pile driving at the LNG jetty, MOF and pioneer facility]), operations (LNG shipping), and decommissioning (dismantling of marine infrastructure) (as identified in Table 4.10-7). A detailed description of the Project's marine construction components and design options is presented in Section 1.2. These activities will introduce new sources of underwater noise to the marine environment. At high enough received sound levels, marine mammals may experience direct physiological effects, including changes in their hearing sensitivity (e.g., Kastak et al. 2005; Kastak et al. 2008; Lucke et al. 2009; Finneran and Jenkins 2012; Kastelein et al. 2013). In-water blasting and pile driving activities, in particular, produce sudden, intense noises, with pressure pulses that can cause auditory injury to marine mammals close to the source. In-water blasting may also result in direct injury to marine mammals via shock waves, blast effects, or flying debris (Ketten 1995). The change in health effect is assessed by describing the measurable parameters (i.e., predicted timing, duration, intensity and extent [based on  $R_{95\%}$  values]) for underwater noise generated by Project activities; this is supported by the results of Project specific acoustic modelling (see the Aurora LNG Acoustic Study: Modelling of Underwater Sounds from Pile Driving, Rock Socket Drilling, and LNG Carrier Berthing and Transiting, Appendix P). The intensity and extent of measurable parameters are discussed relative to published and/or industry standard thresholds for the onset of auditory injury (i.e., PTS) to marine mammals from underwater noise.

This assessment considered potential for injury based on three acoustic metrics: rms SPL, peak SPL, and  $SEL_{24h}$ . Peak SPL and  $SEL_{24h}$  both provide different thresholds based on the different 'functional hearing groups' of marine mammals (Southall et al. 2007). For species found in the RAA, baleen whales all fall under the 'low-frequency cetacean' functional hearing group, dolphins (including killer whales) fall under 'medium-frequency cetaceans', porpoises fall under 'high-frequency cetaceans', and seals and sea lions fall under 'pinnipeds'. The rms SPL values for injury from impulsive noise are only divided between 'cetaceans' (all whales, dolphins, and porpoises) and 'pinnipeds'. Ultimately, ten different threshold intensities at which PTS may occur were compared to underwater sound levels predicted for Project activities. The  $SEL_{24h}$  thresholds are based on the assumption that marine mammals are stationary and remain at the same range from the sound source during the entire 24-hr period; this represents an unlikely overestimate of effects for an individual marine mammal. In contrast, peak SPL thresholds reflect the potential range at which an animal could be injured by a single exposure to an intense short-duration noise (e.g., impact pile driving). Radial distances over which each of the ten considered threshold intensities were achieved are discussed based on their predicted extents to the  $R_{95\%}$  contour. Full acoustic modelling results and further discussion are presented in the Aurora LNG Acoustic Study: Modelling of Underwater Sounds from Pile Driving, Rock Socket Drilling, and LNG Carrier Berthing and Transiting (see Appendix P).

### *DREDGING AND DISPOSAL AT SEA*

The primary mechanisms for potential effects on marine mammals from dredging and disposal at sea are through production of underwater noise, increases in turbidity, and vessel strikes (assessed in Section 4.10.5.4). Indirect effects related to potential changes on quality and availability of marine mammal prey are assessed in Section 4.9. In-water blasting is anticipated to be required in preparation for dredging at the LNG jetty, and this activity is discussed separately below.

Todd et al. (2015) recently undertook a review of the potential effects of marine dredging activities on marine mammals. According to published results of recorded noise outputs from dredgers, SPLs vary widely by dredger type, operational stage, substrate, and environmental conditions; however, in general, sounds produced during dredging are continuous, broadband, and with main energy below 1 kilohertz (kHz). While Todd et al. (2015) found that dredging may contribute to communication masking and behavioural changes, and that TTS is possible if marine mammals remain in close proximity to the dredger for extended periods of time (see Section 4.10.5.3), they determined that sounds emitted during dredging activities are unlikely to injure marine mammal auditory systems (i.e., cause PTS) (Todd et al. 2015).

With respect to potential changes in health due to increases in turbidity during dredging, Todd et al. (2015) concluded that sediment plumes from dredging activities are generally localized and fall within the range of turbidity that marine mammals already experience on a regular basis. As a result, adverse effects from this mechanism are improbable. The pathways of effect on marine mammals from disposal at sea activities (i.e., increased turbidity and production of underwater noise) are comparable to dredging, and potential for changes in health are expected to be similar.

Potential effects on marine mammal prey (i.e., marine fish and invertebrates) resulting from these activities were determined to be localized and not significant (see Section 4.9) and are therefore not expected to adversely affect marine mammal foraging opportunities.

The potential for residual effects of change in health to marine mammals resulting from dredging and disposal at sea is therefore considered low and these potential pathways of effects are not carried further into the assessment of change in health (potential effects associated with change in behaviour are addressed in Section 4.10.5.3). Mitigation measures and BMPs associated with the potential effects of dredging and disposal at sea on water quality are addressed in Section 4.5.

### *IN-WATER BLASTING*

In-water blasting is expected to occur in connection with dredging activities and may result in a change in health to marine mammals as a result of the introduction of impulsive noise (Popper and Hawkins 2012), and potential for injury from shock waves, blast effects, or flying debris (Ketten 1995). At the LNG jetty, in-water blasting is anticipated to be required to fragment bedrock present within the dredge pockets, prior to the commencement of dredging activities. In-water blasting is not anticipated at the MOF or at the pioneer facility. Project specific engineering designs for blasting (e.g., explosive type, charge weight, shot patterns, depth, and configuration of blast holes) were not available at the time of assessment, and therefore acoustic modelling of this activity was not undertaken. Once these parameters become available (and prior to the start of marine construction), acoustic modelling will be done to verify assumptions and predictions made in this assessment and refine mitigation measures as necessary.

*MARINE CONSTRUCTION (ROCK SOCKET DRILLING)*

At the LNG jetty, MOF and pioneer facility, piles are likely to be installed by impact pile driving through soft sediment overburden, followed by rock socket drilling into the underlying till/bedrock, and impact driving to seat the piles. Rock socket drilling will introduce a non-impulsive source of underwater noise to the marine environment (i.e., generally considered less injurious than impulsive noise sources such as impact pile driving). Vibratory installation of piles was deemed to be not suitable from an engineering perspective given the substrate composition. Literature-based source levels for rock socket drilling specific to the proposed drill size and equipment were not located. The broadband (10 hertz [Hz]–20 kHz) source level for rock socket drilling derived in the acoustic analysis for use in modelling was approximated as 170.7 dB re 1  $\mu$ Pa (see the Aurora LNG Acoustic Study: Modelling of Underwater Sounds from Pile Driving, Rock Socket Drilling, and LNG Carrier Berthing and Transiting, Appendix P). Underwater acoustic modelling of rock socket drilling at the LNG jetty did not predict sound levels capable of causing auditory injury for any group of marine mammals under any of the acoustic thresholds considered, with the exception of pinnipeds. However, for injury to pinnipeds to occur, a seal or sea lion would have to remain within 10 m of the active rock socket drilling over the course of 24 hours (see the Aurora LNG Acoustic Study: Modelling of Underwater Sounds from Pile Driving, Rock Socket Drilling, and LNG Carrier Berthing and Transiting, Appendix P). The potential for residual effects of change in health to marine mammals resulting from rock socket drilling is therefore considered low. While modelling of rock socket drilling at the MOF was not undertaken, results are expected to be broadly comparable to modeling conducted at the LNG jetty, in the sense of not exceeding injury thresholds. This activity is therefore not carried further into the assessment of change in health (however see Section 4.10.5.3 for assessment of change in behaviour), nor are mitigation measures associated with this activity proposed.

*MARINE CONSTRUCTION (IMPACT PILE DRIVING)*

Pile-supported structures will be used for the LNG jetty, MOF and pioneer facility. At the LNG jetty and MOF, piles are assumed to be 1.5 m (60 inch) diameter cylindrical steel. Diameters are expected to be smaller for the pioneer facility. Installation of cylindrical steel piles will introduce underwater noise to the marine environment around the LNG jetty, MOF, and pioneer facility. At the LNG jetty, piles will be used to support the access trestle, berths and breasting/mooring dolphins. Construction of the LNG jetty will require the installation of approximately 293 subtidal piles, all of which will be seated on subtidal substrate. The MOF wharf and access trestle(s) would be supported by approximately 418 subtidal piles and 78 intertidal piles for the pile and deck option. Concrete caisson design would include installation of 15 subtidal piles and no intertidal piles. The passenger boat landing area of the pioneer facility would require approximately eight piles to secure the landing pontoon and support the walkway. Acoustic modelling was not undertaken for impact pile driving under the concrete caisson design option or construction of the pioneer facility; but these scenarios are assumed to be conservatively represented by results from modelling of the pile-and-deck option at the MOF.

*LNG SHIPPING (AND SUPPORT VESSEL TRAFFIC DURING ALL PHASES)*

Underwater acoustic modelling of vessel noise was undertaken for the Project-related vessels and scenarios that are expected to result in the highest sound levels (i.e., LNG carriers and accompanying tugs during berthing and maximum transit speed). Results for peak SPLs did not predict sound levels

capable of causing auditory injury at any distance for any species of marine mammal. Injury thresholds based on rms SPLs were only exceeded within 20 m and 10 m of the propellers during berthing for cetaceans and pinnipeds, respectively, and at less than 10 m for both species groups during maximum transit speed. Predictions for SEL<sub>24h</sub> thresholds did not extend further than 30 m (during berthing with four tugs; i.e., less than the footprint of the vessel) or 10 m (during transit at 16 kts (30 km/hr) with two tugs. For injury to occur, a marine mammal would have to remain within 30 m of the active vessels over the course of 24 hours (see the Aurora LNG Acoustic Study: Modelling of Underwater Sounds from Pile Driving, Rock Socket Drilling, and LNG Carrier Berthing and Transiting, Appendix P). Source levels from smaller, slower-moving support vessels are not expected to exceed levels produced by LNG carriers and tugs under the conditions modelled. It is considered highly unlikely that a marine mammal would approach to within 10 – 30 m of a propeller operating at full power. Therefore, the potential for residual effects of change in health to marine mammals during routine operations, or from Project-related vessel traffic during any phase, is considered low and this potential interaction is not carried further into the assessment of change in health. Potential effects associated with change in behaviour are addressed in Section 4.10.5.3 and assessment of increased risk of ship strikes is addressed in Section 4.10.5.4.

#### *DISMANTLING OF MARINE INFRASTRUCTURE*

At the end of the life of the Project, decommissioning of in-water infrastructure will be reviewed in consultation with relevant regulators. It is assumed that infrastructure will be removed in accordance with legislation in effect at the time. Dismantling of marine infrastructure will likely involve the introduction of underwater noise to the marine environment. Should in-water blasting activities be required, mitigation measures will be similar to those applied during construction and BMP will be followed.

#### **MITIGATION FOR CHANGE IN HEALTH**

Table 4.10-8 identifies mitigation measures that will be implemented during construction activities to avoid or reduce potential changes in marine mammal health from exposure to elevated noise levels during in-water blasting and impact pile driving and from shock waves or flying debris during in-water blasting. Mitigation measures were selected based on their effectiveness to mitigate potential injury, technical feasibility, inclusion as mitigation measures in similar projects proposed for the Pacific North Coast, and professional judgment of the effects assessment team.

Sound levels associated with other construction activities (i.e., rock socket drilling, dredging, or disposal at sea) and Project-related vessel traffic are not expected to cause auditory injury, and no mitigation measures are proposed for these activities. Mitigation measures to reduce change in behaviour are discussed in Section 4.10.5.3, although it is noted here that some of the mitigation measures designed to reduce changes in health will also reduce the potential extent of changes in behaviour.

The primary mechanism for reducing potential changes in health to marine mammals during in-water blasting and impact pile driving is by limiting the potential for exposure to injury. This is accomplished first during the engineering and design phase, by reducing the amount of underwater blasting and impact pile driving required, followed by reducing the amount of underwater noise produced by these activities (e.g., through implementation of sound reducing technologies) and thereby the areal extent over which auditory injury is possible. Marine construction details are anticipated to be refined as additional geotechnical information is obtained and Project design is optimized (while taking into consideration potential effects

## **Aurora LNG**

Environmental Assessment Certificate Application

Section 4.10: Marine Mammals

---

on marine mammals) through front end engineering design. Once sound levels have been reduced to the extent practicable, potential for injury is further reduced by monitoring a predefined area (i.e., the exclusion zone) and stopping in-water blasting and impact pile driving activities when a marine mammal is observed within this zone.

Further details on the specifics regarding implementation of these mitigation measures are provided following Table 4.10-8.

**Table 4.10-8 Mitigation Measures Proposed to Avoid or Reduce Change in Health for Marine Mammals**

Mitigation No.	Mitigation/Mitigation Mechanism	Rationale for Selection	Expected Success/Risks and Uncertainty	Timing	Management and/or Compensation Plans
4.10.1	<p><u>Mitigation:</u> To reduce the potential for changes in health and behaviour during in-water blasting:</p> <ul style="list-style-type: none"> <li>▪ In-water blasting guidelines recommended by DFO (Wright and Hopky 1998) will be followed.</li> <li>▪ Inter-charge time delay between sequential detonations will be short (e.g., milliseconds).</li> <li>▪ Bubble curtains will be installed around the blast area to provide noise attenuation and reduce the extent of underwater sound levels capable of exceeding thresholds.</li> <li>▪ In-water blasting will occur only during daylight hours.</li> <li>▪ A marine mammal monitoring program will be implemented to enforce an exclusion zone around the in-water blasting area. The exclusion zone will be a minimum of 500 m (to protect from shock waves, blast effects and flying debris).</li> <li>▪ An underwater noise field verification program will be conducted to verify predicted sound pressure levels and the size of the exclusion zone for in-water blasting.</li> </ul> <p><u>Mitigation Mechanism:</u> The primary mechanism for reducing the potential for harm to marine mammals during in-water blasting is by limiting the potential for exposure to injury. This is accomplished initially during the engineering and design phase, by reducing the amount of underwater blasting required, followed by reducing the amount of underwater noise produced by this activity (e.g., through implementation of sound reducing technologies) and thereby the areal extent over which auditory injury is possible. Monitoring of a predefined area (i.e., the exclusion zone) is used to allow stopping of in-water blasting activities when a marine mammal is observed within this zone.</p>	<p>Compliance with in-water blasting guidelines recommended by DFO (Wright and Hopky 1998) Section 32(1) of SARA prohibits harm to any endangered or threatened wildlife species (including marine mammals). Section 35 of the <i>Fisheries Act</i> prohibits serious harm to fish (including marine mammals) that are part of, or support, a commercial, recreational, and Aboriginal (CRA) fishery. Marine mammals in the RAA have traditional, cultural, ecological, and recreational (including economic) importance.</p>	<p><u>Expected Success:</u> There is a high likelihood of success. The use of a monitored exclusion zone during in-water blasting is considered an industry standard to reduce potential for injury of marine mammals.  The size of the exclusion zone will be determined by acoustic modelling and confirmed in the field. The minimum size of 500 m is expected to be of sufficient size to protect from shock waves, blast effects, and flying debris. <u>Risk and Uncertainty:</u> Marine mammals may be underwater for long periods of time and not visible at the surface. Marine mammals at the surface may not be visible in all weather and lighting conditions. Protocols are designed to lessen this risk (see details below table). There is a low degree of uncertainty that the proposed mitigation will reduce the potential for injury of marine mammals due to in-water blasting.  There is uncertainty regarding design aspects and predicted underwater sound levels associated with Project specific blasting requirements.</p>	<p><u>Project Phase:</u> Construction Decommissioning <u>Effectiveness:</u> Mitigation measures will be effective upon implementation</p>	<p>Marine and Freshwater Resources Management Plan</p>
4.10.2	<p><u>Mitigation:</u> To reduce potential for changes in health and behaviour during marine impact pile driving:</p> <ul style="list-style-type: none"> <li>▪ Confined bubble curtains will be installed around the impact pile driving area to provide noise attenuation and reduce the extent of underwater sound levels capable of exceeding thresholds.</li> <li>▪ A marine mammal monitoring program will be implemented to enforce an exclusion zone during impact pile driving.</li> <li>▪ Impact pile driving will occur only during daylight hours.</li> <li>▪ An underwater noise field verification program will be conducted to verify predicted sound pressure levels and the size of the exclusion zone.</li> </ul> <p><u>Mitigation Mechanism:</u> The primary mechanism for reducing the potential for harm to marine mammals is by limiting the potential for exposure to injury. This is accomplished initially during the engineering and design phase, by reducing the amount of impact pile driving required, followed by reducing the amount of underwater noise produced by this activity (e.g., through implementation of sound reducing technologies) and thereby the areal extent over which auditory injury is possible. Monitoring of a predefined area (i.e., the exclusion zone) is used to allow stopping of in-water impact pile driving activities when a marine mammal is observed within this zone.</p>	<p>Section 32(1) of SARA prohibits harm to any endangered or threatened wildlife species (including marine mammals). Section 35 of the <i>Fisheries Act</i> prohibits serious harm to fish (including marine mammals) that are part of, or support, a commercial, recreational, and Aboriginal (CRA) fishery. Marine mammals in the RAA have traditional, cultural, ecological, and recreational (including economic) importance.</p>	<p><u>Expected Success:</u> There is a high likelihood of success. The use of a monitored exclusion zone during impact pile driving is considered an industry standard to reduce potential for injury of marine mammals. <u>Risk and Uncertainty:</u> Marine mammals may be underwater for long periods of time and not visible at the surface. Marine mammals at the surface may not be visible in all weather and lighting conditions. Protocols are designed to lessen this risk (see details below table). There is a low degree of uncertainty that the proposed mitigation measures will reduce the potential for injury of marine mammals due to impact pile driving. There is uncertainty regarding design aspects and predicted underwater sound levels associated with Project specific pile-driving activities.  The size of the exclusion zone will be confirmed during consultation with DFO. Alternative/additional mitigation methods may need to be considered.</p>	<p><u>Project Phase:</u> Construction <u>Effectiveness:</u> Mitigation measures may require modification through consultation with DFO.</p>	<p>Marine and Freshwater Resources Management Plan</p>

This page intentionally left blank.

In-water blasting will be conducted at the LNG jetty during DFO's north coast least risk timing window for marine fish (November 30 to February 15) (DFO 2014). While timing windows were specifically designed by DFO to reduce potential harm to marine fish and are not optimized to benefit marine mammals, there may be some collateral benefits for certain marine mammals, such as harbour seal, harbour porpoise and humpback whale, which are predicted to be present at relatively lower densities than at other times of the year (see the Marine Mammals TDR, Appendix N). This is discussed in further detail below, under the Characterization of Residual Effects for Change in Health for In-water Blasting.

The following subsections detail the specific implementation practices associated with the proposed mitigation measures.

### *IN-WATER BLASTING*

#### ENGINEERING AND DESIGN FOR IN-WATER BLASTING

- Blast charge weights will be reduced to lowest effective amounts (i.e., where a lesser charge weight can be used to accomplish the task, this weight will be selected over a higher charge).
- Within the overall blast cycle, there should only be a short inter-charge time delay (e.g., milliseconds in duration) between sequential detonations.
- Bubble curtains will be installed around the blast area to provide noise attenuation, in an effort to reduce SPLs as well as the areal extent over which underwater sound levels capable of causing acoustic injury are emitted into the marine environment.

#### MARINE MAMMAL MONITORING PROGRAM DURING IN-WATER BLASTING

- In-water blasting and associated exclusion zone monitoring will only be undertaken during daylight and in conditions of good visibility and sightability. Good sightability conditions require a Beaufort sea state of 3 or less (i.e., large wavelets; crests begin to break; scattered whitecaps), and with no prohibitively thick fog or heavy precipitation impeding visibility of any portion of the defined exclusion zone.
- Prior to the commencement of each blast cycle, the in-water blasting exclusion zone will be visually monitored with binoculars and naked eye, continuously for a 30-minute 'pre-scan' period. The entire extent of the exclusion zone must remain visible during the pre-scan.
- If visibility becomes compromised during the 30-minute pre-scan, in-water blasting must be delayed until visibility increases and the exclusion zone can be fully monitored for a continuous 30-minute period.
- If a marine mammal is detected within the exclusion zone during the 30-minute pre-scan, in-water blasting must be delayed until:
  - The sighted marine mammal has been observed to leave the exclusion zone and the initial 30-minute pre-scan period has been completed without additional sightings of any marine mammal, or,

- The marine mammal has not been re-sighted within the exclusion zone and a full additional 30 minutes has elapsed following the last sighting.
- Once the exclusion zone has been deemed clear of marine mammals during the completed pre-scan, ramp-up procedures can commence.
- In-water blasting ramp-up procedures involve the detonation of smaller mass charges first. Charge mass then increases progressively over a series of blasts.
- In-water blasting will be halted immediately if an MMO detects a marine mammal entering or within the exclusion zone.
- In the event in-water blasting is halted due to a sighting, MMOs will continue to monitor the exclusion zone and the marine mammal(s). In-water blasting will not be resumed until:
  - The previously sighted marine mammal(s) are observed exiting the exclusion zone (and during this time no other marine mammal has been observed to enter), or,
  - The previously sighted marine mammal(s) are not re-sighted within the exclusion zone for 30 minutes following the last sighting and no other marine mammal has been observed to enter.
- If in-water blasting ceases during daylight, activity may resume when needed if there has been no interruption in monitoring and no marine mammals have been observed in the exclusion zone. If monitoring also ceased, the 30-minute pre-scan and ramp-up procedures must be re-instituted in appropriate sightability conditions before the activity can be re-commenced.

#### IN-WATER BLASTING EXCLUSION ZONE

- The size of the in-water blasting exclusion zone will be a minimum of 500 m in radius (to protect marine mammals from shock waves, blast effects, and flying debris). Prior to the start of marine construction, acoustic modelling of in-water blasting and consultation with DFO will be undertaken to determine the size of the exclusion zone and refine mitigation measures as necessary.

#### *MARINE CONSTRUCTION (IMPACT PILE DRIVING)*

#### ENGINEERING AND DESIGN FOR IMPACT PILE DRIVING

- Potential for adverse residual effects on marine mammals will be taken into consideration during the design phase (e.g., in selecting between design options with differing numbers of piles).
- Confined bubble curtains will be installed around the impact pile driving area to provide noise attenuation and reduce the extent of underwater sound levels capable of causing injury.

#### MONITORING AND CESSATION OF IMPACT PILE DRIVING ACTIVITY

- Monitoring protocols during impact pile driving will be the same as those identified above for in-water blasting. The ramp-up procedure for impact pile driving will involve the steady and gradual build-up of underwater acoustic energy output from a lower energy level to full output.

### IMPACT PILE DRIVING EXCLUSION ZONE

- The ultimate size of the impact pile driving exclusion zone will be determined during consultation with DFO and confirmed during field verification studies at the onset of impact pile driving activities.

### ***CHARACTERIZATION OF RESIDUAL EFFECTS FOR CHANGE IN HEALTH***

#### *IN-WATER BLASTING*

#### TIMING

In-water blasting will be conducted during the construction phase, during DFO's north coast least risk timing window for marine fish (November 30 to February 15) (DFO 2014). While timing windows were specifically designed by DFO to reduce potential harm to marine fish and are not optimized to benefit marine mammals, it is important to recognize how this seasonal restriction relates to potential marine mammal presence. While for the purpose of the assessment, marine mammals are conservatively assumed to be in the Project area year-round, marine mammal densities, activities, and use of the area will undergo daily and seasonal fluctuations. Implementation of the least risk timing window for marine fish may therefore have some collateral benefits for marine mammals. For example, harbour seal pupping in northern BC peaks in mid-June (Ford 2014), thus young seal pups are not expected to be in the RAA during marine blasting activities. Results of marine mammal line transect surveys also suggested that sightings of harbour seals were lower at this time of year than during the summer and fall. Similarly, other marine mammal species whose presence in the RAA is expected to peak in the spring, summer, or fall are less likely to be exposed to underwater noise from in-water blasting activities restricted to the winter months. Project surveys and distance sampling suggest that mean relative abundance of harbour porpoise is highest in the RAA during the fall and summer, with few sightings during the winter. This potential timing window benefit does not apply equally to all marine mammal species. For example, while abundance estimates for humpback whales suggest peak presence in the fall, with a decrease in the winter, modelling suggests that winter abundance of humpback whales could still average 100 individuals or more in the RAA (January prediction; 95% CI: 37-290) (see the Marine Mammals TDR, Appendix N). Based on the results of marine mammal line transect surveys conducted during December – February, humpback and minke whales, harbour porpoise, harbour seals, and Steller sea lions were observed within the PRPA boundaries, and fin whales, killer whales, and Dall's porpoises were observed within the broader RAA (see the Marine Mammals TDR, Appendix N). In addition to these species, opportunistic data collected by the BCCSN between 1961 and 2014 showed a few records of grey whales and Pacific-white sided dolphins in the RAA at this time of year (BCCSN 2014). A variety of species of marine mammals may therefore be present in the waters surrounding the LNG jetty at the time of in-water blasting.

### INTENSITY

The intensity of blast pressures generated during in-water blasting events depend on a number of factors, including explosive type, charge weight, shot patterns, depth, and configuration of blast holes (e.g., Hempen et al. 2007). Project design specifics of this nature were not available at the time of assessment, but will be incorporated into acoustic modelling once they become available and prior to the start of marine construction. These parameters will be instrumental in designation of the size of the marine mammal in-water blasting exclusion zone, which will be specifically designed to exclude marine mammals from the area within which blast intensity may be expected to result in injury.

### EXTENT

Shock waves, blast effects, and flying debris from in-water blasting are not expected to be able to injure marine mammals at distances greater than 500 m – the distance typically recommended by DFO as the minimum size for in-water blasting exclusion zones (Wright and Hopky 1998). The distance over which in-water blasting might cause auditory injury could extend further than this and will depend on the specifics of the blast, and a variety of oceanographic factors that attenuate sound (e.g., depth, water temperature, and substrate). For this reason, the size of the exclusion zone will be set based on results of future acoustic modelling and consultation with DFO, to reflect the greater of: 500 m, or; the largest extent over which in-water blasting is predicted to cause auditory injury.

### DURATION

In-water blasting is expected to occur over a period of approximately 2.5 months at the LNG jetty.

### SUMMARY OF RESIDUAL EFFECT FROM IN-WATER BLASTING

With the implementation of mitigation measures, effects of change in health resulting from in-water blasting on marine mammals are expected to be of low magnitude as the implementation of an appropriately designed in-water blasting exclusion zone will effectively limit the potential for marine mammals to be exposed to shock waves, blast effects, flying debris and injurious noise levels. Residual effects from this activity will occur in the LAA as multiple irregular events over the short-term, and be reversible after completion of in-water blasting activities. This effect will occur in a disturbed area of active human development (e.g., port-related development and activity).

### *MARINE CONSTRUCTION (IMPACT PILE DRIVING)*

#### TIMING

Impact pile driving will occur during the construction phase, commencing with building of the pioneer facility. Timing windows for marine fish will not be applied to pile installation. Therefore, it is anticipated that this activity could occur during any month of the year, and for the purposes of the assessment it is assumed that marine mammals may be present in the waters surrounding the MOF, LNG jetty, or pioneer facility during pile installation activities.

### INTENSITY AND EXTENT

Results of acoustic modelling for mitigated impact pile driving (assuming use of a confined bubble curtain) varied across the acoustic thresholds considered and between the MOF and the LNG jetty. When considering the peak SPL metrics of Southall et al. (2007), potential for injury was not predicted at distances  $\geq 0.01$  km ( $R_{\max}$ ;  $R_{95\%}$  was not computed over this range) for any species of marine mammal, at either the MOF or LNG jetty. Under the NOAA interim rms SPL metrics for injury (NOAA n.d.), sound levels capable of causing PTS were predicted at  $R_{95\%}$  distances less than 0.3 km for cetaceans and 0.1 km for pinnipeds at the MOF, and at distances less than 0.09 km and 0.02 km at the LNG jetty, for cetaceans and pinnipeds, respectively. The Wood et al. (2012)  $SEL_{24h}$  metrics predicted the greatest areas of extent for potential injury; however, these depend strongly on the duration of underwater noise produced during this time period, and marine mammals would have to remain within predicted ranges for a full 24-hr period to incur injury. Predicted extents of noise above the metric at the LNG jetty (based on installation of four simultaneous piles in a 24-hr window [noting that impact pile driving will not occur at night]) were: 0.1 km for mid-frequency cetaceans such as killer whales, 1.1 km for low-frequency cetaceans such as humpback whales, 1.8 km for pinnipeds, and 3.2 km for high-frequency cetaceans such as harbour porpoise. At the MOF, predicted extents were 2.1 km for mid-frequency cetaceans, 5.9 km for low-frequency cetaceans, 6.9 km for pinnipeds, and 8.1 km for high-frequency cetaceans (based on installation of simultaneous piles, two at a time, with a total of 8 installed over the 24 hours) (see the Aurora LNG Acoustic Study: Modelling of Underwater Sounds from Pile Driving, Rock Socket Drilling, and LNG Carrier Berthing and Transiting, Appendix P).

DFO has recommended that exclusion zones for this Project be set based on the predicted area of exceedance of the 160 dB re 1  $\mu$ Pa rms SPL isopleth, which is the NOAA interim threshold for behavioural disturbance from an impulsive source (i.e., more conservative than the NOAA interim thresholds for injury discussed above). The majority of marine mammals, particularly 'sensitive' high frequency cetaceans such as harbour porpoise, are expected to vacate the immediate area during intense noise-producing marine construction activities (see Section 4.10.5.3 for assessment of potential behavioural effects), and are therefore not expected to occur within 300 m of active pile driving or thus be exposed to sound levels capable of causing PTS. In-field verification of sound levels will be undertaken to confirm that assigned distances are appropriate. Implementation of conservative exclusion zones will further reduce potential adverse effects of change in health on marine mammals.

### DURATION

According to the current schedule, there would be approximately 2 days of pile installation at the MOF under the concrete caisson design. Total pile installation time over this period would be 15 hours (assuming 1 hour per pile).

Under the pile-and-deck design at the MOF, impact pile installation would introduce up to a maximum of 496 hours of noise from pile installation (assuming one pile at a time and 1 hour per pile), introduced into the marine environment over a period of 8.5 months. The total number of hours of introduced noise may be less (although sound levels somewhat higher) if piles are installed simultaneously. For acoustic modelling, it was assumed that two sets of pile driving equipment would be active simultaneously (maximum expected), a scenario that produces conservative sound levels but reduced potential noise

exposure durations. Under this scenario, at full production (i.e., 8 piles per day) it would take 62 (non-consecutive) days to install the piles, spread out over 8.5 months, with pile driving noise from two simultaneous piles introduced to the marine environment for up to 4 hours each day.

At the LNG jetty, impact pile installation would introduce up to a maximum of 196 hours of underwater noise, spread out over approximately 23.5 months (assuming one pile at a time, at 40 minutes per pile [due to the different geology at the LNG jetty]). The total number of hours of introduced noise may be less (although sound levels somewhat higher) if piles are installed simultaneously. The maximum number of piles driven in one day would be four. For acoustic modelling, it was assumed that all four piles would be installed simultaneously (two at the northern berth and two at the southern berth). This scenario produces conservative (i.e., maximal) sound levels, but the minimum predicted noise exposure durations. Under this scenario, every day of pile driving would result in 40 minutes of underwater noise, during which time four piles are being driven simultaneously. Each pile is anticipated to require three days to install. For every 40 minutes of impact pile driving there will be approximately 10 hours of rock socket drilling. Therefore, over the course of 23.5 months, there would be approximately 73 non-consecutive days that involved 40 minutes of pile driving (49 hours of noise over two years), and each of these days would be followed by at least two days of no pile driving.

#### SUMMARY OF RESIDUAL EFFECT FROM IMPACT PILE DRIVING

Of the three metrics for injury, peak SPLs were not predicted to be exceeded during impact pile driving at distances over 10 m and rms SPLs were not predicted to be exceeded at distances greater than 300 m, even after the conservative sound level assumption of multiple (two to four) pile drivers operating simultaneously. The third metric (i.e., SEL<sub>24h</sub>) predicted that individual marine mammals may be exposed to injurious sound levels within 3.2 km of the LNG jetty or 8.1 km of the MOF, but only if they remain within these distances over a period of 24 hours. The majority of marine mammals, particularly sensitive, high frequency cetaceans such as harbour porpoise, are expected to vacate the immediate area during pile installation activities (see Section 4.10.5.3), reducing their potential for exposure to sound levels capable of causing auditory injury. Marine mammals are not expected to remain in the area, over the scale of exceedances predicted by underwater noise modelling (i.e., within 300 m of active pile driving), and are therefore not expected to be exposed to sound levels capable of causing PTS. In-field verification of sound levels will be undertaken during in-water impact pile driving to confirm that predicted sound level exceedance distances are accurate and implementation of conservative exclusion zones will further reduce potential adverse effects of change in health on marine mammals.

Fisheries and Oceans Canada has recommended that the Project exclusion zone be set based on the predicted area of the 160 dB re 1 µPa rms SPL isopleth (BC EAO 2015), which is the NOAA interim threshold for behavioural disturbance from an impulsive source (i.e., more conservative than the NOAA interim threshold for injury). This threshold was predicted to be exceeded at an  $R_{95\%}$  radius of 3.0 km at the LNG jetty and 5.9 km at the MOF, under the conservative scenarios for simultaneous pile installation. When compared to both the rms SPL and the peak SPL injury thresholds, modelling results suggest that 'instantaneous' injury is unlikely at this distance, as it is only predicted over distances less than 300 m from the MOF or 90 m from the LNG jetty. The size of the monitored exclusion zone will therefore be confirmed through consultation with DFO.

With the implementation of mitigation measures, effects of change in health resulting from impact pile driving are expected to be of moderate magnitude. Residual effects from this activity will extend into the LAA, occur as multiple irregular events over the medium-term (many months), and are expected to be reversible. This effect will occur in a disturbed area of active human development (e.g., port-related development and activity).

#### DISMANTLING OF MARINE INFRASTRUCTURE

Potential marine mammal changes in health due to underwater noise produced from the dismantling of marine based infrastructure during decommissioning are expected to be similar in manner to the predicted residual effects for the construction phase, although they are likely to be of a lesser scale. Similar mitigation measures to those implemented during construction would also be applied where appropriate during this phase to reduce the likelihood of marine mammal injury.

With the implementation of mitigation measures, effects of change in health during this phase of the Project are expected to be of moderate magnitude, limited to a small portion of the LAA, occur as multiple irregular events over the short-term, and be reversible. This effect will occur in a disturbed area of active human development.

#### *SUMMARY*

With mitigation, the Project will result in moderate magnitude residual effects within the LAA during the construction and decommissioning phase (some individual activities within these phases will result in low magnitude effects). This change in health will occur as multiple irregular events during both phases and persist over the short to medium-term depending on Project activity and phase. This effect is anticipated to be reversible after activity completion. Adverse residual effects of change in health are not expected during the operations phase.

#### ***LIKELIHOOD OF RESIDUAL EFFECTS FOR CHANGE IN HEALTH***

Based on the assumption that in consultation with DFO, approved exclusion zones and mitigation measures will be developed and implemented for both in-water blasting and impact pile driving, the likelihood of residual effects of change in health on marine mammals is considered low.

#### **4.10.5.3 Assessment of Change in Behaviour**

##### ***PROJECT MECHANISMS FOR CHANGE IN BEHAVIOUR***

Project components and physical activities have the potential to result in changes to marine mammal behaviour during construction (i.e., dredging and disposal at sea, in-water blasting, and marine construction activities), operations (LNG shipping), and decommissioning (dismantling of marine infrastructure) (as identified in Table 4.10-7). The change in behaviour effect is assessed by describing the predicted timing, duration, intensity and extent (based on  $R_{95\%}$  values) of underwater noise generated by Project activities, supported by the results of Project specific acoustic modelling (see the Aurora LNG Acoustic Study: Modelling of Underwater Sounds from Pile Driving, Rock Socket Drilling, and LNG Carrier

Berthing and Transiting, Appendix P). These metrics are then compared to published and/or industry standard thresholds for marine mammal behavioural responses to underwater noise. At levels of sound not capable of causing injury (assessed in Section 4.10.5.2), the focus of concern shifts to potential changes in behaviour (although these are also predicted at the higher sound levels linked to potential injury). The introduction of anthropogenic (particularly novel) sources of underwater noise can cause stress in marine mammals (Southall et al. 2007; Wright et al. 2007; Rolland et al. 2012); this in turn may cause physiological responses such as diminished reproductive effort and lowered immune responses (Croll et al. 2001; Clark et al. 2009b). Increased underwater sound levels may also impede or mandate alterations in communication (Richardson et al. 1995; Southall et al. 2007; Clark et al. 2009a; Hatch et al. 2012; Risch et al. 2012; Williams et al. 2013). Of particular concern are sound levels that may trigger avoidance behaviours, disrupt migration, or adversely affect foraging patterns and foraging success (e.g., Slotte et al. 2004; Williams et al. 2006; Southall et al. 2007; Sundermeyer et al. 2012; Tougaard et al. 2012; van Opzeeland and Slabbekoorn 2012).

The actual reactions of marine mammals to introduced sources of underwater noise under any particular scenario are difficult to predict with confidence, as they will depend on a multitude of factors, such as the intensity, type, duration of the noise, the individual, species, sex and life history and its distance from the source, the novelty of the activity, as well as state of the animal at the time of exposure (Richardson et al. 1995; Wartzok et al. 2003; Ellison et al. 2012). For example, fin whales and right whales (*Eubalaena glacialis*) have demonstrated higher tolerance to sound sources of a given level if that sound source is stationary, rather than approaching them (Watkins 1986). Bowhead whales (*Balaena mysticetes*) in the Beaufort Sea appear to tolerate much higher levels of underwater noise from seismic survey operations when there are available food sources nearby (i.e., when they are feeding) than otherwise (e.g., when they are migrating) (Koski et al. 2008). While some species of whale have been observed to cease vocalizations in the presence of increased underwater noise (e.g., right and humpback whales in the presence of whale-watching boats) (Watkins 1986), other species continue to call without any apparent change in vocalization characteristics (e.g., fin whale < 1 km from a container ship increasing from idle to full power) (Edds 1988).

At high enough received levels, marine mammals may also experience TTS – a temporary shift in their hearing sensitivity. While this effect differs from PTS in that marine mammals recover from the shift (see assessment of PTS in Section 4.10.5.2), the duration of the recovery period is linked to the magnitude of the shift and there may be ecological consequences during this time period (e.g., reduced ability to detect predators or prey) (Southall et al. 2007; Lucke et al. 2009; Kastelein et al. 2011). This assessment discusses potential for TTS primarily in general terms. Broadly, TTS is most likely at received sound levels below those capable of causing PTS (i.e., ~15 dB for impulsive sounds based on Southall et al. 2007), and is considered less likely at sound levels that do not exceed behavioural disturbance thresholds. The onset of TTS depends on sound pressure level, frequency spectrum, and duration of exposure.

### *DREDGING AND DISPOSAL AT SEA*

It is anticipated that a grab (i.e., clamshell) dredger will be used to dredge rock and soft-sediment at the LNG jetty, and soft-sediment at the MOF. This activity has the potential to produce underwater noise at levels that may cause a change in behaviour in marine mammals. Todd et al. (2015) undertook a review of the potential effects of marine dredging activities on marine mammals, including looking at the published results of recorded noise outputs from dredgers. They determined that SPLs vary widely by dredger type (e.g., between cutter suction dredgers [CSDs], trailing suction hopper dredgers [TSHDs], grab dredgers, and backhoe dredgers), as well as by the operational stage, substrate, and environmental conditions at the time of measurement. Underwater noise may be generated as the dredge bucket strikes the substrate, while the jaws of the bucket are clamping shut, or through winching of the clamshell bucket. Grab dredgers in particular have been found to produce substantially variable sound levels depending on their operational stage, with the most intense SPLs being measured when the dredge bucket strikes the substrate (e.g., 124 dB re 1  $\mu$ Pa rms @ peak frequencies of 0.16 kHz measured at a distance of 150 m; Dickerson et al. (2001)). This value for an impulsive noise source is below the NOAA (n.d.) interim threshold for behavioural disturbance for impulsive sounds (160 dB re 1  $\mu$ Pa rms). Dickerson et al. (2001) found that all other measured rms SPLs for distinct dredge cycle events (i.e., bucket digging, bucket closing, winch up, and barge loading) were below 120 dB re 1  $\mu$ Pa rms at a distance of 158 m from the source. Dredging activities involving the use of a grab dredge are therefore deemed unlikely to cause a measureable change in behaviour of marine mammals, including potential to cause TTS. However, Todd et al. (2015) suggested that dredging may contribute to communication masking. The act of disposing of dredged materials in Brown Passage may also generate comparable levels of underwater noise.

While it is considered unlikely that the NOAA (n.d.) interim thresholds for behavioural disturbance will be exceeded during dredging and disposal at sea activities, sound levels below these thresholds can contribute to communication masking and stress, and this activity will occur concurrently with other more intense sources of underwater noise during Project construction (see below).

### *IN-WATER BLASTING*

In-water blasting at the LNG jetty will introduce impulsive sources of underwater noise, with the potential to cause behavioural change in marine mammals, including TTS. At the LNG jetty, in-water blasting is anticipated to be required to fragment bedrock present within the dredge pockets, prior to the commencement of dredging activities. In-water blasting is not anticipated at the MOF or at the pioneer facility. Project specific engineering designs for blasting (e.g., explosive type, charge weight, shot patterns, depth, and configuration of blast holes) were not available at the time of assessment, and therefore acoustic modelling of this activity was not undertaken. Once these parameters become available (and prior to the start of marine construction), additional acoustic modelling will be done to verify assumptions and predictions made in this assessment and refine mitigation measures as necessary.

*MARINE CONSTRUCTION (ROCK SOCKET DRILLING)*

As discussed under the assessment of change in health, rock socket drilling will be required at the MOF, LNG jetty, and pioneer facility, to insert piles into underlying till and bedrock, respectively (see also description in Section 4.9.2.3). This activity will introduce a non-impulsive source of underwater noise to the marine environment. It was conservatively assumed that up to four drill rigs would operate at once at the LNG jetty: two at the northern berth and two at the southern berth. Literature-based source levels for rock socket drilling specific to the proposed drill size and equipment were not located. The broadband (10 Hz–20 kHz) source level for rock socket drilling derived in the acoustic analysis for use in modelling was approximated as 170.7 dB re 1  $\mu$ Pa (see the Aurora LNG Acoustic Study: Modelling of Underwater Sounds from Pile Driving, Rock Socket Drilling, and LNG Carrier Berthing and Transiting, Appendix P).

Rock socket drilling will produce lower underwater noise emissions than impact pile driving. In a report of underwater noise measurements taken during rock socket drilling at offshore windfarms, Nedwell et al. (2003) concluded that while tonal noise could be detected at distances of up to 7 km, rock socket drilling is a relatively low level noise source, with “little likelihood of the noise from the drilling causing an environmental effect”. Additional mitigation measures have therefore not been recommended.

*MARINE CONSTRUCTION (IMPACT PILE DRIVING)*

Given the presence of resistant substrate at the MOF (and pioneer facility) and LNG jetty, impact pile driving will be required to secure the piles. Underwater noise generated by in-water pile installation has the potential to cause a change in behaviour in marine mammals, including TTS. Responses by marine mammals to impulsive sources of underwater noise are variable, with reactions differing between individuals and age classes, species, and the context (e.g., the activity the marine mammal is engaged in at the time of exposure). Of the marine mammals predicted to occur in the RAA, harbour porpoise are considered the most ‘sensitive’ to disturbance from underwater noise and the most likely to show overt, measurable responses to marine construction. Previous studies of harbour porpoise responses to pile driving suggest there is strong potential for avoidance of areas within behavioural threshold exceedance zones. Brandt et al. (2011) studied harbour porpoise responses to impact pile driving installation of monopiles (3.9 m diameter) at an offshore windfarm, and found a clear adverse effect on porpoise activities out to a mean distance of 17.8 km. They found that at distances out to 2.6 km from the source, porpoise activity was 100% reduced during the first hour after pile driving and did not return to normal levels for 24 to 72 hours. The duration of observed response decreased with increasing distance from the source. Since recovery time following pile installation was longer than the median interval between installations (16 hours), observed activity (and possibly abundance) within 4.8 km was reduced over the entire construction period. The received sound levels resulting in these behavioural effects, measured at a distance of 720 m were 196 dB re 1  $\mu$ Pa peak SPL, and 176 dB re 1  $\mu$ Pa<sup>2</sup>s SEL (unweighted). Using Southall et al.’s (2007) criteria for TTS, Brandt et al. (2011) predicted that harbour porpoise would experience TTS after 1.5 minutes at this distance (i.e., 720 m). Using more conservative thresholds specific to harbour porpoise (Lucke et al. 2009), they predicted TTS immediately at a distance of 720 m and after approximately 2 min at 2.3 km.

### *LNG SHIPPING (AND SUPPORT VESSEL TRAFFIC DURING ALL PHASES)*

During normal weather conditions, all Project-related LNG carriers travelling between the Triple Island pilot station and the LNG jetty will follow the shipping route indicated on Figure 4.10-1. The RAA encompasses the primary and alternate shipping routes. The proposed upper-end LNG carrier transit speed between the Pilot Station and the PRPA boundary is 16 kts (30 km/hr) (average speed of 12 kts [22 km/hr]), while approaching the berth areas speed is reduced to 6 kts (11 km/hr), and berthing speed is negligible.

Approximately 160 to 320 LNG carriers (up to 315 m length and 50 m wide [Q-Flex]) will call on the LNG jetty annually (i.e., up to 640 transits of the RAA or an additional ship passage every 14 hours on average). LNG carriers will travel solo between the Triple Island pilot station and the PRPA boundary, after which they will be escorted by two tugs, and four tugs will assist during berthing (acoustic modelling assumed that LNG carriers would be accompanied by two escort tugs throughout the RAA). The facility may allow concurrent loading of carriers at adjacent berths and it is anticipated that the LNG carriers will typically be at berth for approximately 24 hours. Marine shipping activities will operate year-round and the Project is anticipating a minimum 25 year operating life. Thus, the Project will contribute an additional one to two LNG carrier transits per day to current marine traffic levels in the RAA. Near the LNG jetty, an additional four berthing tugs will operate most days.

### *DISMANTLING OF MARINE INFRASTRUCTURE*

While the exact nature of activities involved in the decommissioning of in-water infrastructure at the end of the life of the Project is not known at this time (see Section 4.10.5.2), it will likely involve the introduction of underwater noise to the marine environment. Underwater noise from these activities may result in a change in behaviour of marine mammals.

### *MITIGATION FOR CHANGE IN BEHAVIOUR*

Table 4.10-9 identifies mitigation measures that will be implemented during the construction phase to avoid or reduce potential changes in marine mammal behaviour from exposure to elevated noise levels. Mitigation measures were selected based on their effectiveness to mitigate potential behavioural change, technical feasibility, inclusion as mitigation measures in similar projects proposed for the Pacific North Coast, and professional judgment of the effects assessment team.

The primary mechanism for reducing potential changes in behaviour to marine mammals during in-water blasting and impact pile driving is by reducing the amount of underwater noise introduced to the marine environment. This is accomplished during the engineering and design phase (e.g., by implementing additional sound reducing technologies such as confined bubble curtains). These actions reduce the amount of underwater noise produced and thereby the areal extent over which change in behaviour is likely. Further details on the specifics of these mitigation measures were provided under the assessment of change in health in Section 4.10.5.2.

This page intentionally left blank.

**Table 4.10-9 Mitigation Measures Proposed to Avoid or Reduce Change in Behaviour for Marine Mammals**

Mitigation No.	Mitigation/Mitigation Mechanism	Rationale for Selection	Expected Success/Risks and Uncertainty	Timing	Management and/or Compensation Plans
4.10.1	<p><u>Mitigation:</u> Measures to reduce potential for changes in behaviour during in-water blasting:</p> <ul style="list-style-type: none"> <li>▪ In-water blasting guidelines recommended by DFO (Wright and Hopky 1998) will be followed.</li> <li>▪ Blast charge weights will be reduced to lowest effective amounts.</li> <li>▪ Inter-charge time delay between sequential detonations will be short (e.g., milliseconds).</li> <li>▪ Bubble curtains will be installed around the blast area to provide noise attenuation and reduce the extent of underwater sound levels capable of exceeding thresholds.</li> <li>▪ In-water blasting will occur only during daylight hours.</li> <li>▪ A marine mammal monitoring program will be implemented to enforce an exclusion zone around the in-water blasting area. The exclusion zone will be a minimum of 500 m (to protect from shock waves, blast effects and flying debris) and may be refined to extend further based on consultation with DFO and the results of acoustic modelling.</li> <li>▪ An underwater noise field verification program will be conducted to verify predicted sound pressure levels and the size of the exclusion zone.</li> </ul> <p><u>Mitigation Mechanism:</u> While the primary objective of the mitigation measures implemented during in-water blasting is to reduce the potential for a change in health in marine mammals, measures that act to reduce the amount of underwater noise produced or the potential exposure of an individual to such noise will also reduce the potential magnitude and extent of behavioural change.</p>	<p>Section 32(1) of SARA prohibits harassment of any endangered or threatened wildlife species (including marine mammals).</p> <p>Section 7 of the Marine Mammal Regulations prohibits 'disturbance' of marine mammals except when fishing for them under the authority of the Regulations.</p> <p>Marine mammals in the RAA have traditional, cultural, ecological, and recreational (including economic) importance.</p>	<p><u>Expected Success:</u> There is a high likelihood of success of reducing the areal extent of residual change in behaviour. While the potential for change in behaviour cannot be eliminated, the scale over which it occurs can be reduced through the implementation of sound reducing technologies.</p> <p><u>Risk and Uncertainty:</u> There is a low degree of uncertainty that mitigation measures to reduce source levels will reduce the areal extents of behavioural change. Field verification of noise levels will be undertaken at multiple locations to confirm extents over the full range of predicted values.</p> <p>There is scientific uncertainty concerning the actual exhibited behavioural responses of marine mammals (i.e., scale of response will vary by species, individual, and context at the time of exposure).</p> <p>There is uncertainty regarding design aspects and predicted underwater sound levels associated with Project specific blasting requirements.</p> <p>Also see Risk and Uncertainty in Table 4.10-8.</p>	<p><u>Project Phase:</u> Construction Decommissioning</p> <p><u>Effectiveness:</u> Mitigation measures will be effective upon implementation</p>	<p>Marine and Freshwater Resources Management Plan</p>

**Table 4.10-9 Mitigation Measures Proposed to Avoid or Reduce Change in Behaviour for Marine Mammals**

Mitigation No.	Mitigation/Mitigation Mechanism	Rationale for Selection	Expected Success/Risks and Uncertainty	Timing	Management and/or Compensation Plans
4.10.2	<p><u>Mitigation:</u>  Measures to reduce potential for changes in behaviour during impact pile driving:</p> <ul style="list-style-type: none"> <li>▪ Confined bubble curtains will be installed around the impact pile driving area to provide noise attenuation and reduce the extent of underwater sound levels capable of exceeding thresholds.</li> <li>▪ A marine mammal monitoring program will be implemented to enforce an exclusion zone during impact pile driving. The ultimate size of the exclusion zone will be confirmed during consultation with DFO and based on the results of acoustic modelling.</li> <li>▪ Impact pile driving will occur only during daylight hours.</li> <li>▪ An underwater noise field verification program will be conducted to verify predicted sound pressure levels and the size of the exclusion zone.</li> </ul> <p><u>Mitigation Mechanism:</u>  While the primary objective of the mitigation measures implemented during impact pile driving is to reduce the potential for a change in health in marine mammals, measures that act to reduce the amount of underwater noise produced or the potential exposure of an individual to such noise will also reduce the potential magnitude and extent of behavioural change.</p>	<p>Section 32(1) of SARA prohibits harassment of any endangered or threatened wildlife species (including marine mammals).</p> <p>Section 7 of the Marine Mammal Regulations prohibits 'disturbance' of marine mammals except when fishing for them under the authority of the Regulations.</p> <p>Marine mammals in the RAA have traditional, cultural, ecological, and recreational (including economic) importance.</p>	<p><u>Expected Success:</u>  There is a moderate likelihood of success of reducing the areal extent of residual change in behaviour. While the potential for change in behaviour cannot be eliminated, the scale over which it occurs can be reduced through the implementation of sound reducing technologies.</p> <p><u>Risk and Uncertainty:</u>  There is a low degree of uncertainty that mitigation measures to reduce source levels will reduce the areal extents of behavioural change. Field verification of noise levels will be undertaken at multiple locations to confirm predicted extents over the full range of predicted values.</p> <p>There is scientific uncertainty concerning the actual exhibited behavioural responses of marine mammals (i.e., scale of response will vary by species, individual and context at the time of exposure).</p> <p>The size of the exclusion zone will be confirmed during consultation with DFO. Alternative/additional mitigation methods may need to be considered.</p> <p>Also see Risk and Uncertainty in Table 4.10-8.</p>	<p><u>Project Phase:</u>  Construction</p> <p><u>Effectiveness:</u>  Mitigation measure will be effective upon implementation</p>	<p>Marine and Freshwater Resources Management Plan</p>

In-water blasting will be conducted at the LNG jetty during DFO's north coast least risk timing window for marine fish (November 30 to February 15) (DFO 2014). Timing windows were specifically designed by DFO to reduce potential harm to marine fish and are not optimized to benefit marine mammals. However, there may be some collateral benefits for certain marine mammals, such as harbour seal, harbour porpoise and humpback whale, which are predicted to be present at relatively lower densities than at other times of the year (see the Marine Mammals TDR, Appendix N).

### ***CHARACTERIZATION OF RESIDUAL EFFECTS FOR CHANGE IN BEHAVIOUR***

#### *DREDGING AND DISPOSAL AT SEA*

##### TIMING

In-water dredging and marine disposal activities will be conducted during DFO's north coast least risk timing window for marine fish (November 30 to February 15) (DFO 2014).

##### INTENSITY

While dredging and disposal at sea are not predicted to produce underwater noise at levels that exceed US regulatory thresholds for behavioural disturbance at distances more than a few hundred metres from the source, they will contribute generally to an overall increase in underwater noise during the construction phase of the Project, and thus may contribute to adverse effects on communication masking and stress.

##### EXTENT

The potential extent of communication masking specific to these activities is expected to be limited based on the source levels associated with this type of dredging equipment and the dynamic and variable nature of the sound outputs (i.e., impulsive sounds associated with bucket strike, followed by continuous sounds of differing and varying frequencies during digging, winching, and barge loading for disposal).

##### DURATION

Based on the current Project schedule, dredging and disposal at sea are expected to occur at the MOF over a 2.5 month period (during the November 30 to February 15 timing window), for two consecutive years. At the LNG jetty, dredging of the north berth is predicted to take two months. At the south berth, blasting will take up the first month or so of the timing window, so dredging is expected to take one month the first year, followed by an additional month during the timing window in the second year.

### SUMMARY OF RESIDUAL EFFECT FROM DREDGING AND DISPOSAL AT SEA

Effects of change in behaviour resulting from dredging and disposal at sea are expected to be of low magnitude in the LAA, occur as multiple irregular events over the short-term, and be reversible. This effect will occur in a disturbed area of active human development and will combine with other marine construction activities for an overall residual effect of change in behaviour on marine mammals during the construction phase.

#### *IN-WATER BLASTING*

##### TIMING

In-water blasting will be conducted at the LNG jetty during DFO's north coast least risk timing window for marine fish (November 30 to February 15) (DFO 2014). Marine mammal line transect surveys and opportunistic data collected by the BCCSN during these months, suggest that humpback, grey, fin, minke and killer whales, Pacific-white sided dolphins, harbour and Dall's porpoise, harbour seals, and Steller sea lions may be observed within the RAA during this time of year (see the Marine Mammals TDR, Appendix N). While DFO's timing windows for marine fish were not optimized to benefit marine mammals, there may be some collateral benefits for certain species, such as harbour seal, harbour porpoise and humpback whale, which are predicted to be present at in the RAA at relatively lower densities than at other times of the year (see the Marine Mammals TDR, Appendix N).

##### INTENSITY AND EXTENT

Prior to additional marine geotechnical information being obtained, the full-scale scope and nature of in-water blasting are considered preliminary at this time. Predictions and conclusions regarding the potential extent of changes in behaviour that may be exhibited by marine mammals will be difficult to determine until further engineering information is obtained. Observations made by Todd et al. (1996) following exposure of humpback whales to low-frequency sounds from explosions (maximum recorded peak source level of 153 dB re 1  $\mu$ Pa at a distance to whales of at least 3 km) showed no obvious behavioural responses or changes in distribution. However, it was concluded that blasting may have led to orientation issues and a subsequent increase to rates of entanglement in fishing gear. A related study by Borggaard et al. (1999) suggested some tolerance of humpback whales to transient blasting, but a potential decrease in return rates in later years to feeding grounds that were subjected to blasting. Since DFO's recommended 160 dB re 1  $\mu$ Pa threshold for exclusion zones is based on the NOAA interim rms threshold for behavioural disturbance (not injury), it is assumed that enforcement of this sized exclusion zone would also be effective at reducing the risk of marine mammals experiencing TTS during in-water blasting, following all monitoring and ramp-up protocols as outlined above under mitigation for change in health.

##### DURATION

In-water blasting is expected to occur over a period of approximately 2.5 months at the LNG jetty.

### SUMMARY OF RESIDUAL EFFECT FROM IN-WATER BLASTING

With the implementation of mitigation measures, effects of change in behaviour from in-water blasting are expected to be of moderate magnitude as sound levels are expected to exceed at least some of the marine mammal behavioural disturbance thresholds over a number of kilometres. Residual effects from this activity will occur in the LAA as multiple irregular events over the short-term, and are expected to be reversible. This effect will occur in a disturbed area of active human development and will combine with other marine construction activities for an overall residual effect of change in behaviour on marine mammals during the construction phase.

#### *MARINE CONSTRUCTION (ROCK SOCKET DRILLING)*

##### TIMING

Rock socket drilling will be undertaken in combination with impact pile driving activities during construction of the LNG jetty, MOF, and pioneer facility. Since timing windows for marine fish will not be applied to pile installation, rock socket drilling is likely to occur year-round and will overlap with periods when marine mammals are present in local waters.

##### INTENSITY AND EXTENT

Underwater acoustic modelling of rock socket drilling at the LNG jetty predicted that sound levels capable of causing sensory disturbance to marine mammals under NOAA's interim thresholds for non-impulsive sources (i.e., 120 dB re 1  $\mu$ Pa rms) would be exceeded over a distance of 3.9 km (see the Aurora LNG Acoustic Study: Modelling of Underwater Sounds from Pile Driving, Rock Socket Drilling, and LNG Carrier Berthing and Transiting, Appendix P).

Use of species-specific behavioural disturbance thresholds resulted in predictions for potential behavioural changes over much smaller distances for most species (i.e., subtle responses for killer whales at 500 m, overt responses at 100 m; 1.4 km for harbour seal; 1.7 km for harbour porpoise; and 3.6 km for humpback whale). This is likely the result of a large portion of sound from rock socket drilling falling within the lower end of the frequency range (i.e., making it more audible to baleen whales [low-frequency-cetaceans] such as humpback whales). Sound levels from rock socket drilling were predicted to drop below audibility for all species of marine mammal at distances of 23 km.

While modelling of rock socket drilling at the MOF was not undertaken, results are expected to be broadly comparable, although extents to thresholds may be somewhat larger at the MOF than at the LNG jetty (based on comparison of predicted extents for impact pile driving).

##### DURATION

For every 40 minutes of impact pile driving at the LNG jetty (i.e., the length of time required to install one pile), there will be approximately 10 hours of rock socket drilling. Since 293 piles will be required to support the access trestle, berths and breasting/mooring dolphins, this will up to require 2,930 hours (i.e., 122 days) of rock socket drilling over a period of 23.5 months (assuming only one pile is installed at a time). Acoustic modelling was based on a scenario involving four instances of rock socket pile

## Aurora LNG

Environmental Assessment Certificate Application

Section 4.10: Marine Mammals

---

installations of 60-inch steel pipe piles (two drill rigs at the northern berth and two at the southern berth). This scenario produces the maximal theoretical sound levels (and maximal extents for threshold exceedances and zones of audibility) but reduces the duration of potential exposure by a factor of four. Under this full production scenario (four drill rigs active at once) noise from rock socket drilling would be introduced into the marine environment for approximately 733 hours (31 days) across two years.

Details concerning the amount of rock socket drilling that would be required at the MOF were not available at the time of assessment. Assuming similar durations to those expected at the LNG jetty (i.e., 10 hours per pile), rock socket drilling under the pile-and-deck design would introduce up to a maximum of 4,960 hours of noise (i.e., 207 days) at the MOF over a period of 8.5 months (assuming only one pile is installed at a time). Under the full production scenario (i.e., 8 simultaneous piles) it would take approximately 620 hours (26 days) spread out over 8.5 months.

### SUMMARY OF RESIDUAL EFFECT FROM ROCK SOCKET DRILLING

Industry does not normally use mitigation measures for rock socket drilling and no additional mitigation measures have been recommended for this Project. Effects of change in behaviour resulting from rock socket drilling are expected to be of moderate magnitude, as marine mammals within 4 km of rock socket drilling may still experience behavioural disturbance (under the assumption of four concurrent drill rigs). Residual effects from this activity will occur within the LAA, as multiple irregular events over the medium-term, and is likely to be reversible for completion of marine construction. This effect will occur in a disturbed area of active human development and will combine with other marine construction activities for an overall residual effect of change in behaviour on marine mammals during the construction phase.

### *MARINE CONSTRUCTION (IMPACT PILE DRIVING)*

#### TIMING

Impact pile driving will occur during the construction phase, commencing with building of the pioneer facility. Timing windows for marine fish will not be applied to pile installation; therefore, it is anticipated that this activity could occur during any month of the year, and will therefore overlap with marine mammal presence in the waters surrounding the MOF, LNG jetty, or pioneer facility.

#### INTENSITY AND EXTENT

Results of acoustic modelling conducted for the Project suggest that sound from pile driving will decrease to below 160 dB re 1  $\mu$ Pa rms SPL (NOAA's interim threshold for sensory disturbance from an impulsive source) at distances greater than approximately 5.9 km at the MOF, and 3.0 km at the LNG jetty (see the Aurora LNG Acoustic Study: Modelling of Underwater Sounds from Pile Driving, Rock Socket Drilling, and LNG Carrier Berthing and Transiting, Appendix P).

Extents to species-specific behavioural disturbance thresholds varied dramatically by species. Behavioural change was predicted over the smallest linear scale for killer whales (i.e., subtle responses: 2.9 km at the LNG jetty and 5.5 km at the MOF; overt responses: 1.1 km at the LNG jetty and 2.1 km at the MOF). Humpback whales saw the highest predicted extents of behavioural disturbance (22.6 and 25.5 km at the LNG jetty and MOF, respectively), alongside harbour seals (22.5 and 21.3 km). Harbour

porpoises fell in the middle with predicted exceedance of behavioural change thresholds over a distance of 20.9 km at the LNG jetty and 10.5 km at the MOF. It is important to note that while linear extents of potential behavioural disturbance are for the most part predicted to be greater at the MOF, sound propagation is restricted along a relatively narrow north and south trajectory because of Casey Cove's location in a confined channel. In contrast, areal extents of potential behavioural disturbance are expected to be higher during marine construction of the LNG jetty, where sound can propagate in a less restricted fashion southward through Chatham Sound to Porcher Island (see modelled sound field figures in Appendix B of the Aurora LNG Acoustic Study: Modelling of Underwater Sounds from Pile Driving, Rock Socket Drilling, and LNG Carrier Berthing and Transiting, Appendix P).

DFO's recommended 160 dB re 1  $\mu$ Pa threshold for exclusion zones is based on the NOAA interim rms threshold for behavioural disturbance (not injury), it is therefore assumed that enforcement of this sized exclusion zone would also be effective at reducing the risk of marine mammals experiencing TTS during impact pile driving.

Audibility of sounds from impact pile driving did not differ substantially from rock socket drilling and sound levels were predicted to drop below audibility for all species of marine mammal at distances of 23 km from the LNG jetty and 28 km from the MOF.

#### DURATION

The predicted duration of exposure to underwater noise from impact pile driving will be the same as discussed under the assessment of change in health (see Section 4.10.5.2).

#### SUMMARY OF RESIDUAL EFFECT FROM IMPACT PILE DRIVING

Residual effects of change in behaviour resulting from impact driving of multiple simultaneous piles are expected to be of high magnitude, as the thresholds considered predicted a broad range of values depending on the location and species of interest. At the LNG jetty, the extent over which marine mammals were predicted to exhibit a potential change in behaviour ranged from 1.1 km for killer whales to 22.6 km for humpback whales. At the MOF, thresholds for behavioural change were exceeded at distances of 2.1 to 25.5 km. Residual effects from this activity will extend into the LAA as multiple irregular events over the medium-term. While effects on marine mammals are expected to be reversible following completion of marine construction, and potentially between activities, it is noted that return to pre-Project conditions may be delayed by a few months to a few years. This result would be particularly true for any marine mammal species that abandons the area of behavioural disturbance during the marine construction period. This effect will occur in a disturbed area of active human development and will combine with other marine construction activities for an overall residual effect of change in behaviour on marine mammals during the construction phase.

## Aurora LNG

Environmental Assessment Certificate Application

Section 4.10: Marine Mammals

---

### *LNG SHIPPING (AND SUPPORT VESSEL TRAFFIC DURING ALL PHASES)*

#### TIMING

Approximately 160 to 320 LNG carriers (up to Q-flex size) will call on the LNG jetty annually (i.e., up to 640 transits of the RAA or an additional ship passage every 14 hours on average).

#### INTENSITY AND EXTENT

Approximately 160 to 320 LNG carriers will call on the LNG jetty annually (i.e., up to 640 transits of the RAA). The Project will therefore contribute an additional 1 – 2 LNG carriers per day to current marine traffic levels in the RAA. Based on the results of underwater acoustic modelling (see the Aurora LNG Acoustic Study: Modelling of Underwater Sounds from Pile Driving, Rock Socket Drilling, and LNG Carrier Berthing and Transiting, Appendix P), sound levels are predicted to decrease to below 120 dB re 1  $\mu$ Pa rms SPL (NOAA's interim threshold for sensory disturbance from a continuous source) at distances greater than approximately 9.6 km from the vessels during berthing. Predicted exceedance of species-specific behavioural disturbance thresholds during berthing events were: 4.2 km for harbour seals, 4.6 to 7.7 km for killer whales (overt and subtle responses, respectively), 11.1 km for humpback whales, and 22.5 km for harbour porpoises.

Maximum vessel speeds for transit scenarios were modelled and the two transit locations modelled (i.e., in south Chatham Sound and near the Triple Island pilot station) included source levels from two escort tugs that are no longer proposed to be transiting through these areas. Predicted values are therefore regarded as overestimates. The NOAA behavioural disturbance threshold under these conditions was exceeded at distances of 12.6 to 15.0 km (Triple Island vs. Chatham Sound) from the vessel. Species-specific behavioural disturbance threshold exceedance distances from the vessel were lower than the NOAA thresholds, extending between 5.6 and 9.6 km for killer whales and up to 10.4 km for harbour seals. The humpback whale and harbour porpoise-specific thresholds extended farther, up to 27.2 km and 43.9 km, respectively.

Erbe (2002) predicted (using a few different TTS levels) that whale watching boats could cause a TTS in killer whales, although these predicted TTS exposures are not directly comparable to Project-related vessels. The whale watching boats could cause a TTS of 12-18 dB in killer whales if the whales spent 30-50 min within 10 m range and depth, or TTS of 5 dB if the whales spent 30-50 min within 450 m. The most conservative metric predicted a TTS of 4.8 dB if the killer whales stayed within 1 km of the boat for 20 min. Whale watching vessels move faster (i.e., 22-32 kts; 40-60 km/h), and generally produce higher frequency sounds (more audible to killer whales) relative to LNG carriers; although their source levels are generally lower (e.g., 145 – 169 dB re 1 $\mu$ Pa @ 1m for whale-watching boats versus 186 dB re 1 $\mu$ Pa @ 1m for LNG carriers during transit). Perhaps more important, however, is the behaviour of the vessels. Whale watching vessels follow killer whales (making occurrence of killer whales within distances and durations capable of causing TTS quite possible), whereas LNG carriers will be transiting through the area. Therefore, while it is feasible for a marine mammal to be tracking nearby and alongside a Project-related vessel for an extended time, this is considered a relatively uncommon scenario at the predicted vessel speeds; TTS during Project operations is therefore considered unlikely.

Communication masking, or reduction in communication space, may also result from underwater noise during Project-related shipping. Based on underwater noise sampling conducted in 2008 near Triple Island, Williams et al. (2013) found that during median ambient deployment noise conditions, fin whales currently experience 50-75% of the communication space that is available under median quietest deployment noise conditions, humpback whales experience 25-50%, and killer whales experience 0-25%. Harbour porpoise have also been reported to experience changes in hearing range as a result of shipping noise (Hermannsen et al. 2014).

The zones of audibility ( $R_{max}$ ,  $R_{95\%}$  not calculated) for all marine mammal species extended over 39 km during berthing and 65 km during transit. Beyond these distances sound from Project-related vessels are no longer perceptible to marine mammals.

### DURATION

The Project is anticipating a minimum 25 year operating life. It is anticipated that LNG carriers will typically be at berth for approximately 24 hours. The shipping route is approximately 51 km (28 nautical miles) between the LNG jetty and the Triple Island pilot station. Travelling at the maximum speeds of 16 kts between the pilot station and the PRPA boundary (~37.4 km), and then at 12 kts (22 km/hr) to Coast Island (~9.2 km), and 6 kts (11 km/hr) to the LNG jetty (~4.5 km), it would take an LNG carrier approximately 2.1 h to cover this distance. At more average expected speeds (12, 10, and 6 kts, respectively), the duration of one-way transit would increase by 0.5 hours.

In predicting sound levels produced during LNG carrier transit, it was assumed that while in the RAA, vessels will travel at the proposed upper-end LNG carrier transit speed of 16 kts (30 km/hr) and be accompanied by two escort tugs. From an acoustics perspective, this assumption produces conservative estimates of potential exposure to underwater noise levels (i.e., sound levels generally increase with vessel speed and LNG carriers will not be accompanied by tugs until they reach the PRPA boundary). While duration of LNG carrier 'time in the RAA' increases slightly under the average scenario, underwater sound levels would be reduced, as would the extent of sound levels above behavioural disturbance thresholds. Because of this, the average duration of potential behavioural disturbance and magnitude of the effect are expected to be lower than the values that were predicted by the modelling.

While transiting through south Chatham Sound, sound levels exceeding 120 dB rms will extend 15 km on all sides of the vessel. At any given location along the shipping lane, a stationary marine mammal may hypothetically be exposed to the 'bubble of sound' around the vessel for a period of up to one hour (i.e., the time it takes for a vessel travelling at 30 km/hr to cover 30 km). At these speeds, it is unlikely that an individual marine mammal will encounter the same LNG carrier more than once in a given day. However, based on the predicted timing, a marine mammal may encounter a second Project-related LNG carrier, increasing its potential maximum exposure duration (to Project-related vessels) to roughly two hours in every 24-hour period.

Such hypothetical examples are more challenging for the berthing scenario, where the vessels are closer to stationary, and the timing and duration of berthing events are less predictable. For the purposes of the assessment it is assumed that marine mammals within 10 km of the LNG jetty during operations may be exposed to sound levels from berthing capable of causing behavioural disruption (under the NOAA criteria).

### SUMMARY OF RESIDUAL EFFECT FROM LNG SHIPPING AND SUPPORT VESSEL TRAFFIC

Residual effects of change in behaviour from LNG shipping are expected to be of moderate magnitude and occur throughout the RAA as multiple irregular events. While effects on marine mammals are expected to be reversible following passage of a vessel, it is noted that (in consideration of Project-related vessels alone) this effect will be recurrent 1 – 2 times daily for 25 years. Residual effects are therefore considered to be long-term to permanent (particularly for local populations) relative to the range of average lifespans of marine mammals present in the RAA. This effect will occur in a disturbed area of active human development (e.g., port-related development and activity).

#### *DISMANTLING OF MARINE INFRASTRUCTURE*

Potential marine mammal behavioural changes due to underwater noise produced during decommissioning, including the dismantling of marine based infrastructure and any associated vessel traffic, are expected to be similar in manner to the predicted residual effects for the construction and operations phases, although they are likely to be of a lesser scale. Effects of change in behaviour during this phase of the Project are expected to be of moderate magnitude, occur as multiple irregular events over the short-term in the LAA, and be reversible. This effect will occur in a disturbed area of active human development.

#### *SUMMARY*

With mitigation, the Project will result in moderate to high magnitude residual effects within the RAA, depending on Project phase (some individual activities will result in low magnitude effects). This change in behaviour will occur as multiple irregular events during all phases. This effect is anticipated to be reversible after activity completion; however, changes to existing conditions may be considered long-term to permanent over the life of the Project and relative to the range of average lifespans of marine mammals present in the RAA.

#### *LIKELIHOOD OF RESIDUAL EFFECTS FOR CHANGE IN BEHAVIOUR*

With currently modelled mitigation measures, the Project is predicted to result in an increase in underwater noise above the US NOAA behavioural disruption thresholds over a distance of up to 6 km from the MOF and 3 km from the LNG jetty during the marine construction phase (impact pile driving). The size of the exclusion zone will be confirmed during consultation with DFO and alternative/additional observation methods and mitigation measures may be considered as needed. . During operations, Project-related underwater noise capable of causing behavioural change in marine mammals will extend up to 10 km from the LNG jetty (during berthing events), and 15 km from LNG carriers transiting through the RAA. It is not currently possible to predict the exact nature of a marine mammal's potential change in behaviour in response to underwater noise (Richardson et al. 1995; Wartzok et al. 2003; Ellison et al. 2012). While in some circumstances, some sensitive species such as harbour porpoise may exhibit avoidance responses over large areas (e.g., Brandt et al. 2011), other species in other circumstances may carry on with their previous activity (e.g., Koski et al. 2008). Based on current shipping and development levels in the RAA and the continued presence of marine mammals, it is considered unlikely that all of the assessed Project activities, across all phases, will lead to habitat displacement

(i.e., avoidance) by all marine mammal species over the geographic scale of predicted disturbance extents, although other potential changes in behaviour may occur. At a minimum, increases in underwater noise during the construction and operations phases will add to the current levels of communication masking that already exist for marine mammals occurring in the RAA. Sensitive species such as harbour porpoises may also exhibit more overt responses (such as avoidance) during impulsive marine construction activities such as blasting and impact pile driving. The likelihood of residual effects of change in behaviour on marine mammals is considered high for both the construction and operations phases and medium during decommissioning.

#### **4.10.5.4 Assessment of Change in Mortality Risk**

##### ***PROJECT MECHANISMS FOR CHANGE IN MORTALITY RISK***

Project components and physical activities have the potential to result in changes to marine mammal mortality risk due to increases in Project-related vessel traffic during construction, operations, and decommissioning (as identified in Table 4.10-7). The change in mortality risk effect is assessed by describing the estimated change in likelihood (qualitative) of mortality or injury to marine mammals resulting from Project-related increases in marine traffic (i.e., increased potential for vessel strike).

##### ***LNG SHIPPING (AND SUPPORT VESSEL TRAFFIC DURING ALL PHASES)***

Vessel strikes have been identified as a leading cause of marine mammal mortality worldwide, particularly in areas of heavy commercial traffic (e.g., Laist et al. 2001; Jensen and Silber 2003; Panigada et al. 2006; Van Waerebeek et al. 2007; Carrillo and Ritter 2010; Neilson et al. 2012; Guzman et al. 2013). During operations, the Project will require up to 320 LNG carrier visits (i.e., 640 transits of the RAA) each year. LNG carriers will transit through Chatham Sound within designated shipping zones, guided by a BC marine pilot. Designation of shipping zones and vessel speeds is at the discretion of Transport Canada and, within the port boundaries, PRPA. The proposed upper-end LNG carrier transit speed within the RAA is 16 kts (30 km/hr) and the proposed speed while approaching the jetty is 6 kts (11 km/hr).

Project-related marine vessel traffic during construction and decommissioning will generally involve slower and smaller-sized vessels such as barges, which will travel at maximum speeds of approximately 12 kts (22 km/hr). Crew boats ferrying workers may travel at speeds of greater than 20 kts (37 km/hr). While all classes, sizes, and speeds of vessel can and have struck marine mammals (e.g., Ritter 2012), ship strikes are more likely to occur when ships are over 80 m in length and travelling at 14 kts or faster (Laist et al. 2001; Panigada et al. 2006). Potential for change in mortality risk is therefore considered greatest during transit operations (relative to other Project phases and vessel types); therefore, strikes involving transiting LNG carriers form the focus of the effects assessment.

While strike risk is considered greatest for the larger whale species in the RAA (i.e., fin, humpback, grey, and minke whales), smaller cetaceans (e.g., killer whales) are occasionally struck by vessels (Van Waerebeek et al. 2007; Williams and O'Hara 2009; Dwyer et al. 2014). Most injuries resulting from vessel strikes relate to either blunt force trauma or propeller lacerations; both can be fatal immediately or later, through secondary infections and internal injury.

***MITIGATION FOR CHANGE IN MORTALITY RISK***

Table 4.10-10 identifies mitigation measures that will be implemented during the construction, operations, and decommissioning phases to reduce potential changes in marine mammal mortality from increased risk of vessel strikes.

The Technical Review Process of Marine Terminal Systems and Transshipment Sites (TERMPOL) process, conducted by Transport Canada, will address vessel speeds and routing, in consideration of mariner safety, environmental effects and feedback through consultation with PRPA, DFO, Aboriginal Groups, and others. Project-related vessels will proceed at a safe speed and respect any regionally-defined or PRPA-specific speed profiles that are applicable at the time of operations, subject to navigational safety. Aurora LNG is willing to collaborate in regional programs planned and developed by government and in conjunction with other proponents, regarding regional management of effects of vessel strikes on marine mammals in the RAA.

**Table 4.10-10 Mitigation Measures Proposed to Avoid or Reduce Change in Mortality Risk for Marine Mammals**

Mitigation No.	Mitigation/Mitigation Mechanism	Rationale for Selection	Expected Success/Risks and Uncertainty	Timing	Management and/or Compensation Plans
4.10.3	<p><u>Mitigation:</u> Aurora LNG will develop educational material that will be distributed to Project-related vessel operators, tug operators, and pilots to inform them of the species of marine mammals in the area, their conservation status, the risk of ship strikes and what mariners can do to help reduce those risks (e.g., reporting the sightings to other mariners, reducing speeds). Educational material will also detail reporting protocols in the event of an accidental strike.</p> <p><u>Mitigation Mechanism:</u> Communication of risks and increasing awareness of all Project-related vessel operators is one of the first steps in reducing risk. In the event of a Project-related marine mammal vessel strike, detailed observations will be recorded and reported immediately to the Marine Mammal Response Network through DFO's 'Observe, Record, and Report 24-hour hotline' (DFO 2013). This program works with partners to track and respond to marine mammal entanglements, strandings, vessel strikes, and other concerns.</p>	<p>Section 32(1) of SARA prohibits harm to any endangered or threatened wildlife species (including marine mammals).</p> <p>Section 35 of the <i>Fisheries Act</i> prohibits serious harm to fish (including marine mammals) that are part of, or support, a commercial, recreational, and Aboriginal (CRA) fishery.</p> <p>Marine mammals in the RAA have traditional, cultural, ecological, and recreational (including economic) importance.</p>	<p><u>Expected Success:</u> There is a moderate likelihood of success. Raising awareness may result in more conscientious operation of vessels when travelling through waters with known concentrations of marine mammals.</p> <p><u>Risk and Uncertainty:</u> Education does not guarantee that vessel operators will take heed of the information provided.</p>	<p><u>Project Phase:</u> Construction Operations Decommissioning</p> <p><u>Effectiveness:</u> Mitigation measure is expected to increase in effectiveness over time, as understanding of potential effects and possible means of reducing risk grows across the marine community.</p>	<p>Marine and Freshwater Resources Management Plan</p>

**This page intentionally left blank.**

## ***CHARACTERIZATION OF RESIDUAL EFFECTS FOR CHANGE IN MORTALITY RISK***

### ***LNG SHIPPING (AND SUPPORT VESSEL TRAFFIC DURING ALL PHASES)***

#### **TIMING**

Approximately 160 to 320 LNG carriers (up to Q-flex size) will call on the LNG jetty annually (i.e., up to 640 transits of the RAA or an additional ship passage every 14 hours on average). Details concerning the exact nature and number of support vessels involved in construction or decommissioning are not known at this time.

#### **INTENSITY**

Through a number of historical assessments and modelling studies, the statistical probability of a marine mammal vessel strike, and its lethality, have been positively correlated with a vessel's speed. Laist et al. (2001) looked at historical records of motorized ship collisions with large whales and concluded that serious injuries to whales are infrequent at vessel speeds <14 kts and rare at speeds <10 kts. Based on data collected for North Atlantic right whales, Kite-Powell et al. (2007) determined that large vessels on a collision course with a whale had a 50% chance of striking it when travelling at 25 kts, and that this was reduced to 30% at 10 kts. Vanderlaan and Taggart (2007) mathematically modelled the probability of severe or lethal injury to large whales based on historical records from 1885 to 2002. In their model, strikes were predicted to be lethal in 92% of cases where vessels travelled at speeds over 18 kts, and from there, probability of lethality decreased with speed, from 78% at 15 kts, to 61% at 13 kts, 31% at 10 kts, and <12% at 7 kts and below (Vanderlaan and Taggart 2007). Conn and Silber (2013) found similar results when examining the effectiveness of mandatory vessel speed restrictions to reduce ship strikes with North Atlantic right whales in US waters. They estimated that vessel speed restrictions of 10 kts or less in seasonal management areas reduced total ship strike mortality risk by 80-90%. While most research has focused on ship strikes involving large vessels, potential marine mammal changes in mortality risk due to increased levels of support vessel traffic are expected to be similar in manner to LNG shipping; however, the relative risks are likely to be of a lesser scale, due to the generally smaller size and speed of the vessels involved.

#### **EXTENT**

The marine access route for LNG carriers will start west of the Triple Island pilot station (where a BC marine pilot from the Pacific Pilotage Authority will board the vessel), and head east through Hecate Strait. The vessel will then turn southeast, travelling through Chatham Sound and passing to the south of East Kinahan Island before turning north and circling the south end of Digby Island to reach the LNG jetty (see Figure 4.10-1 for place names). The potential for vessel strikes exists anywhere along this route.

## DURATION

The Project is anticipating a minimum 25 year operating life, with LNG carriers operating daily over this period. The Project contribution to increased marine mammal strike risk in the LAA will therefore be in effect throughout this period, as well as during the construction and decommissioning phases. While marine mammals may recover from a strike, the duration of effects on an individual marine mammal resulting from an accidental strike are considered permanent.

## SUMMARY OF RESIDUAL EFFECT FROM LNG SHIPPING AND SUPPORT VESSEL TRAFFIC

Project-related marine mammal vessel strikes and resulting injuries or mortalities are not expected to be a routine occurrence. Project-related vessels will proceed at a safe speed and respect any regionally-defined or PRPA-specific speed profiles that are applicable at the time of operations, subject to navigational safety. The increase in vessel traffic of up to 640 LNG carrier transits annually in the RAA for 25 years will, however, increase marine mammal mortality risk in the RAA. Therefore, residual effects of change in mortality risk from LNG shipping (and to a lesser degree support vessel traffic) are expected to be of moderate magnitude. In the event of an accidental vessel strike, effects on the marine mammal involved are assumed to be permanent and irreversible. This effect will occur in a disturbed area of active human development (e.g., port-related development and activity) where strike risk to marine mammals already exists (see also assessment of cumulative effects in Section 4.10.6.5).

### *SUMMARY*

The Project will result in moderate magnitude residual effects within the LAA. This change in mortality risk will occur as single events during all Project phases and is considered permanent over the average lifespan of potentially affected species. This effect is anticipated to be irreversible.

### ***LIKELIHOOD OF RESIDUAL EFFECTS FOR CHANGE IN MORTALITY RISK***

Mortality risk from vessel strikes increases in areas of higher shipping density (Williams and O'Hara 2010) and the Project will contribute to an overall increase in the relative risk of a marine mammal vessel strike occurring within the RAA (see also assessment of cumulative effects in Section 4.10.6.5). While vessel strikes are considered to be accidental events that are rare for any given vessel passage, over the life of the Project, the likelihood of change in mortality risk to marine mammals is considered medium. The likelihood is expected to be lower during the construction and decommissioning phases than during operations.

#### **4.10.5.5 Summary of Project Residual Effects on Marine Mammals**

The Project residual effects on marine mammals are summarized in Table 4.10-11.

**Table 4.10-11 Summary of Project Residual Effects on Marine Mammals**

Project Phase	Residual Effects Characterization						Likelihood
	Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Context	
<b>Change in Health</b>							
Construction	M	LAA	MI	MT	R	D	Low
Operations	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Decommissioning	M	LAA	MI	ST	R	D	Low
<b>Change in Behaviour</b>							
Construction	H	LAA	MI	MT	R	D	High
Operations	M	RAA	MI	LT-P	R	D	High
Decommissioning	M	LAA	MI	ST	R	D	Medium
<b>Change in Mortality Risk</b>							
Construction	M	LAA	S	P	I	D	Low
Operations	M	LAA	S	P	I	D	Medium
Decommissioning	M	LAA	S	P	I	D	Low

**KEY**

See Table 4.10-4 for detailed definitions

N/A: Not applicable

**MAGNITUDE:**

N: Negligible  
L: Low  
M: Moderate  
H: High

**GEOGRAPHIC EXTENT:**

PDA: Project development area  
LAA: Local assessment area  
RAA: Regional assessment area

**FREQUENCY:**

S: Single event  
MI: Multiple irregular events  
MR: Multiple regular events  
C: Continuous

**DURATION:**

ST: Short-term  
MT: Medium-term  
LT: Long-term  
P: Permanent

**REVERSIBILITY:**

R: Reversible  
I: Irreversible

**CONTEXT:**

U: Undisturbed  
D: Disturbed

The combined residual effects of the Project on marine mammals will be moderate to high in magnitude, depending on the Project phase (i.e., high magnitude effects are only expected during construction), and occur in the RAA as multiple irregular events, that are considered to be long-term to permanent (particularly for local populations). Effects on marine mammals will be primarily reversible in nature although it remains possible that a small unknown number of individual marine mammals experiences irreversible effects (e.g., in the event of an accidental vessel strike) and permanent changes (exceeding existing conditions and relative to the life of an individual) are also possible. Combined residual effects of the Project will occur in an already disturbed area of active human development that is expecting to see

## **Aurora LNG**

Environmental Assessment Certificate Application

Section 4.10: Marine Mammals

---

additional future development with or without Project contributions. The likelihood of a combined residual effect of the Project on marine mammals is considered high.

Residual Project effects on species listed on Schedule 1 of SARA from construction and operations of the LNG facility are summarized in Table 4.10-12. Section 79(2) of SARA requires that adverse effects of a proposed project on any species listed in Schedule 1 be assessed, and for measures to be taken to avoid or lessen those effects, and to monitor them. Identified measures must be consistent with any recovery strategies or action plans in place for the species. Four of the eight SARA-listed species have proposed or final recovery strategies or action plans in place (see Table 4.10-12). The proposed Project mitigation measures are consistent with information provided in these documents. The remaining four species are listed as special concern, a status for which recovery strategies and action plans are not developed.

**Table 4.10-12 Species Listed on Schedule 1 of SARA Known or Potentially Occurring in the Regional Assessment Area**

Common Name	SARA - Schedule 1 Status	Species Habitat Requirements	Potential Seasonal Occurrence	Habitat Present in PDA	Habitat Present in RAA	Potential Project Effects			Mitigation Measures	Accordance with Recovery Strategy and/or Action Plan
						Change in Health	Change in Behaviour	Change in Mortality Risk		
Fin whale	Threatened	Open ocean and coastal waters	Year-round	No	Yes	No	Yes	Yes	4.10.1 4.10.2 4.10.3	Mitigation measures are consistent with [Proposed] Partial Action Plan for Blue, Fin, Sei and North Pacific Right Whales ( <i>Balaenoptera musculus</i> , <i>B. physalus</i> , <i>B. borealis</i> , and <i>Eubalaena japonica</i> ) in Canadian Pacific Waters (DFO 2016) and Recovery Strategy for Blue, Fin, and Sei Whales ( <i>Balaenoptera musculus</i> , <i>B. physalus</i> , and <i>B. borealis</i> ) in Pacific Canadian Waters (Gregr et al. 2006).
Grey whale	Special concern	Open ocean and coastal waters	Year-round	No	Yes	No	Yes	Yes	4.10.1 4.10.2 4.10.3	No Recovery Strategy or Action Plan exists for this species since it is listed as special concern. Mitigation measures (see previous column) are expected to address any residual effects.
Humpback whale	Threatened	Open ocean and coastal waters	Year-round	Yes	Yes	Yes	Yes	Yes	4.10.1 4.10.2 4.10.3	No action plan exists for this species. Mitigation measures are consistent with Recovery Strategy for the North Pacific Humpback Whale ( <i>Megaptera novaeangliae</i> ) in Canada (DFO 2013).
Harbour porpoise	Special concern	Open ocean and coastal waters	Year-round	Yes	Yes	Yes	Yes	Yes	4.10.1 4.10.2 4.10.3	No recovery strategy or action plan exists for this species since it is listed as special concern. Mitigation measures (see previous column) are expected to address any residual effects.
Bigg's (transient) killer whale	Threatened	Open ocean and coastal waters	Year-round	Yes	Yes	Yes	Yes	Yes	4.10.1 4.10.2 4.10.3	No action plan exists for this species. Mitigation measures are consistent with Recovery Strategy for the Transient Killer Whale ( <i>Orcinus orca</i> ) in Canada (DFO 2007).
Northern resident killer whale	Threatened	Open ocean and coastal waters	Year-round	Yes	Yes	Yes	Yes	Yes	4.10.1 4.10.2 4.10.3	Mitigation measures are consistent with Recovery Strategy for the Northern and Southern Resident Killer Whales ( <i>Orcinus orca</i> ) in Canada (DFO 2011) and the Action Plan for the Northern and Southern Resident Killer Whale ( <i>Orcinus orca</i> ) in Canada (DFO 2016).
Steller sea lion	Special concern	Open ocean and coastal waters	Year-round	Yes	Yes	Yes	Yes	Yes	4.10.1 4.10.2 4.10.3	No recovery strategy or action plan exists for this species since it is listed as special concern. Mitigation measures (see previous column) are expected to address any residual effects.
Sea otter	Special concern	Coastal waters	Year-round	No	Yes	No	Yes	No	4.10.1 4.10.2	No recovery strategy or action plan exists for this species since it is listed as special concern. Mitigation measures (see previous column) are expected to address any residual effects.

**This page intentionally left blank.**

#### **4.10.6 Assessment of Cumulative Effects on Marine Mammals**

In accordance with the AIR, an assessment of cumulative effects on marine mammals was undertaken as the following two conditions were met:

- The proposed Project is assessed as having residual effects on the VC
- The residual effects could act cumulatively with residual effects of other past, present, or reasonably foreseeable future physical activities.

The Project residual effects described in Section 4.10.5 that are likely to interact cumulatively with residual effects of past, present, or reasonably foreseeable projects and physical activities are identified in this section and the resulting cumulative effects are assessed. This is followed by an analysis of the Project contribution to residual cumulative effects.

##### **4.10.6.1 Project Residual Effects Likely to Interact Cumulatively**

The Project residual effects likely to act cumulatively with other past, present, or reasonably foreseeable projects and physical activities on marine mammals are listed in Table 4.10-13. Where residual effects from the Project act cumulatively with those from other projects and physical activities (see Table 4.10-13), a cumulative effects assessment is undertaken to determine their significance. Where “-” is indicated, a cumulative effect is not expected for marine mammals, or effects from those projects and physical activities fall outside of the RAA and are not discussed further. For a description of the projects and activities listed in Table 4.10-13 see Table 3-4. Predicted numbers of large vessels associated with these activities are presented in Table 6.5-17 (Marine Use and Navigable Waters).

**Aurora LNG**

Environmental Assessment Certificate Application

Section 4.10: Marine Mammals

**Table 4.10-13 Potential Cumulative Effects on Marine Mammals**

Past, Present, and Reasonably Foreseeable Future Projects and Physical Activities with Potential for Cumulative Effects <sup>1</sup>	Potential Cumulative Effects		
	Change in Health	Change in Behaviour	Change in Mortality Risk
<b>Past and Present Projects and Physical Activities</b>			
Fairview Container Terminal Phase I and Phase II Northern Portion	-	✓	✓
Pacific Northern Gas Pipeline	-	-	-
Odin Seafood	-	-	-
Prince Rupert Ferry Terminal	-	✓	✓
Prince Rupert Industrial Park	-	-	-
Prince Rupert Grain Terminal	-	✓	✓
Prince Rupert Airport	-	-	-
Ridley Island Log Sort	-	-	-
Ridley Terminals	-	✓	✓
Atlin Terminal	-	✓	✓
Northland Cruise Terminal	-	✓	✓
Pinnacle Pellet	-	✓	✓
Northwest Transmission Line	-	-	-
Rio Tinto Aluminum	-	✓	✓
Cruise Shipping	-	✓	✓
Forestry Activities	-	-	-
Fishing and Aquaculture Activities	-	✓	✓
Rail	-	-	-
<b>Future Project and Physical Activities</b>			
Pacific NorthWest LNG Project	✓	✓	✓
Prince Rupert LNG Project	✓	✓	✓
LNG Canada Export Terminal Project	-	✓	✓
Douglas Channel LNG Project/BC LNG Project*	✓	✓	✓
Kitimat LNG Terminal Project	-	✓	✓
Enbridge Northern Gateway Project	-	✓	✓
Watson Island Industrial Site Redevelopment/Seaport Terminal**	✓	✓	✓
Fairview Container Terminal Expansion Phase II	✓	✓	✓
Ridley Coal Terminal Expansion	-	✓	✓
Canpotex Potash Export Terminal*	✓	✓	✓
Westcoast Connector Gas Transmission	✓	✓	✓

**Table 4.10-13 Potential Cumulative Effects on Marine Mammals**

<b>Past, Present, and Reasonably Foreseeable Future Projects and Physical Activities with Potential for Cumulative Effects<sup>1</sup></b>	<b>Potential Cumulative Effects</b>		
	<b>Change in Health</b>	<b>Change in Behaviour</b>	<b>Change in Mortality Risk</b>
Prince Rupert Gas Transmission Project	✓	✓	✓
Kinskuch Hydro Project	-	-	-
Ridley Island Road, Rail and Utility Corridor***	-	-	-
Smith Island Quarry Project	-	✓	✓
Grassy Point LNG (Woodside)	✓	✓	✓
WCC LNG Export Facility	✓	✓	✓

**NOTES:**

- <sup>1</sup> Table 3-4 in Assessment Methods (see Section 3.0) provides a description of each project.
- ✓ Other past, present, and reasonably foreseeable future projects and physical activities in the RAA whose residual effects are likely to act cumulatively with Project residual effects.
- Projects that occur in the RAA; however, interactions between the Project residual effects and residual effects of other past, present, and reasonably future projects and physical activities in the RAA are not expected.
- \* The status of this project was revised to halted following write-up of this Application; as such, the project was included in the assessment. This makes the assessment more conservative.
- \*\* The physical activities listed here are shown as future; however, the activities occur on existing cleared areas for a facility that was in operation from 1957 to 2001.
- \*\*\* At the time of modelling and assessment, this was considered a future project; however, this project has now completed construction.

As of September 27 2016, the LNG facilities identified in Table 4.10-13 that have received federal and provincial approval are the PNW LNG Project, the LNG Canada Export Terminal Project and the Kitimat LNG Terminal Project, but none have made an affirmative final investment decision; the owner's formal approval to proceed to construction. Considering that construction of LNG facilities requires substantial capital investment, and due to the competitive nature of the LNG industry, with each new facility affecting the global supply/demand balance, it is unlikely that all of the LNG facilities identified in Table 4.10-13 will be built. Therefore, the cumulative effects case, in which all reasonably foreseeable projects are considered, is highly conservative.

**4.10.6.2 Project Contribution to Cumulative Effects**

The Project will contribute underwater noise and increased marine vessel traffic that will act cumulatively with noise and traffic levels expected from other past, present and reasonably foreseeable future projects and activities in the RAA. Cumulative residual effects will occur around a busy port, and marine mammals in this area are already subject to high traffic volumes and noise levels that are known to already exceed behavioural disturbance thresholds during a small portion of the day (see the Prince Rupert – Aurora LNG Acoustic Monitoring Study, Appendix O).

#### **4.10.6.3 Cumulative Effects Assessment for Change in Health**

The following sections describe the potential cumulative effects of marine mammal change in health resulting from residual effects of the Project acting cumulatively with past, present and reasonably foreseeable projects and activities in the RAA.

##### ***CUMULATIVE EFFECTS MECHANISMS***

Potential cumulative effects of marine mammal change in health may result from the introduction and overlap of high source levels of underwater noise from residual effects of the Project and residual effects of other projects and activities identified in Table 4.10-13. Sources of underwater noise at levels capable of causing auditory injury are primarily expected during marine construction activities (and secondarily during decommissioning), particularly from those activities that involve impulsive noise sources such as in-water blasting and impact pile driving. Residual effects of change in health were not predicted for the operations phase and thus these activities are not carried forward into the assessment of cumulative effects. None of the projects for which '-' was identified in Table 4.10-13 are expected to contribute underwater noise of intensities sufficient to cause a cumulative change in health to marine mammals (i.e., these are mostly terrestrial development projects or past and present projects for which marine construction has already been completed).

The primary anticipated contributors to cumulative effects of change in health will likely be the principal future marine infrastructure projects that are anticipating marine construction operations in the vicinity of the Project (i.e., the PNW LNG project, the Prince Rupert LNG project, the Douglas Channel LNG Project/BC LNG Project, the Watson Island Industrial Site Redevelopment/Seaport Terminal, the Fairview Terminal Phase II Expansion project, the Westcoast Connector Gas Transmission Project, the Prince Rupert Gas Transmission project, and the WCC LNG Export Facility). Marine construction activities associated with these projects will include similar activities to those assessed for this Project (e.g., dredging and disposal at sea, in-water blasting, impact pile driving, vibratory pile installation/rock socket drilling, and support vessel traffic). All of these activities will produce underwater noise; at sufficient intensities, noise from these projects (assuming spatial and temporal overlapping effects) could combine with underwater noise from Project marine construction, to increase the potential for a cumulative change in health of marine mammals in the RAA. The two activities considered to have the highest likelihood of producing a cumulative change in health in marine mammals are blasting and impact pile driving.

The Ridley Coal Terminal Expansion and the Smith Island Quarry Project will contribute to increased shipping activities in the RAA but are not anticipated to produce sound levels that will act cumulatively to cause PTS given the minimal overlap of the shipping lanes with the extent of underwater noise above injury thresholds and associated mitigation measures for Project construction. Construction activities for these projects are terrestrially-based, so are also not anticipated to act cumulatively. Likewise, shipping noise associated with the LNG Canada Export Terminal project, the Kitimat LNG Terminal project, the Enbridge Northern Gateway project, and the Grassy Point LNG project will all have some overlap with Project-related vessels in the vicinity of the Triple Island pilot station; but are not expected to result in a change in health and marine construction activities for these projects will be too distantly located to overlap with Project marine construction activities to act cumulatively. Potential cumulative effects of behavioural change associated with shipping operations for these six projects are included in Section 4.10.6.4.

### ***CUMULATIVE EFFECTS MITIGATION***

Mitigation measures to reduce the magnitude of changes in health of marine mammals caused by underwater noise during Project construction are summarized in Table 4.10-8. For future projects that require regulatory approval, it is anticipated that activities generating high intensity underwater noise will be subject to mitigation measures similar to those that will be applied for the Project (e.g., use of noise quieting technologies during blasting and impact pile driving). Review of recent regulatory application material for a number of the projects listed above has shown this to be the case. Marine development projects in BC require the implementation of an approved marine mammal monitoring program, within which many of the mitigation measures discussed in Section 4.10.5.2 are applied as standard industry practice. For example, while the exact size of the exclusion zone required during in-water blasting and pile driving operations will vary based on each project's engineering requirements and geoacoustic profile, monitored exclusion zones will be required any time these activities are undertaken.

### ***RESIDUAL CUMULATIVE EFFECTS***

Fisheries and Oceans Canada has recommended that exclusion zones for the Project be set based on the predicted area of exceedance of the 160 dB re 1  $\mu$ Pa rms SPL isopleth, which is the NOAA interim threshold for behavioural disturbance from an impulsive source (i.e., more conservative than the NOAA interim threshold for injury). It is assumed that DFO will apply a similar exclusion zone requirement for all projects and activities identified in Table 4.10-13 that are likely to produce intense levels of underwater noise (e.g., through in-water blasting and impact pile driving). Given the separation (spatial and temporal) between the Project and other identified major marine infrastructure projects, it is considered unlikely that underwater sound levels will combine in such a way as to increase the individual areas of potential change in health. However, given the duration of typical marine construction projects, multiple exclusion zone areas may be active at the same time in the RAA, increasing the overall percentage of habitat within which marine mammals may be exposed to sound levels capable of causing a change in health. The majority of marine mammals, particularly sensitive high frequency cetaceans such as harbour porpoise, are expected to vacate the immediate area during intense noise-producing marine construction activities (see Section 4.10.6.4 for assessment of these cumulative behavioural effects). Marine mammals are therefore not expected to be exposed to sound levels capable of causing PTS. In-field verification of sound levels will be undertaken to confirm that predicted sound level exceedance distances are accurate and implementation of conservative exclusion zones will further reduce potential adverse effects of change in health on marine mammals.

### ***SUMMARY***

With the implementation of industry standard mitigation measures, residual cumulative effects of change in health are expected to be of moderate magnitude. Residual cumulative effects from this activity will extend into the RAA, occur as multiple irregular events over the long-term, and are expected to be reversible. This effect will occur in a disturbed area of active human development that is expecting to see further increase in marine development going forward.

### ***LIKELIHOOD OF RESIDUAL CUMULATIVE EFFECTS***

Uncertainty exists concerning reasonably foreseeable future project scheduling and the associated degree of potential temporal and spatial overlap of underwater noise that may result. While uncertainty exists surrounding the exact nature of mitigation measures that will be implemented for this and future projects and activities (see Section 4.10.8), the proponent has committed (and assumedly future proponents will commit) to working with DFO on refining mitigation measures, as necessary, to reduce the likelihood of residual cumulative effects of change in health on marine mammals.

Based on the assumption that DFO will require all other future major marine infrastructure projects in the RAA to implement sufficient mitigation measures, and that exclusion zones for change in health can be appropriately monitored, the likelihood of residual cumulative effects of change in health on marine mammals is considered low.

#### **4.10.6.4 Cumulative Effects Assessment for Change in Behaviour**

The following sections describe the potential cumulative effects of marine mammal change in behaviour resulting from residual effects of the Project acting cumulatively with past, present and reasonably foreseeable projects and activities in the RAA.

#### ***CUMULATIVE EFFECTS MECHANISMS***

Potential cumulative effects of marine mammal change in behaviour may result from the introduction and overlap of underwater noise from residual effects of the Project and residual effects of the construction, operations, and decommissioning of other projects and activities identified in Table 4.10-13.

The primary anticipated contributors to cumulative effects of change in behaviour will be the other major future marine infrastructure projects that are anticipating marine construction and/or shipping operations in the vicinity of the Project (i.e., the PNW LNG project, the Prince Rupert LNG project, the Douglas Channel LNG Project/BC LNG Project, the Watson Island Industrial Site Redevelopment/Seaport Terminal, the Fairview Terminal Phase II Expansion project, the Ridley Coal Terminal Expansion, the Westcoast Connector Gas Transmission Project, the Prince Rupert Gas Transmission project, the Smith Island Quarry Project and the WCC LNG Export Facility). Marine construction and/or operations activities associated with these projects will include similar activities to those assessed for this Project (e.g., dredging and disposal at sea, in-water blasting, impact pile driving, vibratory pile installation/rock socket drilling, shipping and support vessel traffic). These activities will all produce underwater noise that could act cumulatively with underwater noise from Project marine construction and shipping activities to produce larger scale changes in behaviour of marine mammals in the RAA.

Four other future projects and physical activities will have a lesser degree of potential overlap and interaction with the Project due to their more distant locations (i.e., LNG Canada Export Terminal project, the Kitimat LNG Terminal project, the Enbridge Northern Gateway project, and the Grassy Point LNG project); however, these projects have some potential for spatial overlap with Project-related vessels in the vicinity of the Triple Island pilot station. Past and present projects in the RAA with associated shipping or marine traffic activities have also been identified in the first half of Table 4.10-13 (e.g., Prince Rupert Ferry Terminal, Northland Cruise Terminal, etc.) Existing and future vessel traffic, including both

commercial and recreational vessels, will also generate underwater noise that may act cumulatively with noise from Project-related vessels to produce a cumulative change in behaviour for marine mammals.

### ***CUMULATIVE EFFECTS MITIGATION***

Mitigation measures to reduce the magnitude of changes in behaviour of marine mammals caused by underwater noise during Project construction and operations are summarized in Table 4.10-9. For future projects that require regulatory approval, it is expected that activities generating underwater noise will be subject to mitigation measures similar to those that will be applied for the Project (e.g., use of noise quieting technologies during blasting and impact pile driving). Review of recent regulatory application material for a number of the projects listed above has shown this to be the case. Marine development projects in BC require the implementation of an approved marine mammal monitoring program, within which many of the mitigation measures discussed in Section 4.10.5.3 are applied as standard industry practice. For example, sound-reducing technologies such as bubble curtains are frequently implemented (and sound levels verified) for impulsive marine construction activities, to reduce the overall amount of underwater noise introduced to the marine environment, and the overall extent of potential changes in behaviour for marine mammals.

Aurora LNG is willing to collaborate in regional programs planned and developed by government and in conjunction with other proponents and stakeholders, regarding regional management of effects of underwater noise on marine mammals in the RAA.

### ***RESIDUAL CUMULATIVE EFFECTS***

DFO has recommended that exclusion zones for the Project be set based on the predicted area of exceedance of the 160 dB re 1  $\mu$ Pa rms SPL isopleth, which is the NOAA interim threshold for behavioural disturbance from an impulsive source. It is assumed that DFO will apply a similar exclusion zone requirement for all projects and activities identified in Table 4.10-13 that are likely to produce intense levels of underwater noise (e.g., through in-water blasting and impact pile driving). The number of seagoing vessel calls following the designated shipping lanes in the RAA is also predicted to increase to over 1,300 vessels, and 3,200 harbour movements by 2020 (PRPA 2015). From a regional ecological perspective, temporal and spatial overlap of underwater noise from major marine construction and shipping activities in the RAA will result in an overall reduction in availability of marine habitat that is not exposed to sound levels capable of causing a change in behaviour for marine mammals. Some marine mammals, particularly sensitive high frequency cetaceans such as harbour porpoise, are expected to move away from areas of increased underwater noise. While this behaviour is likely to reduce the degree to which TTS may be possible, as the number of projects and activities in the RAA grows, alternative suitable habitat within the RAA may begin to become scarcer for those species with patchy distribution and habitat use in the RAA. Increases in projects and activities in the RAA are also expected to increase the size and number of areas where communication masking could occur.

*SUMMARY*

With the implementation of mitigation measures, residual cumulative effects of change in behaviour are expected to be of high magnitude in the RAA. Given the anticipated operational life of most projects, residual cumulative effects of changes in behaviour are expected to be continuous in nature (i.e., the cumulative increase in underwater noise is expected to increase current levels of stress and communication masking on a near continuous basis, even if thresholds for behavioural change are not continuously exceeded). This cumulative residual effect is also deemed permanent relative to the lifespan of many of the marine mammal species that occur here (i.e., underwater noise levels are unlikely to return to current ambient levels within a marine mammal's lifetime). This effect will occur in a disturbed area of active human development that is expecting to see further increase in marine development going forward.

***LIKELIHOOD OF RESIDUAL CUMULATIVE EFFECTS***

While it is not currently possible to predict the exact nature of a marine mammal's potential change in behaviour in response to underwater noise (Richardson et al. 1995; Wartzok et al. 2003; Ellison et al. 2012), the Project will act cumulatively with past, present and reasonably foreseeable projects and activities in the RAA to increase underwater noise over current levels. This effect would be of increased concern for species that are known to avoid areas of intense underwater noise (e.g., harbour porpoise), and in particular when local populations demonstrate patchy distribution and habitat use (e.g., where there is strong site fidelity to prey concentration areas). The likelihood of residual cumulative effects for change in behaviour on marine mammals is therefore considered high.

**4.10.6.5 Cumulative Effects Assessment for Change in Mortality Risk**

The following sections describe the potential cumulative effects of marine mammal change in mortality risk resulting from residual effects of the Project acting cumulatively with past, present and reasonably foreseeable projects and activities in the RAA.

***CUMULATIVE EFFECTS MECHANISMS***

The Project, along with other projects and activities identified in Table 4.10-13, will introduce increased levels of vessel traffic to the RAA, which will increase marine mammals' potential overall risk of mortality from vessel strikes.

The primary anticipated contributors to cumulative effects of change in mortality risk will be the other major future marine infrastructure projects that are anticipating to have shipping operations in the vicinity of the Project (i.e., the PNW LNG project, the Prince Rupert LNG project, the Douglas Channel LNG Project/BC LNG Project, the Watson Island Industrial Site Redevelopment/Seaport Terminal, the Fairview Terminal Phase II Expansion project, the Ridley Coal Terminal Expansion, the Westcoast Connector Gas Transmission Project, the Prince Rupert Gas Transmission project, the Smith Island Quarry Project and the WCC LNG Export Facility). Four other future projects and physical activities (i.e., LNG Canada Export Terminal project, the Kitimat LNG Terminal project, the Enbridge Northern Gateway project, and the Grassy Point LNG project), will have a lesser degree of potential overlap and interaction with the Project due to their more distant locations; however, Project-related vessels associated with these projects will have some overlap with the RAA in the vicinity of the Triple Island pilot station.

Past and present projects in the RAA with associated shipping or marine traffic activities have also been identified in the first half of Table 4.10-13 (e.g., Prince Rupert Ferry Terminal, Northland Cruise Terminal, etc.). Existing and future vessel traffic, including both commercial and recreational vessels, may also act cumulatively with Project-related vessels to produce an overall increase in mortality risk for marine mammals.

### ***CUMULATIVE EFFECTS MITIGATION***

The mitigation measure to reduce the magnitude of change in mortality risk of marine mammals from potential Project-related vessel strikes (i.e., provision of marine mammal education and awareness material) is summarized in Table 4.10-10. Potentially implementable mitigation measures to reduce the likelihood of lethal vessel strikes (e.g., vessel speed restrictions) are not yet standard practice in BC and the implementation of industry-wide mitigation measures is therefore not expected at this time. The TERMPOL process, conducted by Transport Canada, will address vessel speeds and routing, in consideration of mariner safety, environmental effects and feedback through consultation with PRPA, DFO, Aboriginal Groups, and others. Project-related vessels will proceed at a safe speed and respect any regionally-defined or PRPA-specific speed profiles that are applicable at the time of operations, subject to navigational safety. Aurora LNG is willing to collaborate in regional programs planned and developed by government and in conjunction with other proponents, regarding regional management of effects of vessel strikes on marine mammals in the RAA.

### ***RESIDUAL CUMULATIVE EFFECTS***

The Project will act cumulatively with past, present and reasonably foreseeable projects and activities in the RAA to increase the relative risk of a marine mammal vessel strike, and residual cumulative effects of change in mortality risk from increased marine vessel traffic are expected to be of moderate magnitude. Marine mammal vessel strikes are expected to occur as multiple irregular, albeit infrequent events. In the event of an accidental vessel strike, consequences for the marine mammal involved are assumed to be permanent and irreversible, and would be of heightened concern for SARA-listed species. Based on current marine mammal population sizes and trends for species known to occur in the RAA, changes in mortality risk are considered unlikely to affect population viability. This effect will occur in a disturbed area of active human development where strike risk to marine mammals already exists.

### ***LIKELIHOOD OF RESIDUAL CUMULATIVE EFFECTS***

Increases in cumulative shipping traffic levels in the RAA will result in a corresponding increase in mortality risk from vessel strikes, and since strike risk increases in higher density traffic areas, the likelihood of residual cumulative effects for change in mortality risk to marine mammals is considered high.

#### **4.10.6.6 Summary of Cumulative Effects**

Table 4.10-14 summarizes the residual cumulative effects on marine mammals.

**Table 4.10-14 Summary of Residual Cumulative Effects on Marine Mammals**

Case	Other Projects, Activities and Resource Use	Residual Cumulative Effects Characterization						Likelihood
		Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Context	
<b>Residual Cumulative Change in Health</b>								
Residual Cumulative Effect with the Project	See Table 4.10-13	M	RAA	MI	LT	R	D	Low
Project Contribution to Residual Cumulative Effect		M	LAA	MI	MT	R	D	Low
<b>Residual Cumulative Change in Behaviour</b>								
Residual Cumulative Effect with the Project	See Table 4.10-13	H	RAA	C	P	R	D	High
Project Contribution to Residual Cumulative Effect		H	RAA	MI	LT-P	R	D	High
<b>Residual Cumulative Change in Mortality Risk</b>								
Residual Cumulative Effect with the Project	See Table 4.10-13	M	RAA	MI	P	I	D	High
Project Contribution to Residual Cumulative Effect		M	LAA	S	P	I	D	Medium

**KEY**

See Table 4.10-4 for detailed definitions

N/A: Not applicable

**MAGNITUDE:**

N: Negligible

L: Low

M: Moderate

H: High

**GEOGRAPHIC EXTENT:**

PDA: Project Development Area

LAA: Local assessment area

RAA: Regional assessment area

**FREQUENCY:**

S: Single event

MI: Multiple irregular events

MR: Multiple regular events

C: Continuous

**DURATION:**

ST: Short-term

MT: Medium-term

LT: Long-term

P: Permanent

**REVERSIBILITY:**

R: Reversible

I: Irreversible

**CONTEXT:**

U: Undisturbed

D: Disturbed

The combined residual cumulative effects on marine mammals are anticipated to be high in magnitude, and occur in the RAA as multiple irregular to continuous events over the long-term. Some components of the residual cumulative effects are likely to be permanent. Effects on marine mammals will be primarily reversible in nature although a small unknown number of individual marine mammals may experience irreversible effects. Combined residual cumulative effects will occur in an already disturbed area of active human development that continues to grow.

#### **4.10.7 Determination of Significance**

Using the significance thresholds for residual effects identified in Section 4.10.2.8, this section first assesses and predicts the significance of Project residual effects and assesses and predicts the significance of residual cumulative effects.

##### **4.10.7.1 Significance of Project Residual Effects**

The Project will contribute underwater noise and increased marine vessel traffic to an area that is already subject to high traffic volumes and where behavioural disturbance thresholds are already exceeded during some portion of the day (see the Prince Rupert – Aurora LNG Acoustic Monitoring Study, Appendix O). The residual effects of the Project on marine mammals include change in health, change in behaviour, and change in mortality risk.

Project activities deemed most likely to be capable of causing a change in health for marine mammals are impact pile driving and in-water blasting. Peak SPL thresholds reflect the potential range at which an animal could be injured by a single exposure to loud short-duration noise such as during impact pile driving or blasting. For impact pile driving, mitigated with enclosed bubble curtains, distances to marine mammal peak SPL criteria for injury, as presented by Southall et al. 2007, were not reached beyond 0.01 km from the pile. The NOAA interim rms SPL distances for injury during impact pile driving, which similarly predict areas over which immediate injury could occur, were: 0.1 km from the pile (MOF) and <0.02 km (LNG jetty) for pinnipeds; and 0.3 km (MOF) and 0.09 km (LNG jetty) for cetaceans. Potential for injury over these distances is not expected but will be reduced further through the implementation of monitored exclusion zones.

The Wood et al. (2012) SEL<sub>24h</sub> metrics predicted the greatest areas of extent for potential injury. Predicted extents of noise above this metric at the LNG jetty (based on installation of four simultaneous piles in a 24-hr window [noting that impact pile driving will not occur at night]) were: 0.1 km for mid-frequency cetaceans such as killer whales, 1.1 km for low-frequency cetaceans such as humpback whales, 1.8 km for pinnipeds such as harbour seals, and 3.2 km for high-frequency cetaceans such as harbour porpoise. At the MOF (based on installation of simultaneous piles, two at a time, with a total of 8 installed over the 24 hours), predicted extents were 2.1 km for mid-frequency cetaceans, 5.9 km for low-frequency cetaceans, 6.9 km for pinnipeds, and 8.1 km for high-frequency cetaceans. The SEL<sub>24h</sub> metric depends strongly on the duration of underwater noise produced, and assumes that marine mammals remain within predicted ranges for the full 24-hr period to incur injury.

Monitored exclusion zones will be applied during all in-water blasting and are an industry standard for reducing potential harm to marine mammals during this activity (and will also reduce the potential for TTS and behavioural change). Underwater sound levels and extents to monitored exclusion zones will be confirmed or amended through an underwater noise field verification program at the start of in-water blasting and impact pile driving and through consultation with DFO. With the implementation of appropriate mitigation measures, the likelihood of change in health for marine mammals, including species listed on Schedule 1 of SARA, is considered low and the residual effect is predicted to be not significant, as the residual effect is not anticipated to threaten the long-term persistence of a marine mammal species or local population in the RAA.

## Aurora LNG

### Environmental Assessment Certificate Application

#### Section 4.10: Marine Mammals

---

With mitigation, the Project is predicted to result in an increase in underwater noise above the US NOAA behavioural disruption thresholds over a distance of up to 6 km at the MOF and 3 km at the LNG jetty during the marine construction phase. During operations, Project-related underwater noise capable of causing behavioural change in marine mammals will extend up to 10 km from the LNG jetty (during berthing events), and 15 km from the LNG carriers transiting through the RAA (according to NOAA behavioural disruption thresholds for continuous noise). However, of the species-specific behavioural response thresholds that have been developed and assessed, there is large variation in the extents predicted to result in changes in behaviour. The wide range of differences across species demonstrates some of the challenges with attempting to draw predictive conclusions concerning a marine mammal's potential change in behaviour in response to underwater noise. Behavioural change during impact pile driving was predicted over the smallest scale for killer whales (i.e., overt responses: 1.1 km at the LNG jetty and 2.1 km at the MOF; subtle responses: 2.9 km at the LNG jetty and 5.5 km at the MOF). Humpback whales had the highest predicted extents of behavioural disturbance (22.6 and 25.5 km at the LNG jetty and MOF, respectively), followed by harbour seals (22.5 and 21.3 km). Harbour porpoises had predicted exceedance of behavioural change thresholds over a distance of 20.9 km at the LNG jetty and 10.5 km at the MOF. Large extents of exceedance for behavioural disturbance thresholds were also predicted during LNG shipping operations (see Section 4.10.5.3).

While threshold exceedance predictions can lend insight into generalized areas over which a change in behaviour might occur, it is much more difficult to predict the exact nature of behavioural change. For example, while effects such as communication masking are expected to apply to all marine mammal species and extend beyond the ranges discussed above, some species such as harbour porpoises have displayed strong avoidance responses to impact pile driving over distances of tens of kilometres (e.g., Tougaard et al. 2009; Dähne et al. 2013; Brandt et al. 2016). Potential for avoidance responses would in turn be of increased concern for local populations that demonstrate patchy distribution and habitat use (e.g., where there is strong site fidelity to prey concentration areas).

Results from marine mammal surveys conducted for the Aurora LNG Project (see the Marine Mammals TDR, Appendix N) and for the PNW LNG project (Stantec 2016) suggest that most species of marine mammal in the RAA show fairly broad distributions, and/or seasonal higher density areas in more than one location. For example, humpback whales were observed throughout the RAA, with seasonal (fall/winter) areas of higher relative abundance predicted both in the coastal waters around Kinahan Islands (primarily on the southern side) and between Triple and Melville Islands (Stantec 2016). During impact pile driving, sound levels above the species-specific behavioural disturbance threshold were predicted to overlap with a portion of the higher density area for humpback whales around Kinahan Islands, but not extend around the southwestern side. This suggests that suitable alternative habitat for humpback whales will continue to exist in this area as well as around Triple Islands during Project construction. During operations, underwater noise above behavioural disruption thresholds will overlap both of these higher predicted relative density areas; however, this effect will be transient (i.e., <1-2 hrs per 24-hr period) during Project-related LNG carrier transit.

In contrast to predicted 'hot spots' for humpback whales, highest density areas for harbour porpoises were consistently observed in the waters south of Digby Island, in Porpoise Channel, around Ridley Island, Lelu Island and the northeast coast of Stephens Island. This porpoise high use area shows a large degree of overlap with sound levels above the species-specific behavioural disturbance threshold during marine construction activities.

Based on the distribution and habitat use of marine mammals in the RAA and understood species-specific behavioural responses to underwater noise, this residual effect is not anticipated to threaten the long-term persistence of most marine mammal species or local populations in the assessment area. The likelihood of change in behaviour for marine mammals, including species listed on Schedule 1 of SARA, is considered high for both the Project's construction and operations phases but the residual effect is predicted to be not significant for all species except harbour porpoise. Given demonstrated avoidance responses by harbour porpoise during previous pile driving studies, the residual effect of change in behaviour may threaten the long-term persistence of this local population of harbour porpoise in this area and is therefore considered to be significant.

Vessel strikes with marine mammals, particularly large baleen whales, are a known concern worldwide, particularly for vessels over 80 m in length and travelling at 14 kts or faster (Laist et al. 2001; Panigada et al. 2006). Project-related vessels will proceed at a safe speed and respect any regionally-defined or PRPA-specific speed profiles that are applicable at the time of operations, subject to navigational safety. The increase in vessel traffic of up to 640 LNG carrier transits annually for 25 years will, however, increase marine mammal mortality risk in the LAA, as this risk is known to increase in areas of higher shipping density (Williams and O'Hara 2010). Aurora LNG is willing to collaborate in regional programs planned and developed by government and in conjunction with other proponents, regarding regional management of effects of vessel strikes on marine mammals in the RAA. In the event of an accidental vessel strike, effects on the marine mammal involved are assumed to be permanent and irreversible. Vessel strikes are considered to be accidental events that are rare for any given vessel passage. Over the life of the Project, the likelihood of change in mortality risk to marine mammals, including species listed on Schedule 1 of SARA, is considered medium and the residual effect is predicted to be not significant, as the residual effect is not anticipated to threaten the long-term persistence of a marine mammal species or local population in the RAA.

A suite of mitigation measures has been developed to reduce adverse residual effects of the Project on marine mammals. Based on current shipping and development levels in the RAA and the continued presence of marine mammals, it is considered unlikely that all of the assessed Project activities will lead to habitat displacement (i.e., avoidance) by all marine mammal species over the geographic scale of predicted disturbance extents. However, marine mammals rely on the use of a functional underwater acoustic environment for nearly all aspects of their life history. A significant adverse residual effect is defined as one that threatens the long-term persistence of a marine mammal species or local population in the RAA. Based on the combined residual effects of the Project, it is conceivable that local populations of marine mammals, particularly those such as harbour porpoise that have a history of avoidance responses to underwater noise, may exhibit long-term alterations in current use, presence, and distribution in the RAA.

With mitigation measures, the combined residual effects on marine mammals are considered to be significant for harbour porpoise, and not significant for other species of marine mammal.

**4.10.7.2 Significance of Residual Cumulative Effects**

A number of future projects and activities, including construction of marine infrastructure, have been proposed in the RAA (see Table 4.10-13). The number of seagoing vessel calls following the designated shipping lanes in the RAA is predicted to increase to over 1,300 vessels, and 3,200 harbour movements by 2020 (PRPA 2015). These numbers are in addition to the large amount of smaller commercial, fishing, and recreational traffic that currently frequents this area. Increases in human development and use of marine waters in the RAA is expected to increase the potential occurrence of changes in health, changes in behaviour, and changes in mortality risk for marine mammals.

It is assumed that DFO will apply similar mitigation measures and exclusion zone requirements for all future projects and activities that are likely to produce intense levels of underwater noise. With the implementation of industry standard mitigation measures, residual cumulative effects of change in health are expected to be of low magnitude and not significant.

From a regional ecological perspective, temporal and spatial overlap of underwater noise from past, present and reasonably foreseeable future projects and activities in the RAA may result in an overall reduction in availability of marine habitat that is not exposed to sound levels capable of causing a change in behaviour for marine mammals. This effect is considered to be of somewhat lesser relative concern for local populations that demonstrate a broad-scale distribution of habitat use (e.g., where there is suitable alternative habitat in the vicinity). With the implementation of mitigation measures, residual cumulative effects of change in behaviour are expected to be of moderate to high magnitude and significant for harbour porpoise, and not significant for other species of marine mammal.

Increases in cumulative shipping traffic levels in the RAA will result in a corresponding increase in mortality risk from vessel strikes. A significant adverse residual effect is defined as one that threatens the long-term persistence of a marine mammal species or local population in the RAA. Since strike risk increases in higher density traffic areas, the likelihood of residual cumulative effects for change in mortality risk to marine mammals is considered high. In the event of an accidental vessel strike, effects on the marine mammal involved are assumed to be permanent and irreversible, and would be of heightened concern for SARA-listed species. Based on current marine mammal population sizes and trends for species known to occur in the RAA, changes in mortality risk are considered unlikely to affect population viability, and are therefore expected to be not significant.

While it is not currently possible to predict the exact nature of a marine mammal's potential response to disturbance, some marine mammals, particularly sensitive species such as harbour porpoise, are expected to move away from areas of increased underwater noise. As the number of projects and activities in the RAA grows, alternative suitable habitat within the RAA will begin to become more scarce.

With mitigation measures, the combined residual cumulative effects on marine mammals are considered to be significant for harbour porpoise, and not significant for other species of marine mammal.

#### **4.10.8 Prediction Confidence**

The prediction confidence in the conclusions for Project residual effects and residual cumulative effects for marine mammals is based on:

- Scientific certainty relative to estimating the effects, including the availability and quality of regional data
- An understanding of the effect mechanisms
- Certainty relative to the effectiveness of the proposed mitigation measures
- Assumptions made in the assessment and conservative approach
- Professional judgement from prior experience and understanding of proven mitigation measures.

There is uncertainty regarding the nature of response that different species, and individual marine mammals, may exhibit as a result of increases in underwater noise and marine vessel traffic (i.e., whether animals will exhibit avoidance behaviours or substantial alterations in their activities in the RAA), and what the long-term and/or population-level consequences of these responses might be (Tyack 2008). There is also uncertainty regarding Project details (e.g., the duration of potential effects during marine construction at the MOF vary dramatically depending on whether the pile-and-deck or concrete caisson option are selected). As mitigation measures to reduce the likelihood and degree of adverse residual effects on marine mammals may need to be further developed and refined through consultation with DFO, uncertainty remains over the exact nature of these measures or effectiveness to reduce the overall underwater noise footprints. Assumptions made for a number of scenarios used in acoustic modelling may have over-predicted the extents of potential effect (e.g., LNG carriers will not be accompanied by two tugs beyond the boundaries of the PRPA, and impact pile driving activities may be conducted asynchronously instead of concurrently). These sources of uncertainty diminish the level of prediction confidence in the significance conclusion for Project residual effects. However, acoustic modelling is a commonly used and well-trialed means of predicting the potential extent of adverse effects of injury and/or behaviour on marine mammals, and multiple different thresholds of effect were considered. There is a large and growing body of literature concerning the adverse effects of underwater noise on marine mammals, and some effects have been quite extensively studied (e.g., responses of harbour porpoise to impact pile driving). These factors increase the level of prediction confidence in the significance conclusion for Project residual effects.

Regardless of the exact nature of future projects and activities in the RAA, some amount of increased marine development and shipping in the RAA is expected over the coming years and these activities will continue to increase underwater noise levels over and above current ambient conditions (which already include numerous sources of anthropogenic noise). This increases confidence in the conclusion of residual cumulative effects. Other aspects of understanding and uncertainty discussed above for Project residual effects also apply to the cumulative effects determination.

The level of confidence in the significance conclusions for both the Project residual effects and for the residual cumulative effects is moderate.

### **4.10.9 Follow-up and Monitoring**

With the implementation of standard mitigation measures and BMPs, the combined residual effects on marine mammals are considered to be significant for harbour porpoise, and not significant for other marine mammal species. The level of confidence in this prediction is moderate. This determination is influenced by some uncertainties in the nature of how marine mammals may respond to some activities, as well as on the availability of BMPs and standardized mitigation measures. No follow-up programs are being proposed. To verify compliance of the Project with commitments in the Application and conditions of the Environmental Assessment Certificate, Aurora LNG is committed to the development of the Marine and Freshwater Resources Management Plan.

The Marine and Freshwater Resources Management Plan will be developed in consultation with DFO and the BC Oil and Gas Commission. This plan will describe BMPs and mitigation measures that will be implemented during construction and operations of the LNG facility to avoid or reduce potential adverse effects of Project activities on marine mammals. The plan will include details on the following:

- Prior to the start of marine construction, acoustic modelling of in-water blasting will be done to verify assumptions and predictions made in this assessment and refine mitigation measures, as necessary.
- Field verification will be undertaken at multiple locations to confirm predicted extents of underwater noise levels over the full range of predicted values for in-water blasting and impact pile driving.
- A marine mammal monitoring program will be developed and implemented to enforce an exclusion zone during in-water impact pile driving and around the in-water blasting area.
- Aurora LNG is willing to collaborate in regional programs planned and developed by government and in conjunction with other proponents, regarding regional management of effects of underwater noise and vessel strikes on marine mammals in the RAA.

Additional details of these follow-up programs are found in Section 15.0 Summary of Follow-up Programs and Compliance Reporting.

### **4.10.10 Conclusions**

Project effects on marine mammals are anticipated to occur in the RAA but will be reduced through the implementation of proposed mitigation measures. Residual effects may threaten the long-term persistence of localized harbour porpoise populations in the RAA (particularly in the vicinity of marine construction activities), and are therefore considered to be significant. Residual effects on other species of marine mammal are considered to be not significant.

The potential residual effects of the Project, and their contribution to cumulative effects within the RAA, are considered to be significant for harbour porpoise, but not other species of marine mammal. Based on the quality and availability of acoustic modelling, and regional data, scientific literature, understanding of the potential adverse effects of underwater noise on marine mammals, uncertainty concerning the exact nature of potential behavioural responses, and professional judgement, the level of confidence in this prediction is moderate.

#### 4.10.11 References

- Bailey, H., B. Senior, D. Simmons, J. Rusin, G. Picken and P.M. Thompson. 2010. Assessing underwater noise levels during pile-driving at an offshore windfarm and its potential effects on marine mammals. *Marine Pollution Bulletin* 60(6):888-897.
- Baumgartner, M.F., T.V.N. Cole, P.J. Clapham and B.R. Mate. 2003. North Atlantic right whale habitat in the lower Bay of Fundy and on the SW scotian Shelf during 1999-2001. *Marine Ecology Progress Series* 264:137-154.
- Best, B.D., C.H. Fox, R. Williams, P.N. Halpin and P.C. Paquet. 2015. Updated marine mammal distribution and abundance estimates in British Columbia. *Journal of Cetacean Research and Management* 15, 9-26.
- Borggaard, D., J. Lien and P. Stevick. 1999. Assessing the effects of industrial activity on large cetaceans in Trinity Bay, Newfoundland (1992–1995). *Aquatic Mammals* 25(3):149-161.
- Brandt, M.J., A. Diederichs, K. Betke and G. Nehls. 2011. Responses of harbour porpoises to pile driving at the Horns Rev II offshore wind farm in the Danish North Sea. *Marine Ecology Progress Series* 421:205-216.
- Brandt, M.J., A.-C. Dragon, A. Diederichs, A. Schubert, V. Kosarev and G. Nehls. 2016. *Effects of offshore pile driving on harbour porpoise abundance in the German Bight - Assessment of Noise Effects. Final Report*. Prepared for Offshore Forum Windenergie. Husum. 262 pp.
- British Columbia Cetacean Sightings Network (BCCSN). 2014. Data from opportunistic sightings of cetaceans and sea turtles in the RAA from 1991 to June 2014. Vancouver, BC: Vancouver Aquarium Marine Science Centre and Fisheries and Oceans Canada.
- British Columbia Conservation Data Centre (BC CDC). 2016. *BC Species and Ecosystems Explorer BC* Ministry of Environment,. Available at: <http://a100.gov.bc.ca/pub/eswp/>. Accessed: August 19, 2016.
- British Columbia Environmental Assessment Office (BC EAO). 2015. Tracking Table for Working Group Comments on dAIR. BC EAO Project Information Centre (e-PIC). Accessed August 2016. Available at: [http://a100.gov.bc.ca/appsdata/epic/html/deploy/epic\\_document\\_416\\_39606.html](http://a100.gov.bc.ca/appsdata/epic/html/deploy/epic_document_416_39606.html)
- British Columbia Marine and Pile Driving Contractors Association and DFO. 2003. *Best management practices for pile driving and related operations*.
- British Columbia Parks. 2016. *Conservancies*. British Columbia Ministry of Environment. Available at: <http://www.env.gov.bc.ca/bcparks/explore/cnsrvncy/ksgaxl-stephens-is/>. Accessed: Aug 5, 2016.
- Broudic, M., P. Berggren, S. Laing, L. Blake, F. Pace, S. Neves, I. Voellmy, P. Dobbins, A. Radford, S. Simpson, S. Robinson, P. Lepper and R. Brintjes. 2014, April 28-02 May 2014. *Underwater noise emission from the NOAH's drilling operation at the NaREC site, Blyth, UK*. Proceedings of the 2nd International Conference on Environmental Interactions of Marine Renewable Energy Technologies (EIMR2014), Stornoway, Isle of Lewis, Outer Hebrides, Scotland.
- Brown, M.W. 2002. *A review of the risk of ship strikes from tanker traffic on western North Atlantic right whales in the Bay of Fundy, Canada*. Center for Coastal Studies. Provincetown, MA.

- Buckland, S.T., D.R. Anderson, K.P. Burnham, J.L. Laake, D.L. Borchers and L. Thomas. 2001. *Introduction to Distance Sampling: Estimating Abundance of Biological Populations* Oxford University Press. Oxford, United Kingdom.
- Carrillo, M. and F. Ritter. 2010. Increasing numbers of ship strikes in the Canary Islands: proposals for immediate action to reduce risk of vessel-whale collisions. *Journal of Cetacean Research and Management* 11(2):131-138.
- Clark, C.W., W.T. Ellison, B.L. Southall, L. Hatch, S.M. Van Parijs, A. Frankel and D. Ponirakis. 2009a. Acoustic masking in marine ecosystems: Intuitions, analysis, and implication. . *Marine Ecological Progress Series* 395:201-222.
- Clark, C.W., W.T. Ellison, B.L. Southall, L. Hatch, S.M. Van Parijs, A. Frankel and D. Ponirakis. 2009b. Acoustic masking in marine ecosystems: intuitions, analysis, and implications. *Marine Ecology Progress Series* 395:201-222.
- Clarke, C.L. and G.S. Jamieson. 2006a. *Identification of Ecologically and Biologically Significant Areas in the Pacific North Coast Integrated Management Area: Phase II - Final Report*. Canadian Technical Report of Fisheries and Aquatic Sciences. v + 25 pp.
- Clarke, C.L. and G.S. Jamieson. 2006b. *Identification of ecologically and biologically significant areas in the Pacific North Coast Intergrated Management Area: Phase I - Identification of important areas*. Can. Tech. Rep. Fish. Aquat. Sci. 2678. vi + 89 pp.
- Conn, P. and G. Silber. 2013. Vessel speed restrictions reduce risk of collision-related mortality for North Atlantic right whales. *Ecosphere* 4(4):1-16.
- COSEWIC. 2016, August 5, 2016. *Committee on the Status of Endangered Wildlife in Canada*. Available at: [http://www.cosepac.gc.ca/eng/sct5/index\\_e.cfm](http://www.cosepac.gc.ca/eng/sct5/index_e.cfm). Accessed: 2013.
- Croll, D.A., C. C.W., J. Calambokidis, W.T. Ellison and B.R. Tershy. 2001. Effect of anthropogenic low-frequency noise on the foraging ecology of Balaenoptera whales. *The Zoological Society of London* 4:13-27.
- Dähne, M., A. Gilles, K. Lucke, V. Peschko, S. Adler, K. Krügel, J. Sundermeyer and U. Siebert. 2013. Effects of pile-driving on harbour porpoises (*Phocoena phocoena*) at the first offshore wind farm in Germany. *Environmental Research Letters* 8(2):025002.
- Dawson, S., P. Wade, E. Slooten and J. Barlow. 2008. Design and field methods for sighting surveys of cetaceans in coastal and riverine habitats. *Mammal Review* 38(1):19-49.
- Dickerson, C., K.J. Reine and D.G. Clarke. 2001. Characterization of Underwater Sounds Produced by Bucket Dredging Operations. *DOER Technical Notes Collection (ERDC TN-DOER-E14)*, U.S. Army Engineer Research and Development Center, Vicksburg, MS.
- Dwyer, S., L. Kozmian-Ledward and K. Stockin. 2014. Short-term survival of severe propeller strike injuries and observations on wound progression in a bottlenose dolphin. *New Zealand Journal of Marine and Freshwater Research* 48(2):294-302.
- Edds, P.L. 1988. Characteristics of finback *Balaenoptera physalus* vocalizations in the St. Lawrence Estuary. *Bioacoustics*, 1(2-3):131-149.

- Ellison, W.T., B.L. Southall, C.W. Clark and A.S. Frankel. 2012. A new context-based approach to assess marine mammal behavioural responses to anthropogenic sounds. *Conservation Biology* 26(1): 21-28.
- Erbe, C. 2002. Underwater noise of whale-watching boats and potential effects on killer whales (*Orcinus orca*), based on an acoustic impact model. *Marine Mammal Science* 18(2):394-418.
- Federal Register. 2006. *Doc. 06–5669: Endangered Fish and Wildlife; Proposed Rule to Implement Speed Restrictions to Reduce the Threat of Ship Collisions with North Atlantic Right Whales.* (United States of America). United States of America.
- Finneran, J.J. and A.K. Jenkins. 2012. *Criteria and thresholds for U.S. Navy acoustic and explosive effects analysis.* SPAWAR Systems Center Pacific. San Diego, California.
- Fisheries and Oceans Canada (DFO). 2004. *Identification of ecologically and biologically significant areas.* DFO Can. Sci. Advis. Sec. Stock Status Report. (No. 2004/051).
- Fisheries and Oceans Canada (DFO). 2007. *Recovery Strategy for the Transient Killer Whale (*Orcinus orca*) in Canada.* Species at Risk Act Recovery Strategy Series. Fisheries and Oceans Canada, Vancouver, vi + 46 pp.
- Fisheries and Oceans Canada (DFO). 2011. *Recovery Strategy for the Northern and Southern Resident Killer Whales (*Orcinus orca*) in Canada.* Species at Risk Act Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa, ix + 80 pp.
- Fisheries and Oceans Canada (DFO). 2013. *Recovery Strategy for the North Pacific Humpback Whale (*Megaptera novaeangliae*) in Canada.* Species at Risk Act Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa. x + 67 pp.
- Fisheries and Oceans Canada (DFO). 2013. *Report an Incident - DFO's Observe, Record and Report 24-hour hotline* Available at: [http://www.pac.dfo-mpo.gc.ca/fm-gp/species-especies/mammals-mammiferes/report-signaler-eng.html#Report\\_an\\_incident](http://www.pac.dfo-mpo.gc.ca/fm-gp/species-especies/mammals-mammiferes/report-signaler-eng.html#Report_an_incident). Accessed: Aug 2016.
- Fisheries and Oceans Canada (DFO). 2014. *British Columbia Marine/Estuarine Timing Windows for the Protection of Fish and Fish Habitat – North Coast Area.* Available at: <http://www.dfo-mpo.gc.ca/pnw-ppe/timing-periodes/bc-n-eng.html#area-4>. Accessed: August 17, 2016.
- Fisheries and Oceans Canada (DFO). 2016. [Proposed] Partial Action Plan for Blue, Fin, Sei and North Pacific Right Whales (*Balaenoptera musculus*, *B. physalus*, *B. borealis*, and *Eubalaena japonica*) in Canadian Pacific Waters. Species at Risk Act Action Plan Series. Fisheries and Oceans Canada, Ottawa. iv + 25 pp.
- Fisheries and Oceans Canada (DFO). 2016. Action Plan for the Northern and Southern Resident Killer Whale (*Orcinus orca*) in Canada [Proposed]. Species at Risk Act Action Plan Series. Fisheries and Oceans Canada, Ottawa. iii + 32 pp.
- Fonnesbeck, C.J., L.P. Garrison, L.I. Ward-Geiger and R.D. Baumstark. 2008. Bayesian hierarchical model for evaluating the risk of vessel strikes on North Atlantic right whales in the SE United States. *Endangered Species Research* 6:87-94.

- Ford, J.K.B. 2006. *An Assessment of Critical Habitats of Resident Killer Whales in Waters off the Pacific Coast of Canada*. Canadian Science Advisory Secretariat, Research Document. Nanaimo, BC. 1-34 pp.
- Ford, J.K.B., R.M. Abernathy, A.V. Phillips, J. Calambokidis, G.M. Ellis and L.M. Nichol. 2010. Distribution and relative abundance of cetaceans in western Canadian waters from ship surveys, 2002-2008. *Canadian Technical Report of Fisheries and Aquatic Sciences* 2913:v + 51 p.
- Ford, J.K.B. 2014. *Marine Mammals of British Columbia*. Vol. 6 - The Mammals of British Columbia. Royal BC Museum Handbook. Victoria, BC.
- Ford, J.K.B. and G.M. Ellis. 2006. Selective foraging by fish-eating killer whales *Orcinus orca* in British Columbia. *Marine Ecology Progress Series* 316:185-199.
- Government of Canada. 2016. *Species at Risk Public Registry*. Available at: [www.sararegistry.gc.ca](http://www.sararegistry.gc.ca). Accessed: August, 2016.
- Gregr, E.J., J. Calambokidis, L. Convey, J.K.B. Ford, R.I. Perry, L. Spaven, M. Zacharias. 2006. Recovery Strategy for Blue, Fin, and Sei Whales (*Balaenoptera musculus*, *B. physalus*, and *B. borealis*) in Pacific Canadian Waters. In *Species at Risk Act Recovery Strategy Series*. Vancouver: Fisheries and Oceans Canada. vii + 53 pp.
- Guzman, H.M., C.G. Gomez, C.A. Guevara and L. Kleivane. 2013. Potential vessel collisions with Southern Hemisphere humpback whales wintering off Pacific Panama. *Marine Mammal Science* 29(4):629-642.
- Hatch, L.T., C.W. Clark, S.M. Van Parijs, A.S. Frankel and D.W. Ponirakis. 2012. Quantifying loss of acoustic communication space for right whales in and around a US National Marine Sanctuary. *Conservation Biology* 26(6):983-994.
- Hempen, G.L., T.M. Keevin and T.L. Jordan. 2007. *Volume 1: Underwater blast pressures from a confined rock removal during the Miami Harbour Deepening Project*. International Society of Explosives Engineers. 12 pp.
- Hermanssen, L., K. Beedholm, J. Tougaard and P.T. Madsen. 2014. High frequency components of ship noise in shallow water with a discussion of implications for harbour porpoises (*Phocoena phocoena*). *Journal of the Acoustical Society of America* 136(4): 1640-1653.
- Illingworth and Rodkin Inc. 2007. *Compendium of Pile Driving Sound Data*. California Department of Transportation Petaluma, CA. 129 pp.
- Jensen, A.S. and G.K. Silber. 2003. *Large Whale Ship Strike Database*. U.S. Department of Commerce. NOAA Technical Memorandum. NMFS-ORP. 37 pp.
- Kastak, D., J. Mulsow, A. Ghoull and C. Reichmuth. 2008. Noise-induced permanent threshold shift in a harbor seal. *The Journal of the Acoustical Society of America* 123(5):2986-2986.
- Kastak, D., B. Southall, R. Schusterman and R. Colleen. 2005. Underwater temporary threshold shift in pinnipeds: Effects of noise level and duration. *J Acoust Soc Am*. 118(5):3154-3163.

- Kastelein, R., R. Gransier, R. van Mierlo, L. Hoek and C. de Jong. 2011. Temporary hearing threshold shifts and recovery in a harbor porpoise (*Phocoena phocoena*) and harbor seals (*Phoca vitulina*) exposed to white noise in a 1/1-octave band around 4 kHz. *Journal of the Acoustical Society of America* 129(4):2432-2432.
- Kastelein, R.A., R. Gransier and L. Hoek. 2013. Comparative temporary threshold shifts in a harbor porpoise and harbor seal, and severe shift in a seal. *The Journal of the Acoustical Society of America* 134(1):13-16.
- Ketten, D.R. 1995. Estimates of Blast Injury and Acoustic Trauma Zones for Marine Mammals from Underwater Explosions. In R. A. Kastelein, J. A. Thomas & P. E. Nachtigall (Eds.), *Sensory Systems of Aquatic Mammals*. Woerden: De Spil Publishers. 391-407.
- Kite-Powell, H.L., A. Knowlton and M. Brown. 2007. *Modeling the effect of vessel speed on Right Whale ship strike risk*. (No. NA04NMF47202394). National Oceanic and Atmospheric Administration and National Marine Fisheries Service. 8 pp
- Koski, W.R., Funk, D.W., Ireland, D.S., Lyons, C., Macrander, A.M. and I. Voparil. 2008. Feeding by bowhead whales near an offshore seismic survey in the Beaufort Sea. *IWC Paper SC/60/E14 presented to the International Whaling Commission, Santiago, Chile June 2008*.
- Laake, J., D. Borchers, L. Thomas, D. Miller and J. Bishop. (2015). mrds: Mark-Recapture Distance Sampling. (Version R package 2.1.14. ). <http://CRAN.R-project.org/package=mrds>.
- Laist, D.W., A.R. Knowlton, J.G. Mead, A.S. Collet and M. Podesta. 2001. Collisions between ships and whales. *Marine Mammal Science* 17(1):35-75.
- LNG Canada. 2014. LNG Canada Export Terminal. Marine Resources Technical Data Report. 236 pp + Appendices.
- Lucke, K., P.A. Lepper, M.-A. Blanchet and U. Siebert. 2011. The use of an air bubble curtain to reduce the received sound levels for harbor porpoises (*Phocoena phocoena*). *Journal of the Acoustical Society of America* 130(5):3406-3412.
- Lucke, K., E. Siebert, P.A. Lepper and M. Blanchet. 2009. Temporary shift in masked hearing thresholds in a harbour porpoise (*Phocoena phocoena*) after exposure to seismic airgun stimuli. *Journal of the Acoustical Society of America* 125(6):4060-4070.
- McCauley, R.D., J. Fewtrell, A.J. Duncan, C. Jenner, M.-N. Jenner, J.D. Penrose, R.I. Prince, A. Adhitya, J. Murdoch, et al. 2000. *Marine seismic surveys: Analysis and propagation of air-gun signals; and effects of air-gun exposure on humpback whales, sea turtles, fishes and squid*. Report Number R99-15. Prepared for Australian Petroleum Production Exploration Association by Centre for Marine Science and Technology, Western Australia. 198 pp. <http://cmst.curtin.edu.au/publications/>.
- McKenna, M.F., S.M. Wiggins and J.A. Hildebrand. 2013. Relationship between container ship underwater noise levels and ship design, operational and oceanographic conditions. *Scientific reports* 3:1760.
- National Marine Fisheries Service (NMFS). 2015. *Draft Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Draft: July 23, 2015)*. 187 pp.

## Aurora LNG

Environmental Assessment Certificate Application

Section 4.10: Marine Mammals

---

- National Marine Fisheries Service (NMFS). 2016. *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing: Underwater Acoustic Thresholds for Onset of Permanent and Temporary Threshold Shifts*. U.S. Dept. of Commer., NOAA. 178 pp.
- National Oceanic and Atmospheric Administration (NOAA). 2008. *Endangered fish and wildlife; Final rule to implement speed restrictions to reduce the threat of ship collisions with North Atlantic right whales*. 73, 60173-60191.
- National Oceanic and Atmospheric Administration (NOAA). n.d. *Marine Mammals: Interim Sound Threshold Guidance*. Available at: [http://www.westcoast.fisheries.noaa.gov/protected\\_species/marine\\_mammals/threshold\\_guidance.html](http://www.westcoast.fisheries.noaa.gov/protected_species/marine_mammals/threshold_guidance.html). Accessed: Aug 16, 2016.
- National Park Service. 2003. *Draft Environmental Impact Assessment: Glacier Bay National Park And Preserve, Alaska: Vessel Quotas and Operating Requirements*. National Park Service. U. S. o. A. National Park Service.
- Nedwell, J., J. Langworthy and D. Howell. 2003. *Assessment of sub-sea acoustic noise and vibration from offshore wind turbines and its impact on marine wildlife; initial measurements of underwater noise during construction of offshore windfarms, and comparison with background noise*. COWRIE. Subacoustic Ltd. London, England.
- Neilson, J.L., C.M. Gabriele, A.S. Jensen, K. Jackson and J.M. Straley. 2012. Summary of reported whale-vessel collisions in Alaskan waters. *Journal of Marine Biology* 2012, 18 pp.
- Nowacek, D.P., L.P. Thorne, D.W. Johnston and P.L. Tyack. 2007. Responses of cetaceans to anthropogenic noise. *Mammal Review* 37(2):81-115.
- Pacific North Coast Integrated Management Area (PNCIMA). 2011. *Atlas* Available at: <http://pncima.org/site/atlas.html>. Accessed: 27 November, 2013.
- Panigada, S., G. Pesante, M. Zanardelli, F. Capoulade, A. Gannier and M.T. Weinrich. 2006. Mediterranean fin whales at risk from fatal ship strikes. *Marine Pollution Bulletin* 52(10): 1287-1298.
- Popper, A.N. and A. Hawkins (Eds.). 2012. *Effects of Noise on Aquatic Life* (Vol. 730). New York. Springer.
- Prince Rupert Port Authority (PRPA). 2015. *Port Information Guide*. Prince Rupert October 2015. Harbour Master Port of Prince Rupert. 94 pp.
- R Core Team. 2015. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL <http://www.R-project.org/>.
- Richardson, J., C.R. Greene Jr, C. Malme and D. Thomson. 1995. *Marine Mammals and Noise*. Academic Press. San Diego.
- Risch, D., P.J. Corkeron, W.T. Ellison and S.M. Van Parijs. 2012. Changes in humpback whale song occurrence in response to an acoustic source 200 km away. *PLoS ONE* 7(1):e29741, 29741-29746.
- Ritter, F. 2012. Collisions of sailing vessels with cetaceans worldwide: First insights into a seemingly growing problem. *Journal of Cetacean Research and Management* 12(1):119-127.

- Rolland, R.M., S.E. Parks, K.E. Hunt, M. Castellote, P.J. Corkeron, D.P. Nowacek, S.K. Waaser and S.D. Kraus. 2012. Evidence that ship noise increases stress in right whales. *Proceedings of the Royal Society of Biology* 279(1737):2363-2368.
- Romano, T.A., M.J. Keogh, C. Kelly, P. Feng, L. Berk, C.E. Schlundt, D.A. Carder and J.J. Finneran. 2004. Anthropogenic sound and marine mammal health: Measures of the nervous and immune systems before and after intense sound exposure. *Canadian Journal of Fisheries and Aquatic Science* 61:1124-1134.
- Shannon, G., M.F. McKenna, L.M. Angeloni, K.R. Crooks, K.M. Fristrup, E. Brown, K.A. Warner, M.D. Nelson, C. White and J. Briggs. 2015. A synthesis of two decades of research documenting the effects of noise on wildlife. *Biological Reviews*: 000-000.
- Slotte, A., K. Hansen, J. Dalen and E. Ona. 2004. Acoustic mapping of pelagic fish distribution and abundance in relation to a seismic shooting area off the Norwegian west coast. *Fisheries Research* 67(2):143-150.
- Southall, B.L., A.E. Bowles, W.T. Ellison, J.J. Finneran, R.L. Gentry, C.R. Greene, D. Kastak, D.R. Ketten, J.H. Miller, P.E. Nachtigall, W.J. Richardson, J.A. Thomas and P.L. Tyack. 2007. Marine mammal noise exposure criteria: Initial scientific recommendations. *Aquatic Mammals* 33(4).
- Stantec Consulting Ltd. (Stantec). 2016. Pacific NorthWest LNG Project Marine Mammal Program Final Report. Prepared for Pacific NorthWest LNG Limited Partnership. Burnaby, BC. 154 pp. Available at: <http://www.pacificnorthwestlng.com/media/Marine%20Mammal%20Final.pdf>.
- Sundermeyer, J.K., K. Lucke, M. Dahne, A. Gallus, K. Krugel and U. Siebert. 2012. Effects of Underwater Explosions on Presence and Habitat Use of Harbor Porpoises in the German Baltic Sea. In A. N. Popper & A. Hawkins (Eds.), *Effects of Noise on Aquatic Life*. Vol. 730, 289-291.
- Thomas, L., R. Williams and D. Sandilands. 2007. Designing line transect surveys for complex survey regions. *Journal of Cetacean Research and Management* 9(1):1-13.
- Todd, S., P.T. Stevick, J. Lien, F. Marques and D. Ketten. 1996. Behavioral effect of exposure to underwater explosion in humpback whales. *Canadian Journal of Zoology* 74:1661-1672.
- Todd, V.L.G., I.B. Todd, J.C. Gardiner, E.C.N. Morrin, N.A. MacPherson, N.A. DiMarzio and F. Thomsen. 2015. A review of impacts of marine dredging activities on marine mammals. *ICES Journal of Marine Science: Journal du Conseil* 72(2):328-340.
- Tougaard, J., J. Carstensen, J. Teilmann, H. Skov and P. Rasmussen. 2009. Pile driving zone of responsiveness extends beyond 20 km for harbor porpoises (*Phocoena phocoena*). *Journal of the Acoustical Society of America* 126(1):11-14.
- Tougaard, J., L.A. Kyhn, M. Amundin, D. Wennerberg and C. Bordin. 2012. Behavioral Reactions of Harbor Porpoises to Pile-driving Noise. In A. N. Popper & A. Hawkins (Eds.), *Effects of Noise on Aquatic Life*. Vol. 730, 277-280.
- Tougaard, J., A.J. Wright and P.T. Madsen. 2015. Cetacean noise criteria revisited in the light of proposed exposure limits for harbour porpoises. *Marine Pollution Bulletin* 90(1):196-208.

- Tyack, P.L. 2008. Implications for marine mammals of large-scale changes in the marine acoustic environment. *Journal of Mammalogy* 89(3):549-558.
- Van Der Hoop, J.M., A.S. Vanderlaan and C.T. Taggart. 2012. Absolute probability estimates of lethal vessel strikes to North Atlantic right whales in Roseway Basin, Scotian Shelf. *Ecological Applications* 22(7):2021-2033.
- van Opzeeland, I. and H. Slabbekoorn. 2012. Importance of Underwater Sounds for Migration of Fish and Aquatic Mammals. In A. N. Popper & A. Hawkins (Eds.), *Effects of Noise on Aquatic Life*. Vol. 730, 357-359.
- Van Waerebeek, K., A.N. Baker, F. Félix, J. Gedamke, M. Iñiguez, G.P. Sanino, E. Secchi, D. Sutaria, A. van Helden and Y. Wang. 2007. Vessel collisions with small cetaceans worldwide and with large whales in the Southern Hemisphere, an initial assessment. *Latin American Journal of Aquatic Mammals* 6(1):43-69.
- Vanderlaan, A.S., J.J. Corbett, S.L. Green, J.A. Callahan, C. Wang, R.D. Kenney, C.T. Taggart and J. Firestone. 2009. Probability and mitigation of vessel encounters with North Atlantic right whales. *Endangered Species Research* 6(3):273-285.
- Vanderlaan, A.S.M. and C.T. Taggart. 2007. Vessel collisions with whales: The probability of lethal injury based on vessel speed. *Society for Marine Mammology* 23(1):144-156.
- Vanderlaan, A.S.M., C.T. Taggart, A.R. Serdynska, R.D. Kenney and M.W. Brown. 2008. Reducing the risk of lethal encounters: vessels and right whales in the Bay of Fundy and on the Scotian Shelf. *Endangered Species Research* 4:283-297.
- Wartzok, D., Popper, A.N., Gordon, J. and J. Merrill. 2003. Factors affecting the responses of marine mammals to acoustic disturbance. *Marine Technology Society Journal*, 37(4):6-15.
- Watkins, W.A., 1986. Whale reactions to human activities in Cape Cod waters. *Marine mammal science*, 2(4):251-262.
- Wiley, D.N., M. Thompson, R.M. Pace III and J. Levenson. 2011. Modeling speed restrictions to mitigate lethal collisions between ships and whales in the Stellwagen Bank National Marine Sanctuary, USA. *Biological Conservation* 144:2377-2381.
- Williams, R., D.E. Bain, J.K.B. Ford and A.W. Trites. 2002a. Behavioural responses of male killer whales to a 'leapfrogging' vessel. *Journal of Cetacean Research and Management* 4(3):305-310.
- Williams, R., C.W. Clark, D. Ponirakis and E. Ashe. 2013. Acoustic quality of critical habitats for three threatened whale populations. *Animal Conservation* 17(1):12.
- Williams, R., D. Lusseau and P.S. Hammond. 2006. Estimating relative energetic costs of human disturbance to killer whales (*Orcinus orca*). *Biological Conservation* 133:301-311.
- Williams, R. and P. O'Hara. 2009. Modelling ship strike risk to fin, humpback and killer whales in British Columbia. *Journal of Cetacean Research and Management* 11:1-8.
- Williams, R., A.W. Trites and D.E. Bain. 2002b. Behavioural responses of killer whales (*Orcinus orca*) to whale-watching boats; opportunistic observations and experimental approaches. *Journal of the Zoological Society of London* 256:255-270.

- Wood, J., B.L. Southall and D.J. Tollit. 2012. *PG&E offshore 3D Seismic Survey Project EIR-Marine Mammal Technical Draft Report*. SMRU Ltd. 124 pp.
- Wright, A.J., N.A. Soto, A.L. Baldwin, M. Bateson, C.M. Beale, C. Clark, T. Deak, E.F. Edwards, A. Fernández, A. Godinho, L.T. Hatch, A. Kakuschke, D. Lusseau, D. Martineau, M.L. Romero, L.S. Weilgart, B.A. Wintle, G. Notarbartolo-di-Sciara and V. Martin. 2007. Do marine mammals experience stress related to anthropogenic noise? *International Journal of Comparative Psychology* 20:274-316.
- Wright, D.L. and G.E. Hopky. 1998. *Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters*. Canadian Technical Report of Fisheries and Aquatic Sciences, (No. 2107). Minister of Public Works and Government Services Canada. Winnipeg, MB. 39 pp.

