4.6 Marine Mammals Assessment Highlights:

- Marine mammals, specifically harbour seals and sea lions, are known to use marine areas within the Project alignment. Other species of conservation interest, including southern resident killer whales, do not occur in the Fraser River.
- Underwater noise during construction is the key area of focus for potential Project-related effects on marine mammals.
- Underwater noise in the Fraser River South Arm from existing sources currently exceed thresholds for disturbance to marine mammals approximately 20% of the time.
- The distance from source within which seals could hear underwater noise generated by construction activities is estimated at no more than 7.5 km.
- Standard industry and best management practices will be applied to activities such as impact pile driving that have the potential to generate underwater noise to ensure sound thresholds for the protection of marine mammals are adhered to.
- No Project-related residual or cumulative effects on marine mammals are expected.

4.6 Marine Mammals Assessment

This section presents the results of the assessment of potential Project effects on marine mammals and includes the rationale for selecting marine mammals as a valued component (VC), identification of Project-related effects, proposed approaches to mitigation, and evaluation of residual Project-related and cumulative effects.

4.6.1 Context and Boundaries

This section describes the context for assessment of Project-related effects on marine mammals in terms of Project setting, and defines the spatial, temporal, administrative and technical assessment boundaries. Rationale for selecting the assessment boundaries as defined is also provided.

No jurisdictional, economic, or social constraints that could impose limitations on the assessment of potential Project-related effects, accessibility constraints, or gaps in data that could limit the ability to predict the effects of the Project were identified; therefore, administrative or technical boundaries are not considered relevant.

4.6.1.1 Assessment Context

The Project is located in close proximity to the Strait of Georgia which supports a number of marine mammals, including toothed whales, baleen whales, seals, sea lions, and sea otters. In the Strait of Georgia, marine mammals are the focus of a substantial wildlife viewing and ecotourism industry and are of cultural importance to Aboriginal Groups and the public.

Within the lower Fraser River and the Project alignment, only seals, particularly harbour seals and sea lions, are likely to occur, and their presence is seasonal.

Aboriginal Groups have reported that areas within the wider Fraser River estuary were utilized by *Hul'q'umi'num'*-speaking peoples for harvesting marine mammals such as seals, porpoise, sea otters, sea lions, and whales). The most common marine mammals harvested within the Fraser River estuary included harbour seal, sea lion, and porpoise. It is understood that although there is currently no desire to harvest marine mammals; they remain culturally important to Aboriginal Groups. Details on how Project components and activities have the potential to interact with and adversely affect the availability of resources associated with the exercise of Aboriginal Interests by changing species abundance or habitat, or by causing sensory disturbance, changes in behavior, or harm (physical injury or mortality) to marine mammals is provided in Section 10 Aboriginal Consultation.

Table 4.6-1 details the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designation for marine mammal species that may occur within the Project alignment. Other species of conservation concern, including southern resident killer whales, do not occur in the Fraser River or within the Project alignment.

Table 4.6-1 Marine Mammal Species with Potential to Occur within the Project alignment

Common Name (COSEWIC Designation)	Scientific Name	Likelihood of Occurrence within the Project alignment
Pinnipeds – Seals and Sea Lions		
California sea lion (not at risk)	*Zalophus californianus*	Low (recorded in the Project alignment infrequently)
(Northern) Steller sea lion (Special Concern)	*Eumetopias jubatus*	Moderate (recorded in the Project alignment somewhat regularly)
Harbour seal (not at risk)	*Phoca vitulina*	High (recorded in the Project alignment in relatively high numbers)

4.6.1.2 Methodology

The marine mammals assessment follows the general methodology described in **Section 3.0 Assessment Methodology**.

In early 2014, the Ministry initiated desktop studies and underwater noise modelling to support Project planning and the assessment of potential Project-related effects. The studies were designed to build on existing information and address known data gaps.

Table 4.6-2 provides a summary of the studies conducted to support the marine mammals assessment. Further detail relating to the underwater noise modelling methodology and results can be found in **Section 4.3 Underwater Noise**.

Table 4.6-2 Marine Mammal Studies to Support the Assessment

Study Name	Purpose of Study
Literature review/ Desktop study	• Determine which marine mammals may be present in the local assessment area (LAA). • Identify key data gaps and areas of uncertainty within the LAA. • Sources of data included the *Species at Risk* Public Registry, COSEWIC Wildlife Species Database, and the BC Cetacean Sighting Network database, DFO Recovery Strategies and academic literature.
Modelling Study	• Acoustic models were used to predict the underwater noise footprint of proposed Tunnel decommissioning and bridge construction activities. These models were used to inform the marine mammals assessment.

Selection of Representative Species

Seals and sea lions occur in or near the Project alignment seasonally, with peak abundance in the lower Fraser River and estuary typically coinciding with seasonal physical and biological factors such as availability of prey. Due to similar life histories, habitat requirements, prey preferences, hearing sensitivities, and ecological roles between seals and sea lions, harbour seal was selected as the representative species for the marine mammals VC for the purposes of this assessment. Harbour seals are also common, conspicuous, and well-studied with an established baseline of population information. They are culturally important to Aboriginal Groups and the public. They have the potential to experience similar Project-related effects as sea lions. During consultations, the importance of southern resident killer whale (SRKW) to Aboriginal Groups was acknowledged; however, SRKW have been excluded from the assessment for the following reasons:

- SRKW are not present in the Fraser River; therefore, there is limited potential for direct interaction with Project activities.
- Preliminary results of conservative underwater noise modelling indicate underwater noise generated during construction will not travel beyond the Fraser River.
- Preliminary results of fish and fish habitat studies suggested potential effects of the Project on availability of Chinook salmon are negligible.

Indicator

Change in the acoustic environment from underwater noise was used as an indicator to evaluate potential Project-related effects on marine mammals. Sound pressure level and sound exposure level are two metrics that are commonly used to assess the potential for injury or behavioural disturbance to marine mammals due to Project-related underwater noise. This assessment evaluates the effects of Project-related underwater and in-air noise on harbour seals.

4.6.1.3 Assessment Boundaries

This section describes the spatial and temporal boundaries for the assessment of marine mammals. No administrative or technical boundaries apply to this assessment.

Spatial Boundaries

The LAA and regional assessment area (RAA) for marine mammals are defined in **Table 4.6-3** and shown in **Figure 4.6-1**.

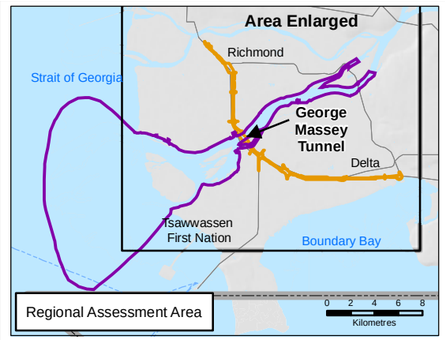
Table 4.6-3 Spatial Boundary Definitions for Marine Mammals

Spatial Boundary	Description of Assessment Area
Local Assessment Area (LAA)	All areas where Project-related effects to marine mammals could potentially occur, including the zone of audibility for harbour seals from modelled underwater noise from construction activities.
Regional Assessment Area (RAA)	Encompasses a portion of the Fraser River from the river mouth upstream to Annacis Island and a portion of Roberts Bank, and provides a regional context for the ecological effects of the Project.

The LAA boundaries were determined by considering the nature and characteristics of harbour seals as the representative VC species, as well as their potential for exposure to Project-related underwater noise, and the maximum extent of potential adverse effects. The RAA was established to provide a regional context for the assessment of Project-related effects.

Project activities during the construction phase are expected to temporarily increase underwater sound levels in the lower Fraser River above existing ambient sound levels within a certain zone upstream and downstream of the Project alignment. Within this zone, noise from Project-related activities may be audible to seals, and has the potential to cause hearing damage, or disturbance resulting in behavioural changes.

Due to the acoustic environment (e.g., riverbed sediment type, channel morphology) within the LAA, the underwater distance from the Project from which seals might hear underwater noise generated by construction activities is estimated at no more than 7.5 km. Beyond that distance, seals will not be able to differentiate Project-related underwater noise from existing ambient sound.



Legend

- Marine Mammals Local Assessment Area
- Marine Mammals Regional Assessment Area
- Project Alignment
- First Nation Reserve
- Municipal Boundaries
- Burns Bog Ecological Conservancy Area
- Waterbody
- Canada - U.S. Border
- Highway
- Arterial/Collector Road

SOURCES

Parks and Protected Lands, First Nations Reserves from GeoBC, United States basemap data courtesy of USGS. Burns Bog courtesy of The Corporation of Delta and based on the Metro Vancouver Burns Bog Ecological Conservancy Area Management Plan - May 2007, all other data courtesy of Canvec - GeoGratis.

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GEORGE MASSEY TUNNEL REPLACEMENT PROJECT

MARINE MAMMALS
LOCAL AND REGIONAL ASSESSMENT AREAS

Figure 4.6-1	14/07/2016

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Temporal Boundaries

Temporal boundaries for the assessment of Project-related effects on marine mammals were established based on the potential for each phase of the Project to interact with, and have an effect on, marine mammals. As discussed in **Section 3.1 Issues Scoping and Selection of Valued Components**, both the construction and operational phases of the Project include components and activities that could interact with, and affect, marine mammals; therefore, the following temporal boundaries will be assessed:

- Existing conditions.
- Project construction (including Tunnel decommissioning).
- Project operation (including maintenance).

Temporal characteristics of the Project phases are discussed in **Section 1.1 Description of Proposed Project**. Specific temporal considerations for the assessment of marine mammals are discussed in the context of Project interactions and potential effects in **Section 4.6.3**.

4.6.2 Existing Conditions

This section provides an overview of the methodology for collecting baseline data and describes the existing conditions of the representative species, harbour seal, in the LAA and RAA, and the factors influencing those conditions. A summary of Steller and California sea lion abundance and habitat requirements in and near the Project alignment is also provided to strengthen rationale for selection of harbour seal as a representative species for the marine mammal VC.

4.6.2.1 Regulatory Context

Regulation and management of marine mammals occurs primarily through the Marine Mammal Regulations SOR/93-56 of the *Fisheries Act*, R.S.C. 1985, c. F-14, and the *Species at Risk Act (SARA)*, S.C. 2002, c. 29.

Fisheries Act

Section 7 of the Marine Mammal Regulations prohibits the disturbance of marine mammals, unless fishing for marine mammals under the authority of the regulations. Marine animals, including marine mammals, are defined as fish under the *Fisheries Act*. The *Fisheries Act* provides for the protection of marine mammal habitat from physical alteration and introduction of deleterious substances.

Species at Risk Act

The purpose of *SARA* is “to prevent wildlife species from being extirpated or becoming extinct, to provide for the recovery of wildlife species that are extirpated, endangered or threatened as a result of human activity and to manage species of special concern to prevent them from becoming endangered or threatened." Section 32 of *SARA* further states that “no person shall kill, harm, harass, capture or take an individual of a wildlife species that is listed as an extirpated species, an endangered species or a threatened species.”

Steller sea lion (*Eumetopias jubatus*) is the only marine mammal species listed under *SARA* Schedule 1 (Special Concern) that may occur in the Project alignment. The term “Special Concern” refers to species that could become threatened or endangered because of a combination of biological characteristics and identified threats (DFO 2010*b*).

Historically, Steller sea lions were the target of subsistence and commercial hunts, and were subject to predator control programs and commercial harvests. As a result, the population decreased substantially by the 1970s to approximately 25 to 33 per cent of early 1900s levels (DFO 2008). In 1971, protection for this species was provided under the *Fisheries Act*. Despite an average increase of 3.2% per year since 1971 in the B.C. population (Pitcher et al. 2007), COSEWIC upgraded the listing for this species from Not at Risk to Special Concern in 2003 for the following reasons:

- There are only three major breeding locations in B.C.
- The species is sensitive to human disturbance while on land.
- There is a threat of acute oil spills, which could hinder recovery of at-risk populations.
- There have been unexplained declines in other populations to the north and west of B.C. (COSEWIC 2003, DFO 2003, 2008).

Other potential threats to Steller sea lions include human disturbance, entanglement in fishing gear, and persecution by humans (SCBC 2009).

Provincial and Other Regulatory Designations

Steller sea lion is provincially Blue-listed (i.e., of Special Concern in B.C.; B.C. CDC 2014). Under the International Union for Conservation of Nature, the eastern Steller sea lion population (which includes the B.C. population) is listed as of Least Concern, and the western population as Near Threatened (Gelatt and Lowry 2012).

4.6.2.2 Existing Conditions

Steller Sea Lion

Steller sea lions use marine habitats to forage and terrestrial locations as haul-out sites (Jeffries et al. 2000, DFO 2010*a*). Steller sea lions haul out on rocky outcrops, logbooms, floats, and docks when not foraging, to avoid predators, thermoregulate, engage in social activity, rest, and reproduce. Breeding of Steller sea lions occurs from May to August (LGL Limited et al. 2009), in four rookeries: northern tip of Vancouver Island, southern tip of Haida Gwaii, as well as central and northern mainland coasts (DFO 2008, BCMCA Project Team 2011). In late summer and autumn, sea lions disperse to wintering haul-out sites. Winter haul-out sites have been identified on the southern B.C. coast, including the Strait of Georgia (Jeffries et al. 2000, DFO 2003, Olesiuk 2009). The documented haul-out site closest to the Project alignment is near Sand Heads (along the Steveston jetty) at the mouth of the Fraser River, approximately 18 km downstream of the Project (Jeffries et al. 2000, DFO 2010*b*). While Steller sea lions can be found year-round in marine waters (COSEWIC 2003, DFO 2010*b*), they occasionally venture into freshwater, as far as 35 km upriver (Olesiuk, unpublished data as cited in DFO 2010*b*). They also congregate in estuaries during autumn to feed on pre-spawning salmon and at the mouth of the Fraser River in spring when eulachon are running (Bigg 1985, Bigg et al. 1990, Olesiuk, unpublished data as cited in DFO 2010*b*). While eastern Steller sea lion may occur near the Project alignment, they are not likely to be present in large numbers. During consultation on the Project, Aboriginal Groups noted that Stellar sea lions were historically hunted in the Project area.

California Sea Lion

California sea lions congregate on rookeries off the coast of California and Mexico to mate and pup between May and August. At the end of the breeding season, they leave the rookeries and disperse. Females and juveniles remain in California and Mexico, while adult and sub-adult males travel north as far as central Vancouver Island, arriving in B.C. in September to October and departing from April to May. Approximately 3,000 California sea lions winter in B.C., where individuals feed mainly on mid-water schooling fish such as herring, hake, pollock, and dogfish (Olesiuk and Bigg 1984). Numbers have increased substantially over the past 30 years, likely due to recovery of the breeding population in California and the recovery of local herring stocks (Olesiuk and Bigg 1988). California sea lions occur in waters adjacent to the Project alignment less frequently than Steller sea lions. They have been documented hauling out near Sand Heads (along the Steveston jetty) at the Fraser River mouth (Jeffries et al. 2000, DFO 2010*b*).

Harbour Seal

The harbour seal is the most abundant marine mammal species in B.C. With a population estimated at about 105,000 individuals in 2008, their numbers may be approaching historic highs (Olesiuk 1999, DFO 2010*a*). Historically, harbour seals were hunted for pelts to the point of population depletion. Since 1970, however, there have been no commercial harvests or predator control efforts (DFO 2008, 2010*a*). The current population size appears to be similar to pre-exploitation levels of the 1880s, and recent increases can be attributed to population recovery since cessation of over-hunting. The highest harbour seal population density occurs in the Strait of Georgia (13.1 seals per km of shoreline), representing 37% (39,000 individuals) of the provincial population (DFO 2010*a*).

Harbour seals inhabit estuarine and coastal waters, and haul out on rocks, reefs, and beaches. Unlike sea lions, harbour seals do not congregate on a few large rookeries, but breed in smaller groups along shorelines throughout most of their range. In southern B.C., female harbour seals give birth to a single pup each year, from early July to late August, while hauled out on shore (Olesiuk et al. 1990, Olesiuk 1999, DFO 2010*a*). Harbour seal pups are relatively mature and mobile at birth and are reared in the water as well as on land (Riedman 1990). The mother and pup remain together until weaning occurs at three to six weeks after birth (Bishop 1967, Bigg 1969). Moulting (shedding of hair) occurs from late June to October during which time harbour seals are typically hauled out on shore.

During late autumn and winter, harbour seals can be at sea continuously for several weeks to feed and regain weight lost during the mating and moulting seasons. They are thought to be an inshore species, occurring within 20 km of land (Spalding 1964); however, some individuals have been observed up to 100 km from shore (DFO 2010*a*). Juvenile harbour seals can travel up to 525 km to forage or disperse when population densities get too high. Adults usually remain closer to their haul-outs (i.e., within about 35 km) (Frost 1997). The smaller home range used by adults suggests strong site fidelity (Pitcher and Calkins 1979, Pitcher and McAllister 1981, Lowry et al. 2001).

Harbour seals are generally non-migratory, but move locally with time of day, tides, weather, season, food availability, and to find mates (Scheffer and Slipp 1944, Bigg 1969, 1981, Frost et al. 1996, 1997, Olesiuk et al. 1995, Swain et al. 1996). They are typically seen in small groups, resting on exposed reefs, boulders, and sandbars, but can also sleep for short periods underwater on the ocean floor if no suitable haul-out is available (Baird 2001).

Harbour seals (*Phoca vitulina*) are common year-round in the Strait of Georgia (Keple 2002), relatively common in the lower Fraser River, especially in channels and sloughs (Fisher 1952), and found in proximity to the Project (Tim McCormick, personal communication, 2014). They forage at the mouth of rivers and streams and enter navigable rivers and lakes in pursuit of prey such as spawning salmon (e.g., Baird 2001). The Fraser River is one of the most important rivers in terms of seal abundance (Fisher 1952) and harbour seals have been known to travel 50 km up the Fraser River (DFO 2010*a*). The nearest documented haul-out site to the Project alignment is at Garry Point, on the southeastern edge of Sturgeon Bank (EAO and VFPA 2012). Fishers on the Fraser River have stated that it used to be unusual to see harbour seals far up the Fraser River, but now they are regularly observed feeding on migrating runs of eulachon and salmon (DFO 2010*a*, Hume 2010). Vessel operators along the river have reported seals at the river mouth and hundreds hauled-out on log booms (Hume 2010). A DFO assessment in 2000 determined that approximately 1,600 harbour seals are present in the Fraser River (Pablo 2008, DFO 2010*a*).

Acoustic Environment

Marine mammals use sound as a primary means of underwater communication and sensing. A considerable number of studies have been undertaken in the last decade to describe the effects of anthropogenic noise on marine organisms (Richardson et al. 1995, U.S. NRC 2003, 2005, Wright 2008).

Underwater noise due to the Project could affect marine mammal hearing, communication, or behaviour. Effects to hearing can include temporary or permanent hearing loss, or auditory masking. Behavioural effects can include increased breathing rates, more time spent under or at the water surface, changes in swimming direction or speed, or displacement or avoidance of habitat. Underwater noise could potentially result in behavioural effects, displacement, or habitat avoidance. The types and ranges of effects are highly dependent on the characteristics of the sound source, the environment in which the sound occurs, and the animal(s) receiving the sounds (Richardson et al. 1995, Southall et al. 2007).

The LAA is currently subject to underwater and in-air noise from a variety of anthropogenic sources — mainly commercial and recreational vessel traffic and industrial activity — that contribute to the ambient noise levels. Existing conditions of underwater noise currently exceed thresholds for behavioural disturbance to marine mammals approximately 20 percent of the time. Details on the existing conditions of ambient underwater sound and underwater noise levels associated with the Project are provided in **Section 4.3 Underwater Noise**.

4.6.3 Potential Effects

This section discusses anticipated interactions of Project components and activities with marine mammals, and the potential effects of such interactions. Information on the mitigation of potential effects, including Project design measures to avoid adverse effects, is provided in **Section 4.6.4**.

4.6.3.1 Project Interactions

This section presents a preliminary evaluation of the potential effects of Project interactions on marine mammals for the purpose of focusing the assessment on those interactions of greatest importance. An overview of potential interactions between Project activities and marine mammals during Project construction is provided in **Appendix A**.

Construction: Potential interaction with, and effects on, marine mammals during Project construction may include the following:

- Physical injury during Project construction activities along the edge of Deas Slough, including pile driving, that can generate underwater noise at levels sufficient to injure the hearing of marine mammals, and injury or mortality due to collisions with construction-related vessels or equipment on land or in water.
- Behavioural changes resulting from construction activities along the edge of Deas Slough and Tunnel removal, including vibrodensification, vibratory pile driving, and operation of support vessels, that can generate underwater and in-air noise at levels sufficient to disturb, but not injure, marine mammals.
- Behavioural changes resulting from construction and operation activities that could generate atmospheric (in-air) noise at levels sufficient to disturb marine mammals hauled out on land.
- Potential effects from changes to sediment and water quality.

Operation: Project operation activities are not anticipated to generate underwater or in-air noise that can physically injure or disturb marine mammal behaviour, resulting in no adverse effects on marine mammals.

4.6.3.2 Potential Effects

Potential effects associated with the identified Project-marine mammal interactions were identified through discussions with regulators, Aboriginal Groups, stakeholders, review of the Project's Application Information Requirements, experience from past projects and activities, and professional judgement of the Project team. Potential effects from construction activities are anticipated to be similar for all marine mammals occurring in the Fraser River in the LAA.

Underwater and in-air noise generated during construction was carried forward into the assessment. Potential changes associated with other Project interactions, including potential changes to sediment and water quality and potential collisions with vessels and other construction equipment either on land or in water, were determined to have a negligible effect on marine mammals and were not considered further.

As harbour seals are not common in the Fraser River and it is not their prime habitat (marine), any short-term effects to their habitat or prey from changes in sediment and water quality will not affect their ability to feed and successfully reproduce. The change in harbour seal habitat quality between existing conditions and the Project was considered negligible.

Collisions between construction-related vessels and construction equipment and harbour seals may be fatal to a harbour seal, or an individual may recover. However, only one record of a pinniped (sea lion) strike has been reported in B.C. (2009), involving a whale watching vessel at Race Rocks Marine Reserve (DFO Marine Mammal Incident Database 1973 to October 2012). Vessel strikes were not identified as a potential threat in the DFO Management Plan for harbour seals and will not be assessed further. Due to their small size and agility, and propensity to flee terrestrial disturbance while on haulouts, the chance of a Project-related vessel or construction equipment striking a seal and resulting in injury or mortality during construction is very low and determined to be negligible and no adverse effects to marine mammals are anticipated.

Mitigation measures, including Project design measures to avoid or reduce adverse effects, are described in **Section 4.6.4**. Potential residual effects residual effects of the Project on marine mammals in terms of established criteria are discussed in **Section 4.6.5**. A determination of the significance of each residual effect, the likelihood of the residual effect, and the level of confidence in each residual effect prediction, if applicable, are also presented in **Section 4.6.5**. The potential for cumulative effects is assessed in **Section 4.6.6**.

Potential Effects of Underwater Noise

Underwater Noise Background

Sound can be classified as either pulsed or non-pulsed (i.e., continuous). Pulsed sound is brief (less than a few seconds) and intermittent, with rapid changes of sound pressure (e.g., a seismic airgun shot or an impact-hammer strike). Non-pulsed sound is characterized by gradual changes in sound pressure over time (e.g., marine vessels transiting and a vibratory pile driver in operation).

Several acoustic metrics (detailed in **Section 4.3 Underwater Noise**) are typically used to characterize pressure levels of underwater sound. Metrics used to assess potential injury and behavioural disturbance to marine mammals as a result of underwater noise generated during Project-related construction activities include:

- Root mean square (rms) sound pressure levels (SPL): the average pressure in a given time window of noise.
- Peak SPL: the maximum level attained by an acoustic pressure signal. This metric is commonly quoted for pulsed sound, and can be a criterion for assessing whether a sound could cause injury.
- Sound exposure level (SEL): the total acoustic energy received at a given location during an acoustic event, and thus the sound energy to which an organism at that location would be exposed. The SEL is also commonly used to quantify the loudness of noise.

Underwater Noise Effect Criteria

In Canada, there are currently no regulations or policies regarding underwater noise and marine mammals. Two widely acknowledged yet different sets of injury and disturbance criteria, however, are commonly used to assess sound exposure of marine mammals (see **Table 4.6-4**; refer also to **Section 4.3 Underwater Noise**):

- Regulatory criteria applied in the U.S. by the National Marine Fisheries Service (NMFS)[1] (Funk et al. 2008).
- Criteria recommended by Southall et al. (2007).

These criteria incorporate available known marine mammal reactions and various physical injury and behavioural effects due to pulsed and non-pulsed underwater noise sources.

The NMFS injury criteria are based on the rms SPL of a single pulse, averaged over the pulse duration to which a marine mammal may be safely exposed before injury occurs. The NMFS has not established injury criteria for exposure to non-pulsed sounds.

Southall et al. (2007) employ a dual criteria based on peak SPL and cumulative M-weighted SEL thresholds; the cumulative injury criteria (SEL) are specified as originating from single- or multiple-exposure events over a 24-hour period. A received sound exposure is assumed to cause injury if it exceeds either the peak SPL or the SEL criterion, or both. Southall et al. (2007) do not recommend specific SPL thresholds for marine mammal disturbance criteria.

[1] The NMFS auditory injury threshold criteria are under review but remain in use until newly proposed draft criteria are revised and formally accepted by the agency.

Table 4.6-4 National Marine Fisheries Service (NMFS) and Southall et al. (2007) Auditory Injury and Disturbance Thresholds for Seals in Water

NMFS rms SPL Thresholds (dB re 1 µPa)				Southall et al. (2007) M-weighted 24-Hour SEL Thresholds (dB re 1 $\mu Pa^2 s$)	Southall et al. (2007) peak SPL Thresholds (dB re 1 µPa)
Continuous Sound		Pulsed Sound		Pulsed Sound	
Injury	Disturbance	Injury	Disturbance	Injury	Injury
-	120	190	160	186	218

Notes: SEL: sound exposure level
rms SPL: root mean square sound pressure level

Potential Effects of Underwater Noise during Construction

Proposed construction activities associated with the Project will generate underwater noise that can potentially injure or disturb marine mammals in the Fraser River. Physical injury and behavioural disturbance effects were assessed based on the distance sound propagates away from the sound source, modelled for six conservative Project construction scenarios that are likely to produce the greatest amount of underwater sound. These scenarios are as follows:

1. Localized impact pile driving along Deas Slough.
2. Localized vibratory pile driving along Deas Slough.
3. Localized vibrodensification along Deas Slough.
4. Cutter suction dredging with tug operating at the Tunnel.
5. Tugs operating at the Tunnel during Tunnel segment lifting.
6. Combined operation of tugs (Tunnel segment lifting) and sediment removal in the Fraser River.

Details on the underwater noise modelling methods, scenarios, source levels, and predicted underwater noise produced during Project construction activities are provided in **Section 4.3 Underwater Noise**. Modelling results are summarized below and in **Table 4.6-5**. It should be noted that modelled scenarios are highly conservative as they assumed construction activities in water up to 5 m in depth, and actual construction work is anticipated to occur on land or in shallow water.

Physical Injury

Project construction activities that will produce underwater noise include impact pile driving, vibratory pile driving, vibrodensification, sediment removal, lifting of the Tunnel segments, and support vessel movements. Of the six scenarios modelled (**Table 4.6-5**), in-water impact hammer pile driving in Deas Slough is the only activity that could potentially generate sound levels sufficient to physically injure the hearing of harbour seals within 53 m of the pile driving noise source. Hearing damage to harbour seals from vibratory pile driving in Deas Slough was predicted to occur within nine metres from the sound source. A worst-case scenario of 100 minutes of impact pile driving (M-weighted 24-hr SEL threshold) resulted in a zone of injury having a maximum radius of 618 m from the source (**Table 4.6-5**). Underwater noise generated during this construction scenario is not predicted to reach the mainstem of the Fraser River and will remain in Deas Slough.

These distances are conservative because they assume that 1) a seal is stationary for the duration of the sound exposure, and 2) that construction activities will occur in water. Avoidance behaviour by seals would reduce their overall sound exposure and thus the effective extent of the injury zone for impact pile driving. Furthermore, the modelled scenario considered pile driving at a depth of five metres below the water surface and localized pile installation may occur between the high and low tide water marks in dry conditions. Underwater noise is expected to be more strongly attenuated in shallow water, restricted by the surrounding slough and river banks, and absorbed by silt and clay sediments. Sediment-borne sound from impact pile driving is approximately 20 dB lower than water-borne sound (Zampolli et al. 2013). Propagation of sound through soil is expected to attenuate water-borne sound levels generated by pile driving. Thus, the six scenarios considered in this study represent the most conservative cases in terms of underwater noise emissions and potential physical injury radii.

Behavioural Disturbance

The Project-related construction activities of vibratory pile driving, vibrodensification, sediment removal, and operation of support vessels are not expected to generate sound at levels that could affect the hearing of harbour seals. However, underwater noise produced during these activities could result in behavioural disturbance.

For marine mammals, the area of potential disturbance is taken to be the zone within which sound levels exceed 120 dB rms SPL. The modelled extent of the 120 dB rms SPL zone for continuous sound sources, such as operation of tugs or vibrodensification, within which behavioural effects could occur ranges from between 441 m to 3,447 m from the source location (**Table 4.6-5**).

Although vibratory pile driving has the highest source level of all continuous sources, noise from this activity is concentrated at low frequencies (<200 Hertz), and would therefore rapidly dissipate in the shallow sediments of Deas Slough, meaning the extent of the behavioural effect zone (120 dB re 1 µPa SPL) would be relatively small (593 m) for this activity. The extent of the behavioural effect 120 dB re 1 µPa SPL zone would be smallest (441 m) for tug and barge activities during crane lifting of the Tunnel segments (scenario 5; **Table 4.6-5**).

Project-related sediment removal in preparation for Tunnel removal is assumed to occur during the prescribed least-risk timing window for the protection of juvenile salmon and eulachon (i.e., July 16 to February 28; FREMP 2006). Use of the Fraser River by seals and sea lions is known to be dependent on the seasonal migration of eulachon and salmon as a predictable and plentiful food source. This work window coincides with the time juvenile salmon and eulachon are absent from the lower Fraser River, and consequently, seals and sea lions that prey on them are also scarce or likely absent. Moreover, Project-related construction activities that have the potential to result in marine mammal behavioural disturbance will generate underwater noise that is similar to ambient acoustic levels measured in the lower Fraser River 20% of the time (see **Section 4.3 Underwater Noise**).

Seals and sea lions are known to habituate readily to human activity, including underwater noise. Previous monitoring of disturbance of seals and sea lions, at Race Rocks Ecological Reserve (Strait of Juan de Fuca, B.C.), from underwater noise generated by blasting of explosives during nearby military training indicated that behavioural changes, including displacement from a haul-out, were short term with little or no consequence on long-term use (Demarchi 2010). Shortly after each observable disturbance, animals typically returned to the haul-out, suggesting their resilience to this type of disturbance. With repeated disturbance over a period of a year, individuals continue to use Race Rocks as habitat with no measureable effect on seal or sea lion populations (Demarchi 2010).

Potential Effects of In-Air Noise during Construction

In-air noise during Project construction will not propagate into waters in the LAA at levels that could result in injury or behavioural effects to marine mammals. However, atmospheric noise could be audible to seals hauled out on land. Behavioural responses of seals to physical and acoustic disturbance range from increased alertness and sometimes threat displays to moving towards and flushing into the water. Some species have been observed to be more habituated to human disturbance (e.g., sea lions), while other species are more sensitive to disturbance (e.g., harbour seals). Studies of the distance of the disturbance source, whether land or water-based, from hauled-out harbour seals have found that the closer the disturbance,

the more likely seals are to flush into the water. The actual distance at which most flushing to the water occurs has varied from study site to study site, but has been given as approximately <100 m from disturbance, including vessels and pedestrian traffic (Allen et al. 1984, Jackson and Wilson 1990, Calambokidis et al. 1991, Brown and Prior 1998, Suryan and Harvey 1998, Jansen et al. 2010). However, the distance at which seals become alert and begin to move towards the water can be as much as 500 to 800 m at some sites (Henry & Hammill 2001, Wilson et al. 2011), and some seals begin to move into the water at 200 to 300 m for all vessels (Suryan and Harvey 1998), 300 to 500 m for cruise ships (Calambokidis et al 1991), 300 m for tour boats (Young 1998), 140 m for kayaks (Henry and Hamill 2001), and 137 m and 371 m for kayaks and stopped power boats respectively (Johnson and Acevedo-Gutiérrez 2007). Habituation to noise has also been observed in seals and sea lions hauled out on docks in direct proximity to regularly scheduled float plane operations in Victoria, B.C. (S. Meier, personal communication). In locations with regular vessel traffic, harbour seals have been observed to habituate and to allow close approach by touring boats that repeatedly visit haul-out locations (Bonner 1982, Johnson et al. 1989).

Potential behavioural effects to hauled-out harbour seals on land are not expected because of habituation. Any temporary behavioural changes will be short-term, and are not anticipated to result in population-level effects. Given this, potential changes in in-air noise levels from the Project are not anticipated to result in adverse effects to marine mammals.

Table 4.6-5 Predicted Distances within which Physical Injury and Behavioural Disturbance to Harbour Seals May Occur from Modelled Construction-related Underwater Noise Scenarios

Construction Scenario[2]	National Marine Fisheries Service Thresholds rms SPL (dB re µPa)			Southall et al. (2007) M-weighted 24-Hour SEL Threshold (186 dB re 1 µPa^{2}s)	Southall et al. (2007) peak SPL Threshold (218 dB re 1µPa)
	120 rms Behavioural Disturbance Radius Continuous Sound (m)	160 rms Disturbance Radius Pulsed Sound (m)	190 rms Injury Radius Pulsed Sound (m)	Injury Radius Pulsed Noise (m)	
1. Impact pile driving in Deas Slough	3,043	1,233	53	618	27
2. Vibratory pile driving in Deas Slough	593	58	9	n/a	n/a
3. Vibrodensification in Deas Slough	951	<10	n/a	n/a	n/a
4. Cutter suction dredging with tug operating at Tunnel crossing	2,726	11	n/a	n/a	n/a
5. Tugs operating at Tunnel crossing during Tunnel segment lifting	441	n/a	n/a	n/a	n/a
6. Combined operation of tugs (Tunnel segment lifting) and sediment removal in the Fraser River	3,447	10	n/a	n/a	n/a

Note: n/a = not applicable (levels were not reached).

[2] Construction scenarios represent the most conservative scenario in terms of potential levels of underwater noise generated

4.6.4 Mitigation Measures

As described in **Section 12.0 Management Plans**, a Construction Environmental Management Plan (CEMP) and an Operational Environmental Management Plan (OEMP) will be developed for works to be undertaken during Project construction and operation. Pertinent to marine mammals, the CEMP will include component plans, organized by environmental topic, including a Marine Mammal Management Plan. The Marine Mammal Management Plan will describe standard best practices and mitigation measures, as well as monitoring efforts, to prevent or minimize potential adverse effects to marine mammals that might otherwise result from the Project during construction. In consultation with Fisheries and Oceans Canada (DFO), mitigation measures will be developed to avoid or reduce the potential adverse effects of the Project on marine mammals (as represented by harbour seals).

4.6.4.1 Mitigation Measure #1: Marine Mammal Management

A Marine Mammal Management Plan of the CEMP will be developed in consultation with DFO to mitigate potential effects of the Project to marine mammals during Project-related underwater construction activities and will describe the measures to be followed to minimize underwater noise. Specifically, construction activities that have the potential to generate underwater sound at levels that can physically injure marine mammals, such as impact pile driving, will adhere to standard industry and best management practices such that sound thresholds for the protection of marine mammals (**Section 4.6.3.2**) are not exceeded. For example, piles could be driven through construction pads to reduce sediment-borne sound levels generated during pile driving before they reach the aquatic medium.

The Marine Mammal Management Plan will focus on best practices and mitigation measures that will be implemented to minimize underwater noise generated during marine-based construction activities, and to mitigate the potential for physical injury to marine mammals. Mitigation and monitoring measures that will be described in the plan will include, but will not be limited to:

- Limited use of engines and propellers on stationary vessels, whenever possible.
- Maintaining consistent navigation courses and speeds.
- Conducting land-based pile driving whenever possible.
- Conducting activities with the potential to generate underwater noise as efficiently as possible.
- Avoiding unnecessary idling of marine-based equipment.

- Procedures to prevent direct or indirect discharge of deleterious substances (including soil, sediment, sediment laden or turbid water, or fuel, and oils) into the marine environment.
- Implementation of marine mammal monitoring during activities anticipated to generate underwater noise, including an underwater noise monitoring program.

4.6.4.2 Mitigation Measure #2: Underwater Noise Monitoring

As part of the Marine Mammals Management Plan, underwater noise monitoring will be conducted during Project construction activities that have the potential to generate underwater sound levels that may exceed auditory thresholds that can cause physical injury to fish and marine mammals. In consultation with DFO, underwater noise monitoring is expected to be conducted during Project construction in the Fraser River South Arm and Deas and Green Sloughs to confirm underwater noise levels and ensure that injury thresholds are not exceeded, as described in **Section 4.3.4.2 Underwater Noise, Underwater Noise Monitoring**.

4.6.5 Residual Effects and their Significance

Residual effects are those that are expected to persist after implementation of mitigation measures. Implementation of mitigation measures described in **Section 4.6.4** is anticipated to prevent physical injury and minimize the potential for behavioural disturbance of marine mammals (as represented by harbour seals). Potential effects of the Project to marine mammals will be temporally limited to the construction phase and spatially limited to those activities occurring within or along the Fraser River South Arm, Deas Slough and Green Slough. Mitigation is expected to be immediately effective in protecting harbour seals from underwater noise levels that could result in injury or mortality. These mitigation measures have been used worldwide for decades to effectively mitigate potential effects of marine industrial noise on marine mammals. As a result of the implementation of mitigation measures, Project-related construction activities are not anticipated to result in population-level effects to marine mammals, including species at risk, and no residual effects on marine mammals are anticipated.

4.6.6 Cumulative Effects and their Significance

Cumulative effects result from interactions between Project-related residual effects and incremental effects of other certain and reasonably foreseeable projects and activities. The Project is not likely to result in any residual adverse effects on marine mammals. Consequently, cumulative effects are not discussed further in this assessment.

4.6.7 Follow-up Strategy

As described above, underwater noise monitoring will be conducted during Project construction in the Fraser River South Arm and Deas and Green Sloughs to confirm underwater noise levels and ensure that injury thresholds are not exceeded, as described in **Section 4.3.4.2 Underwater Noise, Underwater Noise Monitoring**.

No follow-up strategy is proposed for marine mammals.

4.6.8 References

Allen, S. G., D. G. Ainley, G. W. Page, and C. A. Ribic. 1984. The Effect of Disturbance on Harbor Seal Haul Out Patterns at Bolinas Lagoon, California. Fishery Bulletin 82:493-500.

Baird, R. W. 2001. Status of harbour seals, *Phoca vitulina*, in Canada. Canadian Field-Naturalist 115:663–675.

Bigg, M. A., P. F. Olesiuk, G. M. Ellis, J. K. B. Ford, and K. C. Balcomb. 1990. Social organization and genealogy of resident killer whales (*Orcinus orca*) in the coastal waters of British Columbia and Washing State. Report of the International Whaling Commission (special issue) 12.

Bigg, M. A. 1969. The harbour seal in British Columbia. Bulletin of the Fisheries Research Board of Canada 172:1–33.

Bigg, M. A. 1981. Harbour seal, *Phoca vitulina*, Linnaeus, 1758 and *Phoca largha*, Pallas, 1811. Page 359 *in* S. H. Ridgway and R. J. Harrison, editors. Handbook of Marine Mammals. Volume 2: Seals. Academic Press, New York.

Bigg, M. A. 1985. Status of the Steller sea lion (*Eumetopias jubatus*) and California sea lion (*Zalophus californianus*) in British Columbia. Canadian Special Publication of Fisheries and Aquatic Sciences 77:1–20.

Bishop, R. H. 1967. Reproduction, age determination, and behavior of the harbor seal, *Phoca vitulina* L., in the Gulf of Alaska. M.Sc. Thesis, University of Alaska, Fairbanks, AK.

Bonner, W. N. 1982. Seals and man: a study of interactions. Washington Sea Grant Publication 143–161.

British Columbia Conservation Data Centre (B.C. CDC). 2014. B.C. Species and Ecosystems Explorer. Available at http://a100.gov.bc.ca/pub/eswp/search.do. Accessed October 2014.

British Columbia Marine Conservation Analysis (BCMCA) Project Team. 2011. Marine mammals – Steller sea lion haulouts and rookeries. Available at http://bcmca.ca/datafiles/individualfiles/bcmca_eco_mammals_stellersealionrookeries_ply_atlas.pdf. Accessed October 2014.

Brown, E. G. and A. Prior. 1998. Recreational Disturbance to Breeding Seabirds and Seals on Mousa, SSSI. Report to Scottish Natural Heritage, Contract no: HT/97/98/33.

Calambokidis, J., G. H. Steiger, J. R. Evenson, and S. J. Jeffries. 1991. Censuses and Disturbance of Harbor Seals at Woodard Bay and Recommendations for Protection. Final Report to the Washington Department of Natural Resources, Olympia. 44pp.

Committee on the Status of Endangered Wildlife in Canada (COSEWIC). 2003. Assessment and update status report on the Steller sea lion *Eumetopias jubatus* in Canada. COSEWIC, Ottawa, ON. Available at http://www.sararegistry.gc.ca/virtual_sara/files/cosewic/sr_steller_sea_lion_e.pdf. Accessed October 2014.

Demarchi, M. W. 2010. Effectiveness of a five-minute demolition interval to mitigate blasting noise impacts in military training area WQ on sea lions in the Race Rocks Ecological Reserve, British Columbia. Report #: EA3177, Prepared by LGL Limited for the Department of National Defence and Public Works and Government Services Canada, Sidney, B.C. Available at http://racerocks.ca/racerock/admin/military/5mineffective.pdf. Accessed October 2014.

Environmental Assessment Office (EAO), and Vancouver Fraser Port Authority (VFPA). 2012. Vancouver Airport Fuel Delivery Project Assessment Report and Screening Report. EAO and VFPA, Vancouver. B.C. Available at http://portmetrovancouver.com/docs/default-source/PROJECTS-Vancouver-Airport-Fuel-Delivery-/environmental-assessment-report.pdf?sfvrsn=0. Accessed October 2014.

Fisher, H. D. 1952. The status of the harbour seal in British Columbia, with particular reference to the Skeena River. Bulletin of the Fisheries Research Board of Canada 93:1–58.

Fisheries and Oceans Canada (DFO). 2003. Steller sea lion (Eumetopias jubatus). Canadian Science Advisory Secretariat, Stock Status Report 2003/037, Fisheries and Oceans Canada.

Fisheries and Oceans Canada (DFO). 2008. Population assessment: Steller sea lion (*Eumetopias jubatus*). Canadian Science Advisory Secretariat, Science Advisory Report 2008/047, Fisheries and Oceans Canada.

Fisheries and Oceans Canada (DFO). 2010*a*. Population assessment Pacific harbour seal (*Phoca vitulina richardsi*). Science Advisory Report 2009/011, Canadian Science Advisory Secretariat, Fisheries and Oceans Canada, Nanaimo, B.C. Available at http://www.dfo-mpo.gc.ca/Library/338997.pdf. Accessed October 2014.

Fisheries and Oceans Canada (DFO). 2010*b*. Management plan for the Steller sea lion (*Eumetopias jubatus*) in Canada. *Species at Risk Act* Management Plan Series, Fisheries and Oceans Canada, Ottawa, ON. Available at http://www.registrelep-sararegistry.gc.ca/virtual_sara/files/plans/mp_steller_sea_lion_012011_final-eng.pdf. Accessed October 2014.

Fraser River Estuary Management Program (FREMP). 2006. Environmental management strategy for dredging in the Fraser River estuary. Prepared by the Fraser River Estuary Management Program, Vancouver, B.C. Available at http://www.portmetrovancouver.com/docs/default-source/projects-dredging/FREMP_BEAP_Env_Mgt_Strategy_for_Dredging_FINAL-_February_2006.pdf?sfvrsn=0. Accessed October 2014.

Frost, K. F., L. F. Lowry, R. J. Small, and S. J. Iverson. 1996. Monitoring, habitat use, and trophic interactions of harbor seals in Prince William Sound. Exxon Valdez Oil Spill Restoration Project Annual Report, Alaska Department of Fish and Game, Division of Wildlife Conservation, Fairbanks, AK.

Frost, K. F., L. F. Lowry, J. M. VerHoef, and S. J. Iverson. 1997. Monitoring, habitat use, and trophic interactions of harbor seals in Prince William Sound, Alaska. Exxon Valdez Oil Spill Restoration Project Annual Report (Project # 96064), Alaska Department of Fish and Game, Division of Wildlife Conservation, Fairbanks, AK.

Frost, K. J. 1997. Harbour seal, *Phoca vitulina richardsi*. Restoration Notebook, Exxon Valdez Oil Spill Trustee Council.

Funk, D., D. Hannay, D. Ireland, R. Rodrigues, and W. Koski. 2008. Marine mammal monitoring and mitigation during open water seismic exploration by Shell Offshore Inc. in the Chukchi and Beaufort Seas, July-November 2007: 90-day report. LGL Report P969-1, Prepared by LGL Alaska Research Associates Inc., LGL Ltd., and JASCO Research Ltd., Prepared for Shell Offshore Inc., National Marine Fisheries Service (U.S.), and U.S. Fish and Wildlife Service.

Gelatt, T., and L. Lowry. 2012. *Eumetopias jubatus* (Steller sea lion). *In* IUCN 2013. The IUCN Red List of Threatened Species. Version 2013.2. Available at http://www.iucnredlist.org/details/8239/0. Accessed October 2014.

Henry, E. and M. O. Hammill. 2001. Impact of Small Boats on the Haulout Activity of Harbour Seals (*Phoca vitulina*) in Metis Bay, St. Lawrence Estuary, Quebec, Canada. Aquatic Mammals 27:140-148.Hume, M. 2010. Seals, sea lions devastating West Coast salmon runs. The Globe and Mail2010.

Jackson, D. B., and S. C. Wilson. 1990. Tees Seals Programme: The Feasibility Study. Final Report to Teesside Development Corporation. David Bellamy Associates.

Jansen J. K., P. L. Boveng, S. P. Dahle, and J. L. Bengston. 2010. Reaction of Harbour Seals to Cruise Ships. Journal of Wildlife Management 74:1186–1194.Jeffries, S. J., P. J. Gearin, H. R. Huber, S. L. Saul, and D. A. Pruett. 2000. Atlas of seal and sea lion haulout sites in Washington. Washington Department of Fish and Wildlife, Wildlife Science Division, Olympia, WA.

Johnson, A., and A. Acevedo-Gutiérrez. 2007. Regulation Compliance by Vessels and Disturbance of Harbour Seals (*Phoca vitulina*). Canadian Journal of Zoology 85: 290–294.

Johnson, S. R., J. J. Burns, C. I. Malme, and R. A. Davis. 1989. Synthesis of information on the effects of noise and disturbance on major haulout concentrations of Bering Sea pinnipeds. LGL Alaska Research Associates Inc.

Keple, A. R. 2002. Seasonal abundance and distribution of marine mammals in the southern Strait of Georgia, British Columbia. M.Sc. Thesis, University of British Columbia, Department of Zoology, Vancouver, B.C.

LGL Limited, KS Biological Services, and Pottinger Gaherty Environmental Consultants. 2009. Technical Volume 7 of the Environmental Assessment Application for the Naikun Offshore Wind Energy Project, Marine Mammals in the Naikun Offshore Wind Energy Project Area.

Lowry, L. F., K. J. Frost, J. M. Ver Hoef, and R. A. Delong. 2001. Movements of satellite tagged subadult and adult harbor seals in Prince William Sound, Alaska. Marine Mammal Science 17:835–861.

Olesiuk, P. E., L. M. Nichol, M. J. Sowden, and J. K. B. Ford. 1995. Effect of sounds generated by acoustic deterrent device on the abundance and distribution of harbor porpoise (*Phocoena phocoena*) in Retreat Passage, British Columbia. Available from Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo, B.C.

Olesiuk, P. F., M. A. Bigg, and G. M. Ellis. 1990. Recent trends in harbour seal (*Phoca vitulina*) in British Columbia. Canadian Journal of Fisheries and Aquatic Sciences 47:992–1003.

Olesiuk, P. F., and M. A. Bigg. 1984. Marine mammals in British Columbia. Fisheries and Oceans Canada, Nanaimo, B.C.

Olesiuk, P. F., and M. A. Bigg. 1988. Seals and sea lions on the British Columbia coast. DFO/4104, Fisheries and Oceans Canada. Available at http://www.dfo-mpo.gc.ca/Library/214368.pdf. Accessed October 2014.

Olesiuk, P. F. 1999. An assessment of the status of harbour seals (*Phoca vitulina*) in British Columbia. Canadian Stock Assessment Secretariat Research Document, Fisheries and Oceans Canada, Nanaimo, B.C. Available at http://www.dfo-mpo.gc.ca/Library/114690.pdf. Accessed October 2014.

Olesiuk, P. F. 2009. Abundance of Steller sea lions (*Eumetopias jubatus*) in British Columbia. Canadian Science Advisory Secretariat, Research Document 2008/063, Fisheries and Oceans Canada, Nanaimo, B.C.

Pablo, C. 2008. Native seal kills on the Fraser raise questions. Georgia Strait News. Available at http://www.straight.com/news/native-seal-kills-fraser-raise-questions. Accessed October 2014.

Pitcher, K. W., and D. G. Calkins. 1979. Biology of the harbour seal, *Phoca vitulina richardsi*, in the Gulf of Alaska. Final Report to OCSEAP, U.S. Department of Interior.

Pitcher, K. W., and D. C. McAllister. 1981. Movements and haulout behaviour of radio-tagged harbour seals, *Phoca vitulina*. Canadian Field-Naturalist 95:292–297.

Pitcher, K. W., P. F. Olesiuk, R. F. Brown, M. S. Lowry, S. J. Jeffries, J. L. Sease, W. L. Perryman, C. E. Stinchcomb, and L. F. Lowry. 2007. Status and trends in abundance and distribution of the eastern Steller sea lion (*Eumetopias jubatus*) population. Fishery Bulletin 105:102–115.

Richardson, W. J., C. R. Greene, C. I. Malme, and D. H. Thomson. 1995. Marine mammals and noise. Gulf Professional Publishing.

Riedman, M. 1990. The pinnipeds: seals, sea lions, and walruses. University of California Press, Berkeley, CA.

Scheffer, V. B., and J. W. Slipp. 1944. The harbor seal in Washington State. American Midland Naturalist 32:373–416.

Southall, B. L., A. E. Bowles, W. T. Ellison, J. J. Finneran, R. L. Gentry, C. R. Green Jr., 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 33:411–509.

Spalding, D. J. 1964. Comparative feeding habits of the fur seal, sea lion and harbour seal on the British Columbia coast. Fisheries Research Board of Canada Bulletin 146:1–52.

Stewardship Centre for British Columbia (SCBC). 2009. Steller sea lion. Species at risk: a primer for British Columbia. Available at http://www.speciesatriskbc.ca/node/7747. Accessed October 2014.

Suryan, R. M., and Harvey, J. T. 1998. Tracking Harbor Seals (*Phoca vitulina richardsi*) to Determine Dive Behavior, Foraging Activity, and Haul‐out Site Use. Marine Mammal Science 14 361-372.

Swain, U., J. Lewis, G. Pendelton, and K. Pitcher. 1996. Movements, haulout, and diving behavior of harbour seals in southeast Alaska and Kodiak Island. Annual Report: Harbor seal Investigations in Alaska, Alaska Department of Fish and Game, Division of Wildlife Conservation, Douglas, AK.

United States National Research Council (U.S. NRC). 2003. Ocean noise and marine mammals. U.S. National Research Council, Ocean Studies Board, Committee on Potential Impacts of Ambient Noise in the Ocean on Marine Mammals, National Academies Press, Washington, D.C.

United States National Research Council (U.S. NRC). 2005. Marine mammal populations and ocean noise: determining when noise causes biologically significant effects. U.S. National Research Council, Ocean Studies Board, Committee on Characterizing Biologically Significant Marine Mammal Behavior, National Academies Press, Washington, D.C.

Wilson, S., D. O'Malley, D. Cassidy, and D. Clarke. 2011. Surveying the Seals of Carlingford Lough – A Preliminary Study 2008–11. Report to the Loughs Agency (N. Ireland), December 2011.

Wright, A. J., editor. 2008. International workshop on shipping noise and marine mammals. Page v + 33 *in* Okeanos - Foundation for the Sea, Hamburg, Germany. Available at http://www.sound-in-the-sea.org/download/ship2008_en.pdf. Accessed October 2014.

Young, K. 1998. Seal Watching in the UK and Republic of Ireland. IFAW, UK.

Zampolli, M., M. J. J. Nijhof, C. A. F. de Jong, M. A. Ainslie, E. H. W. Jansen, and B. A. J. Quesson. 2013. Validation of finite element computations for the quantitative prediction of underwater noise from impact pile driving. Journal of the Acoustical Society of America 133:72–81.

APPENDIX A

Overview of Potential Project Interactions with Marine Mammals

Table 1 Overview of Potential Project Interactions with Marine Mammals

Project Phase/Component	Interaction Ranking	Project Works and Activities that Interact with the VC	Nature of Potential Interaction
Pre-Construction / Site Preparation			
Pre-construction / site preparation	No Interaction	• Surveying • Clearing and grubbing of vegetation within the existing Highway 99 ROW • Installing temporary drainage structures and diversions • Conducting additional site investigations (i.e., a geotechnical drilling program) • Installing temporary roads, laydown areas, and site offices • Relocating utilities • Preloading for embankment and highway construction • Acquiring property for the Project	**Nature of interaction:** No interaction anticipated. **Rationale:** Activities to be land-based.
	No Effect	• N/A	N/A
	Potential Effect	• Restoration of Green Slough to its historic alignment • Installing temporary bridges and barging facilities	**Potential Project-related effects include:** • Behavioural disturbance (i.e., some individuals hauled out may re-enter the water) from increased atmospheric noise. Potential effect is expected to be negligible, affecting individuals hauled out on land. The nearest haul-out site is at the Fraser River mouth, approximately 18 km downstream of the Project alignment. • Behavioural disturbance, hearing loss, or auditory masking from increased underwater noise.

Project Phase/Component	Interaction Ranking	Project Works and Activities that Interact with the VC	Nature of Potential Interaction
Construction			
New bridge including approaches and ramp connections	No Interaction	• Installing upland piers, including pile installation • Installing drainage structures/settling ponds • Constructing approach spans (concrete deck slab on steel or concrete girder) • Constructing bridge towers and installing support cables using land-based equipment • Installing retaining walls	**Nature of interaction:** No interaction anticipated. **Rationale:** Activities to be land-based.
	No Effect	• N/A	N/A

Project Phase/Component	Interaction Ranking	Project Works and Activities that Interact with the VC	Nature of Potential Interaction
	Potential Effect	• Ground improvements associated with new bridge piers • Installing piers adjacent to Deas Slough and Green Slough, including pile installation • Hoisting pre-assembled deck segments from barges in the river or land-based transport system	**Potential Project-related effects include:** • Behavioural disturbance (i.e., some individuals hauled out may re-enter the water) from increased atmospheric noise. Potential effect is expected to be negligible, affecting individuals hauled out on land. The nearest haul-out site is at the Fraser River mouth, approximately 18 km downstream of the Project alignment. • Auditory physical injury (impact pile driving) or behavioural disturbance (vibratory pile driving and in-river operation of construction vessels) from increased underwater noise. Noise from machinery and equipment during hoisting pre-assembled deck segments from barges in the river or land-based transport system and partial infilling of Green Slough is expected to be minimal.

Project Phase/Component	Interaction Ranking	Project Works and Activities that Interact with the VC	Nature of Potential Interaction
Highway 99 improvements, including interchange upgrades	No Interaction	• Replacement of interchanges at Westminster Highway, Steveston Highway and Highway 17A • Replacement of over/underpasses at Cambie Road, Shell Road, Highway 91 Westbound Ramp, Blundell Road, Ladner Trunk Road and 112th Street • Highway widening from Bridgeport in Richmond to Highway 91 in Delta including construction of embankments, placing and compacting fill for road base, establishing improved drainage and paving	**Nature of interaction:** No interaction anticipated. **Rationale:** Activities to be land-based.
	No Effect	N/A	N/A
	Potential Effect	N/A	N/A

Project Phase/Component	Interaction Ranking	Project Works and Activities that Interact with the VC	Nature of Potential Interaction
Tunnel decommissioning	No Interaction	N/A	N/A
	No Effect	N/A	N/A
	Potential Effect	• Removing electrical/mechanical/utilities equipment from the Tunnel • Removing of four Tunnel segments and associated scour protection • Backfilling of onshore portions of Tunnel approaches • Transporting Tunnel elements for offsite disposal, and operating support vessels for that activity	**Potential Project-related effects include:** • Behavioural disturbance (i.e., some individuals hauled out may re-enter the water) from increased atmospheric noise. Potential effect is expected to be negligible, affecting individuals hauled out on land. The nearest haul-out site is at the Fraser River mouth, approximately 18 km downstream of the Project alignment. • Physical injury or direct mortality to marine mammals from increased risk of vessel strikes by in-river construction support vessels. However, vessel strikes against harbour seals are rare due to their agility. • Temporary changes to the ability to feed on migrating fish stocks, that may in turn be affected from changes in ambient water quality from induced turbidity, re-mobilization of sediment contaminants, and re-deposition of suspended sediment. • Behavioural disturbance from increased underwater noise during operation of in-river dredging equipment and construction support vessels (i.e., tugs).

Project Phase/Component	Interaction Ranking	Project Works and Activities that Interact with the VC	Nature of Potential Interaction
Decommissioning of Deas Slough Bridge	No Interaction	N/A	N/A
	No Effect	N/A	N/A
	Potential Effect	• Removal of Deas Slough Bridge including substructures.	**Potential Project-related effects include:** • Behavioural disturbance (i.e., some individuals hauled out may re-enter the water) from increased atmospheric noise. Potential effect is expected to be negligible, affecting individuals hauled out on land. The nearest haul-out site is at the Fraser River mouth, approximately 18 km downstream of the Project alignment • Behavioural disturbance from increased underwater noise during operation of in-river equipment and support vessels

Project Phase/Component	Interaction Ranking	Project Works and Activities that Interact with the VC	Nature of Potential Interaction
Operation Phase			
Highway 99 and interchanges	No Interaction	• Operating reconfigured Highway 99 and interchanges • Highway 99 and interchange maintenance (drainage maintenance, winter maintenance, emergency maintenance, road cleaning, etc.)	**Nature of interaction:** No interaction anticipated **Rationale:** Activities to be land-based
	No Effect	N/A	N/A
	Potential Effect	N/A	N/A
New Bridge	No Interaction	• Operating the new Bridge. • Bridge maintenance (winter maintenance, emergency maintenance, structure maintenance, etc.)	**Nature of interaction:** No interaction anticipated. **Rationale:** Activities to be land-based.
	No Effect	N/A	N/A
	Potential Effect	N/A	N/A

"N/A" indicates that no Project works and/or activities are applicable to the category