Appendix A
Marine Resources

Pacific NorthWest LNG - Addendum to the Environmental Impact Statement
Marine Resources

Prepared for:
Canadian Environmental Assessment Agency
Pacific and Yukon Regional Office
410-701 Georgia Street West
Vancouver, BC V7Y 1C6

Prepared by:
Pacific NorthWest LNG Limited Partnership
Oceanic Plaza, Suite 1900 – 1066 West Hastings Street
Vancouver, BC V6E 3X1

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Abbreviations

µPa	micropascal
BC	British Columbia
BC MOE	British Columbia Ministry of the Environment
BHD	backhoe dredge
CCME	Canadian Council of Ministers of the Environment
CEPA	Canadian Environmental Protection Act
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CRA	commercial, recreational, and Aboriginal [fisheries]
dB	linear decibel level
DFO	Fisheries and Oceans Canada
EIS	Environmental Impact Statement
ENGO	environmental non-government organization
HHW	higher-high water
HT	hearing threshold
ISQG	interim sediment quality guideline
LAA	local assessment area
LNG	liquefied natural gas
kPa	kilopascal
mg/L	milligrams per litre
MOF	materials off-loading facility
MMO	marine mammal observer
NOAA	National Oceanic and Atmospheric Administration

NTU	nephelometric turbidity unit
PAH	polycyclic aromatic hydrocarbons
PCB	polychlorinated biphenyls
PEL	probable effects level
PFMA	Pacific Fisheries Management Area
pg/g	picogram per gram
PNW LNG	Pacific NorthWest LNG Limited Partnership
PRPA	Prince Rupert Port Authority
PTS	permanent threshold shifts
RAA	regional assessment area
ROV	remotely operated vehicle
SARA	Species at Risk Act
SEL	sound exposure level
SPL	sound pressure level
TDR	technical data report
TEF	toxicity equivalency factor
TEQ	toxicity equivalency
the Project	Pacific NorthWest LNG Project
TSHD	trailing suction hopper dredge
TSS	total suspended solids
TTS	temporary threshold shift
VC	valued component
WQG	water quality guideline

Glossary

Amphipod	*n.* a group of small, laterally compressed crustaceans
Anadromous	*adj.* referring to marine fishes that migrate to freshwater to breed
Anthropogenic	*adj.* caused by/derived from humans
Arthropod	*n.* (phylum Arthropoda) invertebrates that have jointed appendages and a chitinous, segmented exoskeleton
Assemblage	*n.* a colony of different species occurring/living together
Audiogram	*n.* a graphic record of hearing ability for various sound frequencies that is used to measure hearing; varies for different species
Backshore	*n.* the part of a beach between the foreshore and the area where permanent vegetation grows
Baleen Whale	*n.* (suborder Mysticeti) filter-feeding whale
Barotrauma	*n.* injury caused by a change in air pressure, affecting typically the ear or the lung
Bathymetry	*n*. the measurement of the depth of bodies of water
Benthic	*adj.* referring to the animals and plants that live on the floor of the sea
Bigg's Killer Whales	*n.* population of killer whales on the western coast of North America that preys on marine mammals; previously known as 'Northeast Pacific transient killer whales'
Biogenic	*adj.* produced from the activity of living organisms
Biogeographic	*adj.* characterizing a region of the Earth that has distinct fauna and flora, separated from other regions by a natural barrier or change in environmental conditions
Biomass	*n.* the sum of all living organisms in a given area, at a given trophic level, or of a given species (e.g., herring), usually expressed in terms of living or dry mass
Bivalve	*n.* (class Bivalvia) clams, mussels, and other molluscs that possess a two-valved shell, filtering gills, and a shovel-like foot
Calcareous	*adj.* made of calcium carbonate ($CaCO_3$), a mineral that is the major component of the shell and skeleton of many organisms

Canopy (kelp or eelgrass)	*n.* akin to the canopy of a terrestrial forest, the uppermost layer of a marine kelp forest or eelgrass bed, which rarely comes into contact with seafloor and which forms a unique ecosystem to that found in the understory
Cetacean	*n.* a marine mammal of the order Cetacea; a whale, dolphin, or porpoise
Chart Datum	*n.* the plane of vertical reference to which all depths on a nautical chart are related; shown as the lowest depth of water typically found under normal meteorological conditions (tidal datum)
Crustacean	*n.* an arthropod that has two pairs of antennae and an exoskeleton hardened by calcium carbonate
Demersal	*adj.* bottom-dwelling
Echinoderm	*n.* (phylum Echinodermata) invertebrates with five-way radial symmetry and a water vascular system
Eelpout	*n.* a small broad-headed fish of cool or cold seas, having an elongated body and the dorsal and anal fins continuous with the tail
Ensonify	*v.* to fill the ocean or any fluid medium with acoustic radiation
Epibenthic	*n.* relates to the area on top of the sea floor
Epifauna	*n.* animals living on the surface of the substrate (compare to *infauna*)
Estuary	*n.* a semi-enclosed area where a freshwater river meets and mixes with the sea
Fjord	*n.* a long inlet of the sea formed in a deep valley created by a retreating glacier
Flatfish	*n.* a type of fish that lies on its side on the seafloor, with one eye migrating through and around the head to join the other during development (e.g., halibut)
Foreshore	*n.* the shore zone that lies between the average high tide mark and the average low tide mark, and is therefore covered by the sea at high tide and exposed at low tide (see also *intertidal*)
Gastropod	*n.* (class Gastropoda) a mollusc that typically possesses a head with eyes, tongue, and tentacles; a large flattened muscular foot; and a single shell (e.g., snail, limpet)
Habitat	*n.* the natural environment in which an organism lives
Haulout	*n.* a terrestrial location frequented by certain marine mammals (e.g., seals, sea lions) where they leave the water to rest on land
Infauna	*n.* animals that burrow in the substrate (compare to *epifauna)*

Inshore	*adj.* referring to an area of sea near the coast
Intertidal	*adj.* referring to the shore zone that lies between the average high tide mark and the average low tide mark, and is therefore covered by the sea at high tide and exposed at low tide (also referred to as littoral; see also *foreshore*)
Invertebrate	*n.* an animal that lacks a backbone
Kelp	*n.* brown algae characterized by their large size and complexity, which can form dense stands or forests in cold and temperate seawater
Larva (plural larvae)	*n.* the form of an insect or other animal in the immature stage of development after the egg has hatched but before the animal becomes adult
Limpet	*n.* a marine mollusc with a shallow conical shell and a broad muscular foot, noted for the way it clings tightly to rocks
Macroinvertebrate	*n.* animal that has no backbone and is visible without magnification
Mollusc	*n.* an invertebrate with a soft, unsegmented body, a muscular foot, and, with some exceptions, a calcareous shell
Mudflat	*n.* a muddy bottom that is exposed at low tide
Mustelid	*n.* (family Mustelidae) a mammal of the weasel family, distinguished by having a long body, short legs, and musky scent glands under the tail (e.g., sea otter)
Nearshore	*n.* the region of land extending outward from the backshore to the beginning of the offshore zone
Offshore	*adj.* distant from the shore
Pelagic	*adj.* referring to the top and middle layers of sea water; pelagic organisms are those that live in the water column away from the sea bottom (e.g., Pacific herring, smelts, and mackerel)
Photic	*adj.* denoting the layers of the ocean reached by sufficient sunlight to allow plant growth
Pinniped	*n.* (order Pinnipedia) mammals with paddle-shaped flippers (e.g., seal, sea lion)
Polychaete Worm	*n.* a division of annelids having unsegmented swimming appendages, including most of the common marine worms
Population Viability	*n.* In the context of this environmental assessment, the term "population viability" refers to the population (within or extending beyond the LAA) of an individual species, and its ability to maintain itself over a specified period of time (construction and operational phases of the Project). Residual effects were identified and significance determinations were made based on the viability of fish and marine mammal populations in the LAA.

Prickleback	*n.* any of several blennioid fishes of the family Stichaeidae, usually inhabiting cold waters, having spiny rays in the dorsal fin
Ronquil	*n.* a slender bottom-dwelling fish
Rookeries	*n.* breeding sites (of seabirds, seals, or sea lions)
Salmonid	*n.* a fish belonging to the family Salmonidae, which includes salmon and trout
Sessile	*adj.* referring to an organism that lives attached to the bottom or to a surface
Species Richness	*n.* the number of species found in an area
Sponge	*n.* (phylum Porifera) an invertebrate that consists of a complex aggregation of cells, including collar cells, and has a skeleton of fibers and/or spicules
Spring Tide	*n.* a tide that occurs during the time of largest difference between high and low water, which occurs just after a new or full moon every month
Substrata	*n*. the underlying layers of earth (e.g., rock and boulder that lie beneath sediment on the sea floor)
Substrate	*n.* the matter or surface on which an organism lives
Subtidal	*n.* the zone of the shoreline that is submerged most of the time and is exposed only briefly during extreme low tides
Swim Bladder	*n*. a gas-filled sac present in the body of many bony fishes used to maintain and control buoyancy
Toothed Whale	*n.* (suborder Odontoceti) a whale that has teeth (e.g., killer whale, porpoise, and dolphin)
Traditional Ecological Knowledge	*n.* the body of knowledge regarding local environmental resources built up by a group of people through generations of living in close contact with nature
Transect	*n.* a line used in ecological surveys to provide a means of measuring and characterizing the distribution of organisms
Tunicate	*n.* (phylum Chordata) marine filter feeders with a sac-like body structure
Turbidity	*n.* cloudiness of a liquid, resulting from particles being suspended in it

13 MARINE RESOURCES

13.1 INTRODUCTION

Marine resources have been selected as a valued component (VC) because of the potential for interactions with project activities and their importance to local communities. The marine waters surrounding Prince Rupert provide diverse habitats supporting many species that contribute to the ecological, cultural, and economic well-being of the region. Fish (and fish habitat) and marine mammals are the key components of this VC. Marine sediment and water quality are key components of fish habitat, and contaminant levels may affect fish and marine mammals.

The Pacific NorthWest LNG Project (the Project) has potential to affect marine habitats and species during all project phases through:

- Change in sediment or water quality (leading to potential for toxicological concerns or increased total suspended solids [TSS])
- Change in fish habitat
- Direct mortality or physical injury to fish or marine mammals
- Change in behaviour of fish or marine mammals (as a consequence of underwater noise produced by project activities).

The focus of this assessment is on species of commercial, recreational, cultural, or conservation concern, and related habitats. Consideration of potential project effects on marine resources is also required under the *Fisheries Act,* the *Species at Risk Act* (SARA), and the *Canadian Environmental Protection Act* (CEPA).

The Marine Resources assessment focuses on potential effects on fish and marine mammal populations and habitats. There are no indirect effects of the Project on navigation as a result of changes to the environment caused by project-related structures or activities. Marine traffic and the potential effects on fisheries are addressed in the Navigation and Marine Resource Use assessment (Section 15).Effects on traditional harvesting activities are assessed in Section 21.5.2.3, sub-section (a). Baseline information on Traditional Knowledge and Traditional Use (TK/TU) of marine resources is discussed and assessed in Section 21 (Current Use of Lands and Resources for Traditional Purposes). Potential effects on marine resources from accidents and malfunctions, such as accidental fuel release and marine mammal vessel strikes, are assessed separately in Section 22. The Marine Resources Technical Data Report (TDR) (Appendix M of the EIS) provides baseline information on marine resources found within the local assessment area (LAA)/regional assessment area (RAA) to support the assessment of potential effects presented below. The Marine Sediment and Water Quality TDR (Appendix L of the EIS) provides baseline information on sediment and water quality within the LAA/RAA.

13.2 SCOPE OF ASSESSMENT

13.2.1 Regulatory and Policy Setting

Canada's *Fisheries Act*, *1985* (including June 12, 2012, amendments), and SARA, *2002*, administered by Fisheries and Oceans Canada (DFO), are the primary laws providing protection for fish and fish habitat and marine mammals in the project boundaries. The *Canadian Environmental Protection Act* (CEPA), *1999*, administered by Environment Canada, regulates disposal of dredged material at sea. This regulation and the Canadian Council of Ministers of the Environment (CCME) sediment quality guidelines and water quality guidelines (WQG) for protection of marine life are used to assess potential effects of contaminants in sediment and water. Additional draft guidance from Environment Canada (2014) outlines guidelines for dioxins and furans in sediments proposed for open water disposal.

***Fisheries Act*—**Key sections of the *Fisheries Act* that apply to this assessment are:

- **Section 35—**prohibits any serious harm to fish that are part of, or support, a commercial, recreational or Aboriginal (CRA) fishery
- **Section 36—**prohibits the deposition of deleterious substance(s) into waters used by fish.

The following definitions will be used for this assessment. The definition of "fish" in the *Fisheries Act* includes (a) parts of fish, (b) shellfish, crustaceans, marine animals and any parts of shellfish, crustaceans or marine animals, and (c) the eggs, sperm, spawn, larvae, spat and juvenile stages of fish, shellfish, crustaceans and marine animals. "Fish habitat" is defined in the *Fisheries Act* as "the spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly to carry out their life processes". Fish habitat includes marine vegetation. "Serious harm to fish" is defined in the *Fisheries Act* as "the death of fish or any permanent alteration to, or destruction of, fish habitat". "Fish that support a fishery" (i.e., CRA fishery) include key prey species and biogenic habitats (e.g., corals and sponges) that provide direct support functions, as well as species that support CRA fisheries indirectly (Kenchington et al. 2012). The current state of scientific knowledge on the role of direct supporting fisheries (i.e., key prey species and biogenic habitats) is stronger than that of the indirect supporting fisheries. Other important definitions in the *Fisheries Act* remain unchanged. DFO's policies and guidance documents that address the management of fish habitat include:

- Fisheries Protection Policy Statement (DFO 2013a)
- The Fisheries Protection Program Operational Approach (DFO 2013b)
- Fisheries Productivity Investment Policy (DFO 2013c)
- Practitioners Guide to the Risk Management Framework for DFO Habitat Management Staff, Version 1 (DFO 2010a)
- DFO Regional Operational Statements for British Columbia and the Yukon (DFO 2013d).

DFO's *Fisheries Protection Policy Statement* (DFO 2013a) applies to all activities in or near water that could result in serious harm to fish by chemical, physical or biological means. The policy states that proponents are responsible for avoiding and mitigating serious harm to fish that are part of or support a CRA fisheries. When proponents are unable to completely avoid or mitigate serious harm to fish, a Subsection 35(2) authorization of the *Fisheries Act* is required for the Project to proceed without contravening the Act.

DFO interprets serious harm to fish as:

- The death of fish
- A permanent alteration to fish habitat of a spatial scale, duration or intensity that limits or diminishes the ability of fish to use such habitats as spawning grounds, or as nursery, rearing or food supply areas, or as a migration corridor, or any other area in order to carry out one or more of their life processes
- The destruction of fish habitat of a spatial scale, duration, or intensity that fish can no longer rely upon such habitats for use as spawning grounds, or as nursery, rearing or food supply areas, or as a migration corridor, or any other area in order to carry out one or more of their life processes
- To support a request for a Subsection 35(2) authorization, a detailed habitat offsetting plan must be provided outlining the approach to ensure productivity is maintained within the study area. A draft Habitat Offsetting Plan is in development and will be refined through discussions with DFO and consultation with Aboriginal groups. A final Habitat Offsetting Plan will be developed during the permitting phase as part of an application for a Section 35(2) authorization for the Project.

Marine mammals are protected under the Marine Mammal Regulations (SOR/93-56) of the *Fisheries Act*, which prohibit the disturbance and killing of marine mammals for reasons other than fishing under a licence. Some marine mammal species found in the LAA are also protected under SARA (see Section 13.3.2).

***Species at Risk Act* (SARA)—**Through SARA, the Government of Canada manages endangered and threatened species to prevent them from becoming extinct and to aid in their recovery. SARA also provides management direction for species of special concern to prevent them from becoming threatened or endangered. The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) is designated under SARA as the independent body of experts tasked to assess species according to their level of conservation concern: *extinct*, *extirpated*, *endangered*, *threatened*, *special concern*, *not at risk* or *data deficient*. DFO takes COSEWIC assessments into account, along with recovery potential assessments, socio-economic assessments, and other information, before listing aquatic species under *SARA*. For SARA-listed marine mammal species in this assessment, their COSEWIC status is either the same as the SARA listing or is a status of lesser concern (e.g., humpback whale [Appendix M of the EIS]). Marine fish species that are not listed under SARA, but have been identified by COSEWIC, are referred to in this assessment as species of management concern.

If a species is listed under Schedule 1 of SARA as *extirpated, endangered* or *threatened*, it is an offence to kill, harm, harass, capture or take an individual (s. 32[1]), and that species has legal protection related to the species' residence and critical habitat as specified in SARA (s. 56, 58[1]).

***Canadian Environmental Protection Act* (CEPA)—**Environment Canada administers *CEPA* under Part 7, Division 3. A permit under CEPA will be required for disposal at sea of clean dredged or excavation materials. Schedule 6 of *CEPA* provides several provisions for disposal at sea, including reduction and management of material to be disposed; information requirements for the material to be disposed, including chemical and physical characterization; disposal at sea site selection information requirements; and several other provisions required for inclusion within a permit application for disposal at sea. Environment Canada has several permitting requirements, including Minimum Sample Collection Guidelines, Minimum Sample Analytical Requirements, and Data Requirements for Dredging Projects (see Appendix L of the EIS, Marine Sediment and Water Quality TDR), in addition to new sediment sampling guidelines that are currently being developed.

Sediment quality is assessed against screening criteria for disposal at sea and CCME sediment and water quality guidelines for protection of marine life, including interim sediment quality guidelines (ISQG) and probable effects levels (PEL).

13.2.2 Influence of Consultation on the Assessment

Concerns regarding the potential effects of the Project on the marine environment have been identified by Aboriginal groups, government departments, stakeholders, and the public (see Table 13-1).

Table 13-1 Key Issues Raised During Consultation

Issue	Issue Raised by	Influence on the Assessment
Cumulative effects	Aboriginal groups, government agencies	• Assessed in Section 13.6.
Effects on Skeena River fisheries	Aboriginal groups, fishing industry, local community, environmental non-government organizations (ENGOs)	• Focus on assessment of effects to fish species of Aboriginal, commercial, and recreational importance • Field studies were conducted within the project development area (PDA) and within approximately 500 m of the jetty-trestle centre line • Project-specific studies were integrated with data from the literature on Skeena River fisheries (see Appendix M of the EIS, Marine Resources TDR).
Effects on fish habitat (e.g., Flora Bank eelgrass bed)	Aboriginal groups, fishing industry, local community, ENGOs and other organizations, DFO	• The marine terminal was redesigned and the berth was relocated to remove project infrastructure (i.e., piles) on Flora Bank; and eliminate the need for dredging on Agnew Bank and the associated disposal at sea of the dredged materials • Field studies were conducted within 500 m of the PDA to fully characterize fish habitat • Field studies were conducted to delineate and characterize Flora Bank, augmented with review of satellite images at Flora Bank and other areas around Lelu Island • Habitat offsetting will potentially involve eelgrass transplantation.
Re-suspension of sediment containing dioxins and furans	Aboriginal groups, local community, Environment Canada	• Additional samples, beyond Environment Canada's recommended number, were collected to quantify vertical (depth) and horizontal (surface area) distribution of contaminants (including dioxins and furans) in the materials off-loading facility (MOF) (see Appendix L of the EIS, Marine Sediment and Water Quality TDR) • Samples of marine country food tissues were collected and analyzed for the human health and ecological risk assessment (see Section 19).
Effects on fish and marine mammals from underwater noise	Aboriginal groups, local community	• Project activities that will generate underwater noise at levels higher than ambient conditions have been modelled.

Issue	Issue Raised by	Influence on the Assessment
Effects from the disposal of sediment at sea	Aboriginal groups	• The marine terminal was redesigned and the berth was relocated to remove project infrastructure (i.e., piles) on Flora Bank; and eliminate the need for dredging on Agnew Bank and the associated disposal at sea of the dredged materials • The disposal of sediments from dredging at the MOF is assessed in Sections 13.5 and 13.6.
Project effects resulting in effects to traditional resources, especially marine foods	Aboriginal groups	• TLU information regarding species of interest has been incorporated into Section 13.
Concerns about the potential release of invasive species, noise and pollution	Aboriginal groups	• Section 13.4.1. details the standard procedures and best management practices in place to effectively mitigate potential effects of release of bilge and ballast water from LNG carriers • Potential effects of noise on marine resources are assessed in Section 13.5.4 (with respect to potential for auditory injury) and 13.5.5 (with respect to potential for change in behaviour).
Full characterization of sediment to be dredged and disposed of at sea	Environment Canada	• Sediment sampling program was adapted based on discussions with Environment Canada and recent changes to their sampling requirements.

NOTE: Beyond the key issues raised during consultation, information on traditional use used in the EIS was obtained from publically available sources, and from Traditional Use Study (TUS).Further information on concerns raised by Aboriginal groups is provided in Section 27.

Five project-specific Traditional Use Studies were reviewed for information regarding traditional knowledge and traditional use within the Prince Rupert Habour Area. These studies included:

- Metlakatla First Nation Traditional Land Use and Ecological Knowledge of the Proposed Pacific NorthWest LNG Project (the Metlakatla report)
- The Gitxaala Use Study, Prepared for Port Edward Area LNG Projects (the Gitxaala Use Study)
- Kitselas First Nation Traditional Use Study Analysis: The North Coast Territories—Lelu Island (The Kitselas Report)
- The Kitsumkalum Traditional Interim Use Study Report and the Kitsumkalum Traditional Use Study Report for Pacific Northwest (the Kitsumkalum Interim Report and the Kitsumkalum Final Report)
- The Gitga’at First Nation Traditional Use and Occupancy Study. Prince Rupert Region. Preliminary Results Report (The Giga’at Preliminary Report).

Species identified in the Traditional Use Studies include: salmon, black cod, ling cod, red snapper, eulachon, herring, seals, whales, clams, cockles, mussels, chitons, sea cucumber, Dungeness crab, king crab, prawns, and shrimp, while specific areas of concern include: Flora and Agnew Banks and Brown Passage (Calliou Group 2014; Crossroads Cultural Resource Management Ltd. 2014; DM Cultural Services Ltd. and Metlakatla First Nation 2014; Inglis Consulting Services 2014; Pulla 2014). A number of fisheries resources (e.g., sockeye and pink salmon, steelhead trout, and clams) are harvested extensively in the LAA. Harvesting locations were identified and captured in regards to navigation and marine resource use.

Potential effects to Skeena River fisheries coupled with concerns about the eelgrass bed on Flora Bank were the key issues expressed during consultation for this Project by Aboriginal groups, the public, and stakeholders. Flora Bank is an important rearing area for Skeena River salmon, containing a rich community of invertebrates, including Dungeness crab and Pandalus shrimp (Department of the Environment 1973a; Higgins and Schouwenburg 1973), and is important to local avifauna (see Section 11). The recent closure of the Skeena River sockeye fishery to Aboriginal, commercial, and recreational fisheries has amplified this issue among Aboriginal groups, stakeholders, and non-government organizations. Media coverage of the closure was reported by CBC (2013).

In recognition of the importance of the Flora Bank eelgrass bed to these fisheries and the ecological processes of Chatham Sound, field surveys were conducted to characterize the eelgrass bed, building upon available information (see Section 13.3.2.2 and Appendix M of the EIS for details). Results of these surveys informed the assessment of change in fish habitat (Section 13.5.2).

DFO and Environment Canada attended Working Group meetings and Environment Canada was provided with field survey workplans and survey results to obtain feedback on potential project effects. Environment Canada provided comments on the sediment sampling program for disposal at sea and requested additional, and more detailed, characterization of dioxins and furans in sediment. This occurred in October 2013 and results (see Appendix L of the EIS) are used to assess changes in sediment and water quality as a result of project activities (Section 13.5.2).

13.2.3 Selection of Potential Effects

Potential effects on marine resources were identified through discussions with Environment Canada and DFO, consultation with Aboriginal groups, public consultation, and professional judgment and experience of the study team. The following potential effects on marine resources were identified:

- Change in sediment or water quality
- Change in fish habitat
- Direct mortality or physical injury to fish or marine mammals
- Change in behaviour of fish or marine mammals.

13.2.3.1 Change in Sediment or Water Quality

Sediment and water will be affected by sediment disturbance during project construction (dredging, blasting, sediment disposal) and operations (vessel maneuvering at the terminal). These activities have the potential to increase TSS levels, which can reduce light penetration for plant growth and affect gills and other sensitive tissues of fish and marine mammals. Physical harm effects associated with elevated TSS levels, such as gill abrasion for fish, are assessed in Section 13.5.4, and chronic effects related to TSS and contaminants are assessed in Section 13.5.2. Sediment dispersal could introduce contaminants (such as dioxins and furans) to new locations where they could become available for uptake by marine biota. Human and ecological health effects are discussed in Section 19.

13.2.3.2 Change in Fish Habitat

Change in the quantity and quality of the physical and biological attributes of fish habitat (including marine vegetation) will occur as a result of project activities during the construction, operations, and decommissioning phases. Project activities expected to result in quantifiable changes to fish habitat include dredging, blasting, excavation of intertidal and subtidal habitats within the MOF, pile and bridge foundation (i.e., southwest anchor block and southwest tower) installation, and sediment deposition from vessel maneuvering at the berths during operations. Pile installation for the marine terminal, MOF, and pioneer dock will also result in negligible changes to fish habitat.

13.2.3.3 Direct Mortality or Physical Injury to Fish or Marine Mammals

Direct mortality or physical injury to fish can be caused by burial, crushing or blasting. Blasting can also injure or kill marine mammals. Project activities that could cause burial or crushing include one-time events during construction such as dredging and excavation, pile installation, and disposal of dredged sediment at sea. Some sedimentation (burial) from vessel maneuvering at the berths may occur during operations. The potential for chronic (sub-lethal) effects as a result of TSS concentrations are discussed in Section 13.5.2.

Underwater noise from blasting and pile installation can cause injury to marine mammals, potentially causing indirect mortality (or direct mortality in the case of blasting), and can cause mortality to fish. Marine mammals and fish could sustain auditory injury from underwater noise associated with impulsive (pulse) sounds such as blasting and impact pile driving. These activities also produce pressure waves, which can rupture fish swim bladders or other internal organs, causing injury or potential mortality (Popper and Hastings 2009). Skeena River CRA fisheries were identified during consultation as a key concern with respect to potential injury or mortality to species.

13.2.3.4 Change in Behaviour of Fish or Marine Mammals

Underwater noise from project activities has the potential to result in changes in behaviour of marine organisms and may impair communication or cause displacement of fish or marine mammals from preferred habitats. Project activities likely to generate underwater noise include blasting, pile installation, dredging, disposal at sea, construction-related vessel traffic, and shipping liquefied natural gas (LNG). Increases in TSS during dredging and disposal at sea may also cause temporary and localized avoidance behaviours in adult fish and highly mobile invertebrates.

During operations, LNG carriers will travel through the LAA between the marine terminal and the Triple Island Pilot Boarding Station (accompanied by one escort tug during both inbound and outbound transits). At full capacity, one LNG carrier per day is expected to call on the marine terminal, and one carrier will depart from the marine terminal. Berthing will involve the LNG carrier and up to four tugs. Site decommissioning and clean-up will also require use of vessels. All of these activities will emit underwater noise that could affect the behaviour of fish or marine mammals.

13.2.4 Selection of Measurable Parameters

Table 13-2 identifies measurable parameters used to assess potential effects on marine resources.

Table 13-2 Potential Effects, Measurable Parameters, and Rationale for Selection of Measurable Parameters

Potential Effect	Measurable Parameter(s) and Units of Measurement	Notes or Rationale for Selection of the Measureable Parameter
Change in sediment or water quality	• Contaminant concentrations in sediment and water • TSS concentrations in water (mg/L).	• Disposal at sea screening criteria and CCME and BC guidelines for protection of marine life are used to assess potential for effects • Draft guidance from Environment Canada outlines criteria specific to dioxins and furans for sediment proposed for open water disposal.
Change in fish habitat	• Area of fish habitat permanently altered or destroyed (m^2).	• Area of habitat permanently altered or destroyed is required under Section 35 of the *Fisheries Act*, according to the definition of "serious harm to fish".
Direct mortality or physical injury to fish or marine mammals	• Qualitative likelihood of injuring or killing marine mammals or fish.	• Direct mortality, or injury that leads to mortality or reduced fitness, can negatively affect population viability • Compliance with Section 35 of the *Fisheries Act* and Section 32(1) of SARA • Predicted noise levels can be compared to published thresholds predicted to cause injury to marine mammals and mortality to fish.
Change in behaviour of fish or marine mammals	• Timing (seasonal), duration (hr.), sound level [linear decibel level (dB)] and extent (km from sound source) of underwater noise potentially affecting marine mammals • Timing (seasonal) and duration (hr.) of underwater noise potentially affecting fish.	• Change in behaviour can reduce access to habitats important for completing life-cycle stages (e.g., feeding), potentially affecting population viability • Predicted noise levels can be compared to published thresholds predicted to affect marine mammal behaviour • Published thresholds do not exist for fish; therefore, time and duration are used to qualitatively assess changes in behaviour caused by underwater noise.

13.2.5 Boundaries

13.2.5.1 Temporal Boundaries

The temporal boundaries encompass all project phases and activities that potentially interact with fish and fish habitat and marine mammals. Based on the current project schedule, the temporal boundaries for each project phase are:

- **Construction** Approximately 5 years from the *Canadian Environmental Assessment Act* approval
- **Operations** Over 30 years from construction completion
- **Decommissioning** After cessation of operations.

Temporal boundaries also include timing of ecologically important events such as peak seasons of species abundance. These are linked to important life cycle stages (e.g., feeding, migration, spawning); periods of peak plant growth (e.g., eelgrass and kelp) providing for high productivity and an increase in available fish habitat; and population or habitat trends that occur over several years.

Spring and summer are the most important seasons for fish and marine mammals in the LAA. Juvenile salmon, the most common life stage of salmon using the LAA, migrate from the Skeena and Nass rivers into coastal waters in June seeking food and refuge. Eulachon begin to migrate into the Skeena and Nass Rivers from offshore environments in February and March (see Appendix M of the EIS).

Many marine mammals are found within the LAA year-round. Humpback and northern resident killer whales use the LAA seasonally. Generally, they arrive in May and feed in the area until October and July, respectively (see Appendix M of the EIS).

13.2.5.2 Spatial Boundaries

The following spatial boundaries for the Marine Resources assessment were determined in consultation with the working group and the public through development of the Application Information Requirements. Figure 13-1 illustrates the spatial boundaries for Marine Resources.

- Project development area (PDA)—Lelu Island to within 30 m of the average high water mark, the bridge abutments, and access road corridor, and areas covered by the Lelu Island access bridge, pioneer dock, MOF, marine terminal, and associated dredging. This includes the physical area over which construction (e.g., dredging, blasting, pile installation) and operations (e.g., berthing, shipping, effluent disposal) activities will occur (see Figure 13-1). The project components likely to affect marine resources are the marine terminal (i.e., suspension bridge, jetty-trestle, and LNG carrier berth) extending southwest from Lelu Island, the MOF and turning basin on the north side of Lelu Island, the pioneer dock east of the MOF, and the bridge between Lelu Island and the mainland. During dredging, the immediate area surrounding operating construction equipment will be referred to as the 'active work area'. At any given time during construction, dredging will occur within only a portion of the dredge area (i.e., in the active work area [See Appendix G.6 for further discussion of the active work area])
- Local assessment area (LAA)—the area over which project effects on marine resources are expected to occur. The LAA includes the PDA, three potential shipping routes (between the terminal and Triple Island Pilot Boarding Station), plus an approximate 10 km buffer on either side of the potential shipping routes but extending further south into Arthur Pass (between Smith and Porcher islands) to assess potential effects from underwater noise based on acoustic modelling results (see Appendix N of the EIS: Modelling of Underwater Noise for Pacific NorthWest LNG Marine Construction and Shipping Scenarios). The landward boundary of the marine environment is the higher-high water (HHW) mark. The four effects may occur at different spatial scales and locations within this boundary. Effects on fish are not expected to extend throughout the LAA, and will be concentrated within 500 m around the jetty-trestle, berths, bridge, MOF and turning basin, and pioneer dock. Effects on fish at the presented disposal at sea site, Brown Passage (see Figure 13-1), are predicted to occur within a 1 km diameter of the disposal site, as determined by sediment dispersal modelling (see Appendix O of the EIS: Sediment Modelling of Dredging off Lelu Island, Prince Rupert, BC Canada and Disposal of Dredgeate at Brown Passage)

- Regional assessment area (RAA)—the same boundary as the LAA, providing the biogeographic context for assessing effects on populations of fish and marine mammals. Geographic areas beyond the RAA are considered, where appropriate, to provide a full description of key life-history stages for marine mammals and, to a lesser degree, fish stocks. The RAA includes the Skeena River upstream to the zone under tidal influence. The rationale is that the effects assessment on marine resources includes species that migrate through and stage in the PDA and LAA, but also complete critical stages of their life cycle upstream in the Skeena River (and this accounts for fish populations that utilize the area, are unique, and could be affected at the population level by project specific and cumulative effects).

The LAA boundary encompasses the extent of expected project effects and the RAA provides the biogeographic context and area over which cumulative effects may occur in combination with other projects. These boundaries are the same for the marine resources VC, due to the large nature of the LAA, which includes effects on marine mammal behavior from shipping. The RAA was delineated to capture only those projects expected to overlap spatially with the Project. The Triple Island Pilot Boarding Station is the outermost extent where overlap with other projects is most likely to occur.

13.2.5.3 Administrative and Technical Boundaries

Several administrative boundaries are considered in this assessment:

- The Prince Rupert Port Authority (PRPA) boundary, where regulations pertinent to project activities, such as vessel speed limits, apply in particular areas
- Pacific Fisheries Management Area (PFMA) 4, managed by DFO; PFMA sub-areas 4-1, 4-2, 4-5, 4-9, 4-10, 4-11, 4-12, and 4-13 are found in the LAA. This is particularly important when considering linkages between the fisheries component of the Navigation and Marine Use VC (Section 15 of the EIS) and the Marine Resources VC
- A bivalve shellfish closure for Paralytic Shellfish Poisoning (red tide) and other marine biotoxins from algae exists for all sub-areas of PFMA 4. This applies to oysters, clams, scallops, mussels, and geoducks (DFO 2013e). The majority of PFMAs 1 through 10 are closed to the harvesting of bivalve shellfish due to the inconsistent and incomplete biotoxin monitoring program and water quality testing program on the north coast of BC (Davies 2013). There are specific openings in well-defined areas that have fisheries with established management programs. These fisheries have all necessary components in place (e.g., biotoxin monitoring, water quality testing) to be classified as “approved” for shellfish harvesting and meet all of the requirements set out under the Canadian Shellfish Sanitation Program (Davies 2013)
- A year-round long-term ban on crab harvesting is in place for PFMA sub area 4-11, which encompasses Porpoise Harbour to the westernmost point of Lelu Island (DFO 2013f) and includes the MOF and turning basin
- There is a Sanitary Shellfish Closure (number 4.3), “Prince Rupert Harbour”, that encompasses the waters surrounding the PDA (except the MOF and pioneer dock sites). Shellfish harvesting is prohibited in this area, which is one of many sanitary closures related to release of untreated domestic sewage on the north coast (DFO 2013e).

Technical boundaries are defined by the availability and quality of data and information. Technical information was obtained from peer-reviewed published literature, government reports, and scientific literature.

13.2.6 Residual Effects Description Criteria

Residual effects are those that cannot be fully addressed through avoidance, mitigation or offsetting measures. Descriptors used to characterize and assess residual effects on marine resources are defined in Table 13-3.

Table 13-3 Characterization of Residual Effects for Marine Resources

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Characterization of Residual Effects		
Context	Refers primarily to the current and future sensitivity and resilience of the VC to change caused by the Project. Consideration of context draws heavily on the description of existing conditions of the VC, which reflect cumulative effects of other projects and activities that have been carried out, and especially information about the impact of natural and human-caused trends in the condition of the VC.	**Low resilience (L)**—under baseline conditions, marine resources are rarely exposed to anthropogenic effects and are highly sensitive to them; such changes could trigger large and lasting ecological effects. **Moderate resilience (M)**—under baseline conditions, marine resources are occasionally exposed to anthropogenic effects and are sensitive to them; such changes trigger small and short-term ecological effects. **High resilience (H)**—under baseline conditions, marine resources often experience anthropogenic effects and are unaffected by them; such changes trigger no detectable ecological effects.
Magnitude	Refers to the expected size or severity of the residual effect. When evaluating magnitude of residual effects, consideration is given to the proportion of the VC affected within the spatial boundaries and the relative effect	**Negligible (N)**—no measurable change in fish and marine mammal populations, habitat quality or quantity, or contaminant levels. **Low (L)**—a measurable change but within the range of natural variability (change in population levels or contaminant concentrations consistent with baseline levels). Will not affect population viability. **Moderate (M)**—measurable change outside the range of natural variability but not posing a risk to population viability. **High (H)**— measurable change that exceeds the limits of natural variability and may affect long-term population viability (includes exceedances of toxicological thresholds for sediment and water and thresholds for underwater sound levels, considering natural background levels).
Extent	Refers to the spatial scale over which the residual effect is expected to occur	**P**—effect is restricted to the PDA. **L**—effect is prevalent in the LAA.

Characterization	Description	Quantitative Measure or Definition of Qualitative Categories
Duration	Refers to the length of time the residual effect persists—which may be longer than the duration of the physical work or activity that gave rise to the residual effect	**Short-term (S)**—change limited to project construction and decommissioning phases. **Medium-term (M)**—change continues for up to two years following construction or decommissioning before returning to baseline condition. **Long-term (L)**—change continues for more than two years after construction project phase, or continues during operations project phase. **Permanent (P)**—measurable parameter unlikely to return to baseline level.
Reversibility	Pertains to whether or not the residual effect on the VC can be reversed once the physical work or activity causing the disturbance ceases	**Reversible (R)**—will recover to baseline conditions after project closure and reclamation. **Irreversible (I)**—permanent.
Frequency	Refers to how often the residual effect occurs and is usually closely related to the frequency of the physical work or activity causing the residual effect	**Single event (S)**—occurs once. **Multiple regular event (M)**—occurs often throughout the construction, operations, or decommissioning phase. **Continuous (C)**—effect occurs continuously throughout the life of the Project.
Likelihood of Residual Effects		
Likelihood	Refers to whether or not a residual effect is likely to occur	**L**—low probability of occurrence **M**—medium probability of occurrence **H**—high probability of occurrence

13.2.7 Significance Thresholds for Residual Effects

A requirement of both the federal and provincial environmental assessment process is that the proponent includes a significance determination for each valued component assessed. The ultimate determination of whether the Project is likely to result in any significant adverse effects lies with the federal and provincial governments.

A significant residual adverse effect on marine resources is one that results in any of the following:

- A change in sediment or water quality that would result in toxicological risks to aquatic life, considering the water and sediment quality guidelines (and conservatism built into those guidelines)
- Any residual effect with a high likelihood of affecting population viability of fish or marine mammals (these effects are likely to be of high magnitude and permanent)
- Any residual effect with a high likelihood of causing mortality to species at risk (i.e., listed under SARA)[1].

[1] For SARA-listed marine mammal species in this assessment, their COSEWIC status is either the same as the SARA listing or is a status of lesser concern (e.g., humpback whale [Appendix M of the EIS/Application]). Marine fish species that are not listed under SARA, but have been identified by COSEWIC are referred to in this assessment as species of management concern. Species of management concern are given additional consideration in assessing the overall determination of significance; however, they are not explicitly addressed under this significance criterion.

The level of confidence is provided for each prediction, which is typically based on expert judgment, and which characterizes the level of uncertainty associated with both the significance and likelihood determinations. A characterization of level of uncertainty is provided for each significance determination based on scientific information, statistical analysis, professional judgment, effectiveness of mitigation, and assumptions made. This includes consideration of the confidence and risk associated with the effectiveness of presented mitigation measures.

13.3 BASELINE CONDITIONS

13.3.1 Baseline Methods and Data Sources

Baseline information was compiled from literature reviews and focused field studies (Appendices M and L). Literature review combined information from three sources: published literature (i.e., primary peer-reviewed research and “grey” literature, including technical reports); publically available databases on species distributions; and expert knowledge (e.g., personal communications and expert knowledge of the assessment team).

In addition to the review of existing information, the following complementary field studies were completed:

- **Sediment and water quality**: Physical and chemical characteristics of intertidal and subtidal sediment and water quality were identified through field studies to assess the potential for release of contaminants and TSS during dredging at the MOF and disposal of the sediment. The field program was developed through consultation with Environment Canada and was compliant with Environment Canada’s guidance for screening sediment for disposal at sea. Detailed methods and results are provided in Appendix L of the EIS. Sediment was sampled from the dredge area within the MOF and turning basin in May, July, and October 2013 at a variety of depths at 36 locations. Parameters of interest were polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), metals, dioxins and furans, particle size and total organic carbon. Detailed surveys to identify horizontal and vertical distribution of dioxins and furans within the dredge area were included
- **Intertidal surveys:** Intertidal species and habitats were quantified at the MOF, the jetty-trestle abutment, the bridge, and the pioneer dock locations where the Project has the potential to affect these communities. Standard methods were used to quantify community assemblages. Specifically, quadrats (0.5 m x 0.5 m) were distributed across intertidal zones along transects placed perpendicular to the shoreline. Within each quadrat, density (for solitary organisms such as snails, limpets etc.) or relative abundance (% cover, for encrusting and colonial species, such as seaweeds and sponges) of marine species was recorded for all species observed. In addition, eelgrass patches were delineated using a hand-held GPS unit; eelgrass shoot density and percent cover were estimated within 0.25 m x 0.25 m quadrats randomly distributed across the patches. Infaunal invertebrate communities were described by excavating 0.25 m x 0.25 m quadrats to approximately 30 cm; all animals were identified to the lowest practical taxonomic level and recorded as density m^{-2}
- **Subtidal surveys:** Subtidal surveys were carried out to describe the pre-construction subtidal environment, including habitat characteristics and dominant biota around the terminal on Lelu Island. This survey in May/June 2013 identified and mapped substrate types along the seafloor (such as soft bottom, rocky areas, and bedrock), and identified potentially sensitive subtidal features (eelgrass and kelp beds). Subtidal substrates and species were quantified using a remotely operated vehicle (ROV), which collected video footage for analysis. The ROV transects were positioned to capture all subtidal habitat types within the LAA and included 28 ROV transects, spaced ~150 m apart, spread roughly uniformly from 0 m (chart datum) to a

maximum depth of 60 m (Appendix M of the EIS). Resulting footage was analysed by trained biologists, who identified the presence of marine species and dominant substrate types. Links between species presence and substrate types were identified. Furthermore, since ROV transects were geo-referenced, the distribution of these species and substrates were mapped to identify spatial trends. An additional subtidal ROV survey was conducted throughout Brown Passage in July 2014 to document conditions at the previously used disposal at sea site and surrounding areas. Twelve transects, incorporating a total of approximately 53 linear kilometres of benthic habitat, were surveyed (11 km within the disposal site and 42 km outside). See Appendix G.21 for further details

- **Eelgrass Surveys:** Owing to the importance of Flora Bank as salmon rearing habitat, several methods were used to estimate, triangulate and ground-truth eelgrass extent and composition across this area during field surveys in May 2013. The extent of eelgrass was estimated by circumnavigating the bank with a hand-held GPS unit. These surveys were supplemented by assessing conditions on transects running perpendicular to the slope of the bank, from subtidal to intertidal zones, along which the first (i.e., deepest) observation of eelgrass was noted. In addition, eelgrass shoot percent cover and canopy height were estimated in 0.5 m x 0.5 m quadrats distributed across the Bank in a stratified random manner. These field surveys were supplemented by analysis of satellite imagery acquired in 2011 to further estimate the distribution of eelgrass across the Bank. These estimated distributions were compared to previous remote-sensing estimates to obtain insight into interannual variability in the extent of this important eelgrass area
- Additional eelgrass surveys were conducted in September 2014 to delineate and describe eelgrass beds at the MOF and pioneer dock, mapping eelgrass beds in areas where incidental observations were made in 2013. Two small beds of *Z. japonica* were delineated at the pioneer dock site. Twenty-five eelgrass beds or patches were delineated at the MOF site. Both species of eelgrass were found at the site, with *Z. japonica* found higher and *Z. marina* found at or below the low tide line. In 2014, the total area of eelgrass recorded at both sites combined was approximately 1,832 m^2
- Incidental observations of broadly dispersed or rare species that did not fall within the structured field surveys were also incorporated. Additionally, the complete distribution and abundance of fish and marine mammals found in the field survey area (as defined in Section 13.2.5.2) at different times of the year could not be captured during field surveys. These limitations are well understood and supplemented by information in the literature review, which indicates the seasonal importance of the LAA for several species including salmon.

See Appendix L and Appendix M of the EIS for results of detailed surveys, which are summarized below.

13.3.2 Overview of Baseline Conditions

Marine habitats and species within the LAA are typical of the north coast of BC. The physical oceanography of the region, including the seafloor topography and substrata, water conditions and currents, are similar to those found elsewhere on the north coast; however, the LAA is strongly influenced by the Skeena River. The outflow of the Skeena River affects currents, salinity, and turbidity and influences species and community assemblages in the area.

Human activities have affected the marine environment around Prince Rupert (Stantec Consulting Ltd. 2009a). Coupled with environmental factors, fish population abundance is influenced by human activities including exploitation by fisheries, stock and enhancement activities (e.g., hatcheries), and habitat changes. Contaminant levels in sediment and water have been affected by historical and current industrial activities such as a pulp mill (now closed), terminals and port facilities, fish processing facilities, a log dump, and release of sanitary waste and storm water from developed areas.

13.3.2.1 Sediment and Water Quality

13.3.2.1.1 MOF Dredge Area – Sediment Quality

Intertidal surface sediments in the MOF dredge area are composed primarily of sand and silt. Subtidal surface sediments are composed of fine sand, silt and clay; and deeper sediments contain some pockets of gravel, coarse sand, or clay. Bedrock occurs at 5.5 m to 12.5 m below mudline in core samples. Information on existing contaminant levels in samples taken in the MOF dredge area is provided in Appendix L of the EIS and summarized below, with guideline exceedances discussed further, below:

- Arsenic concentrations were higher than the ISQG (7.24 mg/kg) in 45 of 82 samples, with a maximum of 12.8 mg/kg, but did not exceed the PEL (41.6 mg/kg)
- Copper concentrations were higher than the ISQG (18.7 mg/kg) in 56 of 82 samples, with a maximum of 40.7 mg/kg, but did not exceed the PEL (108 mg/kg)
- Mercury, cadmium and lead concentrations were below the disposal at sea screening criteria (0.75, 0.60, and 30.2 mg/kg, respectively)
- Total PAH concentrations were below the disposal at sea screening criterion of 2.5 mg/kg in all samples; when detected, concentrations of some individual PAH compounds exceeded their CCME ISQG
- PCB concentrations were all below the detection limit (0.02 mg/kg) and the disposal at sea screening criterion of 0.1 mg/kg
- Dioxin and furan concentrations were higher than the CCME ISQG in some samples.

13.3.2.1.1.1 Arsenic and Copper

Arsenic and copper were consistently higher than their ISQGs throughout the MOF dredge area at all depths of sediment. Extensive sampling at both the MOF (see Appendix L of the EIS) and previously-presented LNG carrier berth area (see Appendix A of the EIS of the Technical Memorandum: *Follow-Up Report on Sediment and Water Quality Associated with Construction of the Terminal Berth Area* submitted in June 2014) dredge areas, and for the Canpotex Potash Export Terminal and Fairview Terminal projects (see Appendix L of the EIS), indicates that arsenic and copper levels are elevated at all depths in the sediment sampled and occur naturally, not as a result of contamination. Similarly elevated levels of copper and arsenic are also reported for soils in the Skeena Region (British Columbia Ministry of Environment 2010). Although levels in sediment are higher than the CCME ISQGs, these levels are not considered to pose a risk to marine biota, as evidenced by the high levels of biological diversity and productivity of the marine environment in this area. Concentrations are well below the PELs, thresholds above which adverse effects are likely to occur, and the ISQGs incorporate large safety factors.

13.3.2.1.1.2 Dioxins and Furans

Concerns about dioxins and furans in the marine environment around Prince Rupert have been identified since the late 1980s, related to effluent discharges from the former WatCo (formerly Skeena Cellulose) pulp and paper mill at Watson Island from the 1950s to 1980s (see Appendix L of the EIS). Although the use of elemental chlorine to bleach pulp was discontinued in response to regulatory requirements, dioxins and furans remain in the sediment off Prince Rupert, in some areas buried with fresh sediment. These contaminants are of concern because they persist (degrade very slowly), bioaccumulate in the food chain, lead to toxicological risks to vertebrates (including fish, and marine mammals) and have implications for human consumption of seafood. The MOF dredge area is within the historical pulp mill effluent plume.

Dioxin and furan concentrations are reported as toxic equivalencies (TEQ), calculated using toxic equivalency factors (TEF) for fish based on the World Health Organization (WHO) 1998 guidelines (CCME 2001; Van den Berg et al. 1998). The TEQ is the sum of all toxicities associated with individual dioxin and furan compounds and can be compared with the CCME ISQG (0.85 pg/g TEQ) and PEL (21.5 pg/g TEQ). The ISQG and PEL are protective of benthic and epibenthic fish because these are the most sensitive receptors to sediment exposure (the closest organisms to the sediment for food chain effects). Dioxins and furans do not appear to be toxic to invertebrates such as crabs (they lack the aryl hydrocarbon receptor responsible for toxicity (Butler et al. 2001; CCME 2001)) and no TEFs are provided for them.

There are TEFs for birds and mammals (including humans), published in Van den Berg et al. (1998) and updated for mammals/humans by the WHO in 2005 (Van den Berg et al. 2006), which reflect the differing sensitivity of these organisms and their place in the food chain. The TEFs for mammals and humans were updated in 2005 to reflect new information on toxicity of some of the congeners; no update of TEFs for fish was considered necessary as there was no new literature available to support an update. The mammal TEFs are not appropriate for interpreting concentrations of dioxins and furans in sediment because these animals do not consume sediment; however, they are appropriate for assessing exposure via food sources (e.g., using mammal TEFs to calculate TEQs in fish or crab tissue for human consumption). Only TEQs calculated using WHO 1998 TEFs for fish are discussed further in this assessment.

Locations of sampling sites for dioxins and furans in the MOF dredge area are shown in Figure 13-2.

TEQs in this area ranged from 0.06 to 2.64 pg/g TEQ (see full results in Appendix L of the EIS), with highest concentrations measured in the top two layers (0-0.2 m and 0.2-0.4 m) of subtidal sediment:

- Dioxins and furans were measurable in all 35 samples (includes one duplicate) collected from sediment to 1.5 m depth in intertidal and subtidal habitat and were higher than the CCME ISQG in 11 samples
- In intertidal sediment, TEQs were below the ISQG in six of seven samples from the surface 0.075 m (with one exception, the duplicate for sample SS15, with 0.90 pg/g)
- In subtidal habitat, samples from shallow sediment (from 0 m to 0.4 m or 0.5 m depth) had TEQs higher than the ISQG in eight of the twelve samples collected from surface grabs and cores, with a range of 0.23 pg/g to 2.64 pg/g
- In subtidal areas, samples from deeper sediment (from 0.4 m or 0.5 m to 1.0 m depth) had TEQs higher than the ISQG in two of sixteen samples (exceptions were 1.37 pg/g and 1.06 pg/g), and negligible levels (0.06 pg/g to 0.08 pg/g) in the three samples collected from 1.0 m to 1.4 m
- All concentrations were well below the PEL, with the maximum concentration (2.64 pg/g) at about 12% of the PEL (21.5 pg/g).

Dioxin and furan levels were similar to those reported from other locations around Lelu Island, from the Fairview Phase II and Canpotex programs (see Appendix L of the EIS), and from sediment sampled at the previously-presented LNG carrier berth area (full results in Appendix A of the Technical Memorandum: *Follow-Up Report on Sediment and Water Quality Associated with Construction of the Terminal Berth Area* submitted in June 2014).The highest average concentrations were typically measured in the upper 0.075 m of sediment (surface grabs) or the upper 0.2 m (core samples). No surface cap of sediments over the layer containing dioxins is evident at the MOF dredge area.

Although dioxin and furan concentrations at the MOF dredge area are higher than CCME ISQGs, these exceedances are a conservative indicator of potential for adverse effects on biota: the concentrations are well below the PEL (the maximum is 12% of the PEL) and well below remediation standards listed in the provincial Contaminated Site Regulations (130 pg/g TEQ for sensitive aquatic sites, 260 pg/g for typical contaminated sites; (2003).

Environment Canada (2014) draft guidance for disposal of sediments containing dioxins and furans has provided regulatory guidance on evaluating risk associated with presence of these contaminants should dredged sediment be disposed of at sea at a non-dispersive site. The draft guidance includes a lower action level (LAL, the 95% upper confidence limit (UCL)) of 9 pg/g TEQ in specific sediment layers and an overall management objective (OMO) of 0.85 pg/g TEQ, calculated as a volume-weighted average for the entire dredge area. The LAL for a dispersive site is a 95% UCL of 0.85 pg/g TEQ. The dispersive or non-dispersive character of the Brown Passage disposal site is being investigated through additional monitoring of near bottom currents from mid October 2014 to mid April 2015 (see Section 13.5.1.1.1.1).

Sediment from the MOF met both draft criteria for non-dispersive sites, with a 95% upper confidence limit of 3.2 pg/g and a volume weighted average of 0.22 pg/g TEQ (detailed calculations outlined in the Technical Memorandum: *PNW LNG Proposed Materials Off-Loading Facility – Review of Dioxin and Furan Data from the Proposed Dredge Site According to Environment Canada (2014) Guidance* submitted in June 2014). This calculation was based on a previously-calculated dredge volume (350,000 m^3). Table 1 from this technical memorandum, the 95% upper confidence limit dioxin and furan toxic equivalency quotients for sediment sampling units in the proposed MOF dredge area, is repeated below (Table 13-4) and remains relevant, as all primary core samples initially used in this calculation remain within the proposed dredge footprint.

Table 13-4 95% Upper Confidence Limit Dioxin and Furan Toxic Equivalency Quotients for Sediment Sampling Units in the Materials Off-Loading Dredge Area

Sampling Unit	n	TEQ (pg/g)[a]								95% UCL > LAL (9 pg/g TEQ[a])
		Min	Max	Mean	Median	SE	95% Standard Bootstrap UCL	Suggested UCL Calculation Method[c]	Suggested UCL Value	
0-0.2 m	3	0.72	2.64	1.48	1.07	0.59	N/A[b]	95% Student's-t	3.20[d]	**No**
0.2-0.4 m	3	0.23	1.63	0.85	0.68	0.41	N/A[b]	95% Student's-t	2.05[d]	**No**
0.4-0.6 m	3	0.16	1.06	0.53	0.36	0.27	N/A[b]	95% Student's-t	1.32[d]	**No**
0.6-0.8 m	3	0.21	0.49	0.33	0.29	0.08	N/A[b]	95% Student's-t	0.57[d]	**No**
0.8-1.0 m	3	0.13	0.31	0.21	0.20	0.05	N/A[b]	95% Student's-t	0.36[d]	**No**
1.0-12.5 m	5	0.06	0.31	0.16	0.13	0.04	0.221	95% Student's-t	0.25	**No**

Notes:
n = number of samples; min = minimum; max = maximum; SE = standard error; UCL = upper confidence limit; LAL = lower action level (9 pg/g TEQ)
UCLs calculated using ProUCL (Version 5.0) software
[a] All TEQs were mid-point values (concentrations of congeners below the detection limit were considered equal to one half of the detection limit value) and calculated using WHO 1998 TEFs for fish (EC 2014)
[b] 95% Standard Bootstrap UCLs could not be calculated due to low sample size (n=3)
[c] Proposed UCL calculation method as per ProUCL software
[d] Due to the limited sample size (n=3), suggested UCLs (from recommended 95% Student's-t UCL calculations) were higher than the maximum TEQ measured in sediments from that sampling unit

Data for the cores sampled at 0.5 m intervals and for surface grabs indicated similar trends with depth to the data for 0.2 m interval cores, with 0.48 to 2.53 pg/g TEQ in samples from 0 to 0.5 m depth and 0.063 to 1.37 pg/g TEQ in samples from 0.5 m and deeper.

While the 95% UCL values of all sampling units meet the EC LAL of 9 pg/g TEQ (applicable to a non-dispersive site), those from the surface 0.6 m of sediment are greater than 0.85 ng/kg TEQ (applicable to a dispersive site). However, the concentrations in each sampling unit are low enough that the volume-weighted concentrations would be below the OMO if smaller sediment volumes were disposed

Table 13-5 reflects a worst-case scenario, in which only the surface 1 m of sediment is accounted for in the volume-weighted calculation of dioxins and furans in the MOF dredge area (updated from Table 2 of the Technical Memorandum: *PNW LNG Proposed Materials Off-Loading Facility – Review of Dioxin and Furan Data from the Proposed Dredge Site According to Environment Canada (2014) Guidance* submitted in June 2014). Rather than each 0.2 m sediment horizon accounting for 2.5% of the total dredge volume, each horizon has been conservatively weighted to constitute 20% of the overall dredge volume. The calculation would address the surface 1 m of sediment (assumed to be up to 40,000 m^3, with an estimated surface area of 40,000 m^2, reflecting the presence of rock in the surface sediment layer).

Table 13-5 Worst-Case Volume-Weighted Dioxin and Furan Toxic Equivalency Quotients for Surface 1 m of Sampling Units in the Materials Off-Loading Facility Dredge Area

Sampling Unit	% of Total Dredge Volume	Mean TEQ (pg/g)	Volume-weighted TEQ (pg/g)
0-0.2 m	20	1.48	0.30
0.2-0.4 m	20	0.85	0.17
0.4-0.6 m	20	0.53	0.11
0.6-0.8 m	20	0.33	0.06
0.8-1.0 m	20	0.21	0.042
Overall Volume-Weighted TEQ for the Entire MOF Dredge Area			**0.68**

Notes:
n = number of samples; MOF = materials off-loading facility
All TEQs were mid-point values (concentrations of congeners below the detection limit were considered equal to one half of the detection limit value) and calculated using WHO 1998 TEFs for fish (EC 2014)

Considering only the top 1 m of sediment, a volume-weighted average of 0.68 pg/g TEQ was calculated, which is expected to be highly conservative for any volume of sediment less than the 350,000 m^3 used for the original calculation, including the current estimate of a maximum sediment volume of 200,000 m^3.

13.3.2.1.2 Brown Passage Disposal Site – Sediment Quality

The previously used Brown Passage disposal site is considered the preferred site for disposal at sea and no alternative disposal at sea sites are under consideration (see Appendix G.8). Sediment that meets disposal at sea screening criteria has been deposited at Brown Passage several times in the past decades. Contaminant levels in sediments at the previously used disposal site in Brown Passage were analyzed in samples collected by Environment Canada in April and October 2011 (Lewis 2013, pers. comm.). Results for the 55 samples collected in 2011 were generally similar to those collected from around Lelu Island, with the exception of lower arsenic, copper and dioxin/furan levels at Brown Passage. The sediment characteristics are:

- Total PAH: <0.02 mg/kg to 1.86 mg/kg, below the disposal at sea screening criterion
- Arsenic: 1.7 mg/kg to 7.7 mg/kg, one sample higher than the screening criterion
- Copper: 3.1 mg/kg to 24.3 mg/kg, nine samples higher than the screening criterion
- Cadmium: 0.06 mg/kg to 0.67 mg/kg, one sample higher than the screening criterion (0.6 mg/kg)
- Mercury: 0.006 mg/kg to 0.064 mg/kg, all below the screening criterion (0.75 mg/kg)
- Dioxins and furans: 0.026 pg/g to 0.509 pg/g TEQ, below the ISQG (0.85 pg/g TEQ).

13.3.2.1.3 Water Quality

Baseline water quality data were obtained from project field programs and literature review. Water samples were collected and in situ water quality recorded on July 25, 2013 during the MOF sediment sampling program (see Appendix L of the EIS for results). Samples were collected 1 m below the surface during flood and ebb tides, and TSS levels were 7.4 mg/L and 7.0 mg/L, respectively (turbidity was not analyzed; See Appendix G.6). Water samples collected in January and February 2014 were analyzed for TSS and turbidity. Samples collected southwest of the MOF area (in the previously-presented LNG carrier berth dredge area) had up to 2.7 mg/L TSS and 1.45 NTU (nephelometric turbidity units) turbidity, respectively. Samples collected on Flora Bank had up to 4.0 mg/L TSS and

1.68 NTU turbidity, respectively (see the Follow-up Report on Sediment and Water Quality Associated with Construction of the Terminal Berth Area). The PRPA water quality program includes quarterly monitoring at several sites, including sites close to the project area; TSS and turbidity levels were in the range reported for the MOF area and Flora Bank (SNC Lavalin Environment 2013a, 2013b, 2013c, 2013d). Information on sediment plumes in the Flora Bank area was provided in the technical memorandum, Sediment Transport into the Project Development Area from the Skeena River (ASL Environmental Sciences Inc 2014).

13.3.2.2 Fish and Fish Habitat

A rich diversity of marine fish and invertebrates inhabit the LAA, and many of these species are of importance to CRA fisheries. Appendix M of the EIS and the Technical Memorandum: *Species Use of Marine Habitats in the Local Assessment Area* submitted in June 2014 provide an in depth discussion of CRA fishery species and life-stage use of habitat within the LAA. A summary is provided below.

All five Pacific salmon (*Oncorhynchus* spp.) occur around the project site. These anadromous species show landward and seaward migrations, the exact timing of which varies among species. Generally, juveniles migrate (predominantly from the Skeena River) through Flora Bank and then to the deep waters of the North Pacific from March through to July; adults return to their natal streams to spawn from June through to November. Refer to Table 13-6 for a summary of these sensitive life history periods. Many adults and juveniles pass the project site during these migrations. In addition to salmon, other important CRA species in the area include anadromous eulachon (*Thaleichthys pacificus*), Pacific herring (*Clupea pallasii*), Pacific halibut (*Hippoglossus stenolepsis*) and rockfishes (*Sebastes* spp.).

Table 13-6 Sensitive Life History Periods of Pelagic Marine Fish Species

Species	January	February	March	April	May	June	July	August	September	October	November	December
Chinook[1] *Oncorhynchus tshawytscha*					●		●	P				
Chum[2] *Oncorhynchus keta*			●	●								
Pink[2] *Oncorhynchus gorbuscha*			●		●			P				
Sockeye[3] *Oncorhynchus nerka*				●		●		P				
Coho[4] *Oncorhynchus kisutch*					●	●					P	
Steelhead[5] (summer run) *Oncorhynchus mykiss*												
Steelhead[5] (winter run) *Oncorhynchus mykiss*												
Eulachon[6,7] *Thaleichthys pacificus*			P		●				●			
Pacific herring[8] *Clupea pallasii*			P	P	●					●		

NOTE:

Grey boxes = Return spawning migration (salmon)

Cross hatch = General spawning period (for salmon, steelhead, and eulachon this occurs outside the LAA, upriver within the Skeena River)

P = Peak spawning period

Lines with dots = Outbound juvenile migration (salmon and eulachon) / offshore juvenile migration (herring).

SOURCES:

[1] Naughton et al. (2008), [2] Hyatt et al. (2007), [3] DFO (2005), [4] DFO (1999), [5] Beacham et al. (2012), [6] McCarter and Hay (1999) [7] Moody and Pitcher (2010), [8] DFO (2013g)

Invertebrates are ubiquitous in the LAA, with community composition defined by habitat type, and several species form important components of local CRA fisheries. Soft substrates, including those within naturally protected areas around Lelu Island, support sediment-dwelling ("infaunal") invertebrates, such as clams (e.g., *Macoma* spp. and *Clinocardium nuttallii*), shrimps, amphipods, and worms (polychaetes and nemerteans). The Technical Memorandum: *Species Use of Marine Habitats in the Local Assessment Area* submitted in June 2014 describes the life history of marine invertebrates found within the LAA, including information on sensitive molting life stages.

Seven rockfish species of conservation concern may be present in the LAA (Table 13-7); however, none of these species were observed during ROV surveys (see Appendix M of the EIS). Some or all of these rockfish species are likely to occur in deeper water habitats within the LAA. Given that most demersal rockfish species inhabit rocky substrates of high structural complexity, it is presumed that rockfish abundance within the PDA is relatively low, as this area is dominated by soft substrates. Bluntnose sixgill shark, eulachon, green sturgeon, North Pacific spiny dogfish, and Northern abalone may also be present but were not observed during ROV surveys (Appendix M of the EIS).

Table 13-7 Marine Fish and Invertebrates of Conservation Concern Potentially Occurring in the LAA

Common Name	Scientific Name	Provincial Status[1]	SARA Status[2]	COSEWIC[3]
Bluntnose sixgill shark	*Hexanchus griseus*	No status	Schedule 1, *special concern*	*special concern*
Bocaccio	*Sebastes paucispinis*	No status	No status	*endangered*
Canary rockfish	*Sebastes pinniger*	No status	No status	*threatened*
Darkblotched rockfish	*Sebastes crameri*	No status	No status	*special concern*
Eulachon (Nass/Skeena Rivers population)	*Thaleichthys pacificus*	Blue	No status	*special concern*
Green sturgeon	*Acipenser medirostris*	Red	Schedule 1, *special concern*	*special concern*
North Pacific spiny dogfish	*Squalus suckleyi*	No status	No status	*special concern*
Quillback rockfish	*Sebastes maliger*	No status	No status	*threatened*
Northern abalone	*Haliotis kamtschatkana*	Red	Schedule 1, *endangered*	*endangered*
Rougheye rockfish	*Sebastes aleutianus*	No status	Schedule 1, *special concern*	*special concern*
Yelloweye rockfish (Pacific Ocean outside waters population)	*Sebastes ruberrimus*	No status	Schedule 1, *special concern*	*special concern*
Yellowmouth rockfish	*Sebastes reedi*	No status	No status	*threatened*

NOTES:
[1] Information obtained from the BC Ministry of Environment (BC Ministry of Environment 2013).
[2] Information obtained from the Species at Risk Public Registry (Government of Canada 2012).
[3] Information obtained from the Committee on the Status of Endangered Widlife in Canada Wildlife (COSEWIC 2013).

The eelgrass beds on Flora Bank are ecologically valuable to the region (Department of the Environment 1973b) and provide rearing habitat for out-migrating salmon, predominantly from the Skeena River, and support healthy populations of invertebrates including Dungeness crab and *Pandalus* shrimp (DFO 1985). Existing literature, field surveys, and remote sensing inferences of eelgrass distribution, indicate that Flora Bank eelgrass beds are fairly consistently distributed over time. Eelgrass beds are restricted to the intertidal areas of Flora Bank because the high TSS influence of the Skeena River limits the photic zone, impairing subtidal plant growth (Faggetter 2009, 2013); see Appendix M of the EIS). Additional eelgrass field studies were conducted in September 2014 to supplement existing information. A complete summary of the 2014 findings are presented in the Eelgrass Survey Report (Appendix G.22).

Agnew Bank has relatively low species diversity, with the main fauna consisting of sparsely distributed invertebrates, such as orange sea pens (*Ptilosarcus gurneyi*), *Pandalus* shrimp, tunicates, sponges, and various mollusc species.

Photic (sunlit) waters over the hard substrate of Porpoise Channel support kelp stands, in which thrive numerous species of crab, echinoderms, and fishes.

The rocky shorelines of Lelu Island and nearby areas, which comprise a mix of bedrock, large boulders, rocks and gravel areas, support a rich subtidal and intertidal seaweed community. These communities are dominated by rockweed (*Fucus gardneri*), sea lettuce (*Ulva* spp.), Turkish washcloth (*Mastocarpus papillatus*), sea sac (*Halosaccion glandiforme*), and kelps (e.g., *Laminaria* spp., *Alaria* spp.). Invertebrate communities on rocky shores include barnacles (*Balanus* spp. and *Semibalanus* spp.), limpets (e.g., *Lottia* spp.) and periwinkles (e.g., *Littorina littorea*). The most important commercially-harvested invertebrates within the LAA are Dungeness crab and *Pandalus* shrimp, which are abundant around Agnew Bank.

Rocky subtidal areas support diverse seaweed communities, including numerous species of kelp. These plants provide food and shelter for mobile and sessile invertebrates and fish. Soft sediments rarely support seaweeds but provide suitable habitat for burrowing invertebrates, crabs (e.g., Dungeness, *Metacarcinus magister*), shrimp (*Pandalus* spp.) and flatfish (family Pleuronectidae).

The area is known to be important to juvenile salmon (DFO 1985; Higgins and Schouwenburg 1973), rockfish (*Sebastes* spp.), cod (family Gadidae), particularly Pacific cod, (*Gadus macrocephalus*), eulachon (*Thaleichthys pacificus*) and Pacific herring (*Clupea pallasii*) (Hart 1988). Sand lance (*Ammodytes hexapterus*) is an important forage species that may be found in the LAA and has historically been caught around Flora Bank (Higgins and Schouwenburg 1973). In the area that is most likely to be affected by construction activities and where field surveys were focused, flatfish, eelpouts (Zoarcidae), and pricklebacks (Stichaeidae) are the most common fish in the LAA year round. Of these, only flatfish are commercially valuable.

Recent observations of fish distribution are consistent with past studies conducted at and adjacent to Flora Bank and Lelu Island (Anderson 1986; Carr-Harris and Moore 2013; Gottesfeld et al. 2008; Higgins and Schouwenburg 1973). Past studies observed small benthic fish species (sculpins, flatfish) and low numbers of juvenile crab in soft sediment habitats outside areas of eelgrass on the northern edge of Flora Bank. Juvenile salmonids were observed from May to June during smolt migrations in sites on the southern portions of Flora Bank (Horsey Bank) and in low-water channels with strong tidal currents, immediately adjacent to Lelu Island and outer Kitson Island. Salmonids were observed in greater numbers in more complex nearshore habitats of Chatham Sound islands, particularly in habitats with pronounced channels and tidal current (Anderson 1986; Carr-Harris and Moore 2013; Higgins and Schouwenburg 1973). Plankton feeding sockeye (*Oncorhynchus nerka*) and pink (*O. gorbuscha*) salmon were observed in large schools outside Lelu Island and Flora Bank in areas of pronounced current following migratory pathways (Gottesfeld et al. 2008; Manzer 1969). Salmonids were not observed in soft sediment shallow depth areas of Agnew Bank and along the northern edge of Flora Bank (Anderson 1986). Chinook (*O. tshawytscha*), coho (*O. kisutch*) and chum (*O. keta*) salmon were observed in catches within complex habitats in bays and eelgrass beds (Anderson 1986; Carr-Harris and Moore 2013; Higgins and Schouwenburg 1973). An in depth description of

CRA species and life-stage use of habitats associated with the marine terminal are presented in the Technical Memorandum: *Species Use of Marine Habitats in the Local Assessment Area* submitted in June 2014.

13.3.2.2.1 Brown Passage

The ROV survey conducted in July 2014 also provided additional details on benthic fauna present within the previously used Brown Passage disposal site and general area. The area was dominated by soft bottom substrates with minimal rocky outcrops, and no observed marine plants. Ratfish and pricklebacks were the most commonly observed fish species. Low densities of rockfish were observed in all surveyed areas (average density for all areas and all species of 0.5 individuals/100 m), with only a single silvergrey rockfish and a single tiger rockfish observed within the disposal site, neither of which are listed species at risk. Furthermore, no large rocky outcrops (the preferred habitat for rockfish) were observed at the disposal site. Halibut were observed in low numbers (0.04 to 0.71 individuals/100 m) throughout Brown Passage, while eulachon were observed only south of the previously used disposal site.

The most frequently observed invertebrates were various species of sea stars, Pandalus shrimp and scallops. While Pandalus shrimp were considered highly abundant during the ROV survey conducted by Environment Canada (Canada 2011) at the Brown Passage disposal site, they were not present in high densities within the disposal site in this 2014 survey (average of 3 individuals/100 m). While Brown Passage falls within an area identified by DFO (2009a) as being an important Dungeness crab area, no Dungeness crab were observed on any of the transects surveyed in 2014. The disposal area, at 200 m depth, is not considered to be important habitat for Dungeness crab. Cloud sponges were observed throughout the survey area as developing individual sponges, but with no dense reef forming structures observed. Other sponge species, including sharp lipped boot sponge, were found in low numbers throughout the surveyed Brown Passage area.

13.3.2.3 Marine Mammals

Several marine mammal species are resident or seasonally present in the LAA (see Table 13-8). Of the most commonly observed species, humpback whale (*Megaptera novaeangliae*), northern resident and Bigg's killer whale (*Orcinus orca*) and harbour porpoise (*Phocoena phocoena*) have been identified by the Province of British Columbia, COSEWIC, and SARA as species of conservation concern. Dall's porpoise (*Phocoenoides dalli*), Pacific white-sided dolphin (*Lagenorhynchus obliquidens*), and harbour seal (*Phoca vitulina richardsi*) also frequent the area. Other species that are less common in the LAA include Loughlin's northern sea lion (*Eumetopias jubatus monteriensis*, previously 'Steller' sea lion), fin whale (*Balaentoptera physlaus*), grey whale (*Eschrichtius robustus*), minke whale (*Balaenoptera acutorostrata scammonii*), and sea otter (*Enhydra lutris*). There are no Loughlin's northern sea lion rookeries in the LAA (DFO 2010b). The closest known year-round haulout site in on Warrior Rocks (outside the LAA to the southwest of Stephens Island) and the closest known major winter haulout is west of Baron and Dunira islands, just north of the LAA (DFO 2010b) (see Figure 13-1). Marine mammals in the Prince Rupert area generally increase in numbers during the summer months, coinciding with the seasonally migrating fish (e.g., salmon, Pacific herring). More detailed baseline information on resources found within the LAA is presented in the Marine Resources TDR (Appendix M of the EIS). Further information on marine mammal and fish habitat utilization, timing, and abundance is provided in Appendix G.1 and in the Technical Memorandum: *Species Use of Marine Habitats in the Local Assessment Area* submitted in June 2014, which includes an assessment of marine mammal presence in the local assessment area during salmon and eulachon runs.

Table 13-8 lists marine mammal species that are considered most likely to occur within the LAA.

Table 13-8 Provincial, Federal, or International Listings of Marine Mammal Species found in the LAA

Common Name	Scientific Name	Provincial Status[1]	SARA Status[2]	IUCN Category[3]
Fin whale	*Balaentoptera physlaus*	Red	*threatened*	*endangered*
Humpback whale	*Megaptera novaeangliae*	Blue	*threatened*	*least concern*
Minke whale	*Balaenoptera acutorostrata scammonii*	Yellow	Not listed	*least concern*
Grey whale	*Eschrichtius robustus*	Blue	*special concern*	*least concern*
Northern resident killer whale	*Orcinus orca*	Red	*threatened*	*data deficient*
Bigg's killer whale (previously 'transient' killer whale)	*Orcinus orca*	Red	*threatened*	*data deficient*
Dall's porpoise	*Phocoenoides dalli*	Yellow	Not listed	*least concern*
Harbour porpoise	*Phocoena phocoena*	Blue	*special concern*	*least concern*
Pacific white-sided dolphin	*Lagenorhynchus obliquidens*	Yellow	Not listed	*least concern*
Sea otter	*Enhydra lutris*	Blue	*Special concern*	*endangered*
Harbour seal	*Phoca vitulina richardsi*	Yellow	Not listed	*least concern*
Loughlin's northern sea lion (previously 'Steller' sea lion)	*Eumetopias jubatus monteriensis*	Blue	*special concern*	*least concern*

NOTES:

[1]Information obtained from the BC Ministry of Environment (BC Ministry of Environment 2013).

[2]Information obtained from the Species at Risk Public Registry (Government of Canada 2012).

[3]Information obtained from the IUCN Red List of Threatened Species (IUCN 2012).

Data sources to determine the qualitative likelihood of occurrence of these species in the local and regional assessment areas (LAA/RAA) included opportunistic sightings data from the BC Cetacean Sightings Network (2013) and abundance and distribution data from (Best and Halpin 2011) and (Ford et al. 2010), among others. These studies provide the baseline information considered necessary to assess the potential pathways of effects.

13.4 PROJECT INTERACTIONS WITH MARINE RESOURCES

Project activities with the potential to interact with marine resources are listed in Table 13-9 and ranked by their potential to result in effects.

Table 13-9 Potential Effects on Marine Resources

Project Activities and Physical Works	Potential Effects			
	Change in Sediment or Water Quality	Change in Fish Habitat	Direct Mortality / Physical Injury	Change in Behaviour
Construction				
Site preparation (land-based)	1	0	0	0
Onshore construction	1	0	0	0
Vehicle traffic	0	0	0	0
Dredging	2	2	2	2
Marine construction	2	2	2	2
Waste management and disposal	1	0	0	0
Disposal at sea	2	2	2	2
Operational testing and commissioning	1	0	0	0
Site clean-up and reclamation	1	0	0	0
Operations				
LNG facility and supporting infrastructure on Lelu Island	0	0	0	0
Marine terminal use	2	0	0	2
Shipping	1	1	0	2
Waste management and disposal	1	0	0	0
Fish habitat offsetting	0	0	0	0
Wetland habitat offsetting	0	0	0	0
Decommissioning				
Dismantling facility and supporting infrastructure	1	1	1	2
Dismantling of marine terminal	1	1	1	2
Waste disposal	1	0	0	0
Site clean-up and reclamation	1	1	1	0

KEY:

0 = No interaction.

1 = Potential adverse effect requiring mitigation, but further consideration determines that any residual adverse effects will be eliminated or reduced to negligible levels by existing codified practices, proven effective mitigation measures, or best management practices (BMPs).

2 = Interaction may occur, and resulting effect may exceed acceptable levels without implementation of project-specific mitigation. Further assessment is warranted.

13.4.1 Justification of Interaction Rankings

Activities ranked as 0 are considered to have no interaction with marine resources, with no spatial overlap causing effects.

Activities ranked as 1 in Table 13-9 have an interaction that could result in adverse effects, therefore requiring some mitigation. These include:

- Site preparation (land-based)
- Onshore construction
- Waste management and disposal (during all project phases)
- Operational testing and commissioning (with respect to change in sediment or water quality as a result of liquid waste discharges)
- Marine terminal use with respect to change in sediment or water quality as a result of liquid waste discharges, bilge, or ballast water release and change in fish habitat
- Shipping (with respect to change in fish habitat and in sediment quality)
- Dismantling facility and supporting infrastructure, including the marine terminal
- Site clean-up and reclamation for the decommissioning and construction phases.

Based on experience with similar projects, professional judgment, and ability to mitigate through legislated standards, the potential effects associated with the activities listed above will be negligible, but are considered here.

Land-based site preparation and onshore construction could result in change in sediment or water quality as the interaction will occur mainly through release of TSS in runoff from the construction sites. These effects will be managed through standard erosion and sediment control plans (e.g., sediment fences for foreshore activities, use of temporary diversion berms and sandbags) that ensure water quality guidelines are met in the marine environment (see Summary of Proposed Environmental and Operational Management Plans, Section 24).

Waste management and disposal for liquids, solids, and hazardous materials are subject to federal and provincial regulations and monitoring; following codified and best management practices and adhering to permit conditions will manage any effects. As described in the Project Description (Section 2 of the EIS), the only discharges for the Project will be from stormwater runoff (construction and operations phases) and seawater used for LNG storage tank testing (construction phase). These are discussed in Sections 2.2.3.5 (hydrostatic testing) and 2.2.3.6 (stormwater) for construction and Section 2.3.2.4 for operations.

The stormwater management system will be designed to collect, segregate and treat any contaminated stormwater (such as oily water), water contaminated by the LNG process, water discharge from steam or condensate blow-down, and solvent or hydrocarbon contaminated wastewater and wash water, and surface runoff. The Stormwater Management Plan will meet or exceed regulatory requirements, and PETRONAS standards for stormwater management. Greater detail about the operations and maintenance of stormwater systems will be provided as design details are finalized during permitting for the Project. Stormwater management plans for construction will be developed during the permitting phase of the Project. They will form part of the Marine and Freshwater Resource Management Plan (Section 24.4.5 of the EIS and Appendix J.8).

Approximately 197,000 m^3 of sea water will be used for hydrotesting tanks and utilities during commissioning. The sea water will initially be treated with sodium hypochlorite to mitigate biological growth during testing, and will later be treated with sodium bisulphate to remove the sodium hypochlorite before disposal through an outfall at the marine terminal (see Section 2.2.6.5).

As per Section 13.4.1, potential effects of wastewater disposal on the marine environment will be effectively mitigated by following codified and best management practices and adhering to permit conditions. Sanitary and maintenance wastewater will be transferred to the Port Edward publicly owned treatment works. Specific details of locations for these discharges will be included in the applicable permit applications. All outfalls will be located at least 30 m from sensitive habitats (such as eelgrass beds on Flora Bank [as noted in Section 2.2.3.6]).

Liquid waste discharges within the Port Authority jurisdiction are regulated by the PRPA and are also regulated by the BC Ministry of Environment (BC MOE) under the *Environmental Management Act* (EMA), 2004 and must meet the associated Waste Discharge Regulation. The Project would likely fall under the "Oil and Natural Gas Industry – Large" classification of the regulation and would be considered a Tier 1 industry that is deemed to be a risk to the environment and public health. As such, discharges associated with the Project (including those during operational testing and commissioning) will require a Waste Discharge Permit(s) and will be required to meet permit conditions for effluent quality. If guidelines cannot be met, effluent will either be treated or disposed of off-site. Monitoring programs will be in place, to track compliance to permit conditions. Other best practices to reduce the entry of deleterious substances into the water require fuelling and maintenance of vehicles and equipment be conducted away from the water. A spill containment plan will also be developed (see Section 22: Accidents and Malfunctions).

The potential effects of release of bilge and ballast water from LNG carriers during marine terminal use on water quality are assigned a rank of 1 because they are effectively mitigated through standard procedures and best management practices. In particular, all vessels visiting the facility will manage ballast water in compliance with the *Canada Shipping Act*, 2001 Ballast Water Control and Management Regulations. An International Maritime Organization approved ballast water management plan will be required, with ballast water exchanged not less than 200 nautical miles offshore. All vessel-based waste will be managed according to the *Canada Shipping Act, Vessel Pollution and Dangerous Chemicals Regulations*, which requires treatment of oily bilge water prior to release. These practices are intended to prevent the introduction of invasive species and oily contaminants. Vessels calling on the Pacific NorthWest LNG Limited Partnership (PNW LNG) marine terminal will comply with all applicable federal and international regulations that reduce the potential for introducing alien and/or invasive species.

Shipping is not expected to result in wake effects outside the range of natural variation; shoreline habitats in the LAA are exposed to large open ocean swells and wind generated waves from Hecate Strait. The results of previous wake effects studies in more confined environments of Douglas and Principe Channels (Moffatt and Nichol 2010, 2011) can be used to conservatively infer wake effects in the LAA, which is more exposed. These studies suggest that the height and frequency of wake waves generated by LNG carriers and associated escort tugs in this area would be within the range of naturally occurring wind and swell generated waves (Moffatt and Nichol 2010, 2011). Marine fish and habitats that occur in the LAA are adapted to wave action, and are not expected to be adversely affected by vessel wake. As a result, no further assessment of the effects of vessel wake on fish and fish habitat is warranted.

The lifespan of the Project will likely exceed 30 years. Upon closure, a final Decommissioning Plan will be developed consistent with PRPA planning initiatives and the standards and regulations that will be developed at the time. The potential interactions between decommissioning and marine resources (e.g., underwater noise) are similar to those during construction. Based on current information regarding existing fish habitat, and decommissioning methods and technologies, serious harm to fish, including permanent alteration to, or destruction of, fish habitat is not expected as a consequence of decommissioning activities, though this conclusion should be reviewed closer to the time such activities would take place. Decommissioning activities could have an effect on fish habitat or sediment and water quality by dismantling and removal of marine-based structures and shore-based clean-up activities; however, it is expected that all intertidal-based structures that have been colonized by encrusting marine epifauna and seaweeds will be left in place; others will be removed. The fate of structures away from the intertidal (e.g., marine terminal piles) is less certain and will likely depend on public opinion, political/regulatory climate and engineering capabilities.

Post-commissioning clean-up and potential decommissioning of the MOF could increase the likelihood of injury or mortality to fish if equipment and activities crush marine organisms. Although decommissioning and clean-up mechanisms are not yet known, this potential effect would be highly localized, have a low magnitude effect on local populations, and be easily reduced through mitigation measures. Similarly, clean-up mechanisms following construction will apply standard best practices and appropriate mitigation measures.

Because all of these effects can be mitigated through the standard practices outlined above, no additional analysis is warranted.

Project activities identified in Table 13-9 that could potentially cause a significant adverse effect were ranked as 2. A conservative approach is used in applying rankings, whereby potential interactions with a meaningful degree of uncertainty are assigned a rank of 2, ensuring that a detailed effects assessment is conducted. These activities are carried forward in the assessment and are discussed in Section 13.5.

13.5 EFFECTS ASSESSMENT

13.5.1 Analytical Methods

13.5.1.1 Analytical Assessment Techniques

The focus of the Marine Resources VC assessment is on species of importance to CRA fisheries, species of conservation concern, and culturally important species. Where information on such species is not available, inferences are made based on information about other species with similar biology. Generally, the process for assessing each effect is as follows:

1. Using measurable parameters, identify the pathway to each effect as a result of project activities, the location where these effects are likely to occur, and the potential effects on baseline habitat, species, or sediment and water quality conditions
2. Determine mitigation measures to avoid, reduce, or offset potential effects
3. Characterize the residual effects using residual effects description criteria (Table 13-3) and determine significance based on thresholds identified in Section 13.2.7.

Baseline information from field studies and literature reviews (presented in Appendices K and L) is used to discuss potential effects or residual effects, depending on where it is most appropriate. Following the significance determination, the degree of confidence is discussed, considering limitations of data and information and effectiveness of mitigation. Further details on the methods used to assess each effect are described below.

13.5.1.1.1 Change in Sediment or Water Quality

Change in sediment or water quality is assessed by comparing baseline and predicted project-related chemical concentrations to relevant guidelines. These include the CCME and BC water and sediment quality guidelines for protection of marine life, Environment Canada screening criteria for disposal of sediment at sea and Environment Canada draft guidance on evaluating dioxins and furans in sediments proposed for open water disposal.

The CCME environmental quality guidelines are levels of chemicals below which there is a negligible risk to biota (CCME 2001). Canadian WQGs are derived directly from results of toxicity testing in the laboratory. Tests are conducted by exposing organisms to a known range of chemical concentrations to identify toxicity thresholds for an adverse effect. A variety of species are tested. Safety factors are then applied to the lowest threshold value of all species tested, to account for uncertainties, including variability among individuals within a species and variability among species. Due to the range of endpoints assessed through toxicity testing, as well as the application of safety factors to the lowest threshold concentration value, the resulting guidelines are conservative. Ideally, sediment quality guidelines would be derived similarly; however, to date, spiked-sediment toxicity data are limited. The ISQGs are based on associative data, obtained when levels of a contaminant in field-collected sediments (which may contain a mixture of other chemical contaminants) are associated with any adverse biological effect observed. Because correlation does not necessarily infer causation, the contaminant present at levels higher than the guideline may not be responsible for the associated adverse effects; thus the ISQGs may not accurately reflect a level above which adverse effects may occur (Smith et al. 1996).

Project effects on water quality were also assessed by modelling the sediment plumes predicted to result from dredging at the MOF and vessel maneuvering at the LNG carrier berth, and comparing results to WQGs for TSS, which pertain to chronic effects on marine biota. Predicted TSS levels are compared to the CCME WQG for protection of marine aquatic life (CCME 2013) and BC Approved WQG (MOE 2006), which are the same. For continuous activities (24 hours to 30 days), the WQG is an increase in TSS of no more than 5 mg/L above background for clear waters (<25 mg/L background) and 10 mg/L above background for turbid waters (25 to 100 mg/L background). For activities of 24 hours or less, the WQG is an increase of no more than 25 mg/L above background. The continuous activity WQG is appropriate to dredging and disposal operations, which will occur over periods within a six month time frame. The WQGs conservatively reflect levels at which chronic (non-lethal) effects to aquatic life may occur.

Turbidity is also important when considering the effects of TSS on marine organisms. Turbidity and TSS are indirectly related, as turbidity is measured using optical instruments that are sensitive to clarity of a water sample, while TSS is defined as the total mass of sediments present per unit volume of water, derived using laboratory-based methods. A water sample containing mainly sand could have elevated TSS level, but low turbidity, given that sand settles quickly, leaving little turbid material in suspension. A sample containing mainly silt and clay could have a similar TSS level but high turbidity, as the fine material remains in suspension for a longer period. The numerical values of TSS (in mg/L) and turbidity (in NTU) are usually similar (roughly 1:1 ratio), except for very low TSS values of less than 1 mg/L or very high TSS values exceeding several hundred mg/L (Fissel 2014). This relationship depends on particle size distribution of the suspended sediments. Since only turbidity can be monitored in the field in real time, the relationship between TSS and turbidity is established on a project-specific basis by analyzing representative samples for turbidity and TSS and developing a correlation curve. This curve can then be used during construction monitoring to relate observed turbidity levels to predicted TSS levels.

13.5.1.1.1.1 Sediment Dispersion Modelling - Dredging and Disposal

A three dimensional numerical modelling study was conducted by ASL Environmental Services Inc. at the MOF dredge area and Brown Passage disposal site to predict TSS levels and deposition of sediments from dredging and disposal activities (Appendix O of the EIS). The models were run using assumptions for a previous MOF design that involved dredging of 615,000 m^3 of sediment, assuming use of a clamshell dredge but no other mitigation measures. The models assumed dredging and disposal for the period January 1 – June 25, 2015 (1 day for spin up, 153 days for dredging and disposal, 20 days for post-disposal). Disposal events were modelled to occur every 18 hours at the center of the disposal site. The current design for the MOF was developed during detailed project planning and identifies a maximum of 200,000 m^3 to be dredged with a trailing suction hopper dredge (TSHD) and a backhoe dredge. The original TSS plume predictions remain valid but the estimates of sediment deposition are overestimated, given the two-thirds reduction in sediment volume. This assessment uses the results of TSS plume modelling for the MOF and Brown Passage disposal site provided in Appendix O of the EIS and a refined sediment deposition estimate for the 200,000 m^3 dredge and disposal volume, as presented in Section 13.5.2.3.

The sediment plume dispersion modelling presented in Appendix O of the EIS is applicable to the change in dredge and disposal timing, reduced sediment volume, and change in equipment.. The changes in sediment volume, timing for dredging and disposal, and equipment do not materially change the predictions of TSS plumes provided in Appendix O of the EIS for the following reasons:

- The dredge area and sediment characteristics within the dredge area have not changed
- The TSS plume predictions are based on daily activities that release sediment, not the total dredge volume; although the duration of TSS plumes will be less than originally considered, TSS levels will not change because the sediment particle size will remain the same
- The change in construction schedule to dredging and disposal between October and March rather than the modelled period of January to June will not affect TSS plume predictions, given that similar high energy storm events are captured in both time periods, and the effects assessment presents the maximum predicted plumes
- The change in equipment for construction is expected to have a minimal effect on the predictions of TSS plumes. The TSS modelling assumed that 1% of the sediment would be released from a clamshell dredge. The construction equipment now being considered by contractors is a TSHD and a backhoe dredge, and this information may change again during the tendering of the work. The TSHD will be used for initial dredging to expose rock in the MOF; this dredge has a 1% sediment release rate (including release of turbid overflow water from the hopper), the same as for a clamshell dredge. The backhoe dredge will be used to dredge up the blasted rock and sediment; this dredge has a larger sediment release rate of 3% but will be picking up a mix of rock and sediment, not pure sediment, and the overall sediment release should be similar to that presented in Appendix O of the EIS.

Ocean current data sets at Brown Passage generated by DFO's Institute of Ocean Sciences were used to validate the 3D ocean circulation model and sediment deposition modelling. Historical current data has been collected at site CP02 (54° 18.8 N, 130°45.1 W), which is within the previously used Brown Passage disposal site. Ocean current data for this site were collected between late June 1991 and early July 1992 at the near-surface (15 m depth) and at the mid to lower part of the water column (maximum 98 m depth). Calibration and verification of the ocean circulation model was conducted with modelled versus observed currents for two periods at both 15 and 98 m: September 5-22, 1991 when the effect of winds was relatively weak and October 5-22, 1991 when wind forcing was large. In both model comparisons, and at both depths, modelled and observed currents were reasonably similar (at 98 m, modelled currents were modestly larger than the observed currents, about 10% to 20% for average speeds and about 0.1 m/s larger for maximum speed; Jiang and Fissel, 2010). Modelling of an extreme wind event and an extreme tidal forcing event over a 40 year period occurring simultaneously is considered to reflect a large upper bound to the actual values for sediment resuspension. Even under the extreme forcing conditions simulated for the near-bottom currents arising from the largest wind speeds over 40 years coinciding with the largest tidal currents in 40 years (which is an unlikely occurrence), the model derived maximum near-bottom current speed was 0.47 m/s. Furthermore, model results were consistent with the current speeds of non-dispersive sites (defined by Environment Canada as having peak 1% near-bottom current speeds of up to 0.25 m/s over a period of one year).

The data for 98 m depth indicate low currents reflective of non-dispersive conditions (i.e., deposited sediment will stay in place over the long term). Further validation will be provided from the results of a metocean measurement program currently underway to measure the maximum and peak 1% values of the near-bottom currents at Brown Passage. PNW LNG deployed an acoustic Doppler current profiler (ADCP) at the Brown Passage disposal site (54° 18.392' N, 130° 45.862' W) on October 15, 2014. The ADCP will remain in place for six months over the winter (to April 2015) to correspond with the strongest predicted winds, and highest seasonal current speeds. The ADCP has been placed 5 to 10 m off the ocean bottom, oriented upwards to provide current profiles over most of the water column, with a single point Doppler current meter at 3 to 5 m off the ocean bottom oriented down to capture near-bottom current speeds. Measured currents retrieved from this metocean measurement program will be used to confirm the model input parameters and confirm whether the disposal site is non-dispersive. Sensors will also collect conductivity, temperature, and turbidity data.

Appendix O of the EIS describes how the sediment mound at Brown Passage would behave in terms of stability and resuspension of sediment. Conditions were modelled for 20 days after completion of sediment disposal. The maximum daily resuspension event modelled between January 1 and June 25, 2015 is shown in Figure 2 of Appendix G.5and indicates only limited areas of predicted erosion (none within the disposal site). For this reason, and because of the small amount of erosion associated with the weak bottom currents, no appreciable resuspension of the disposal mound is predicted. The need for long-term modelling of sediment resuspension will be further considered when near-bottom current data are available for the Brown Passage disposal site, following retrieval of the ADCP deployed by PNW LNG. Information will also be provided in the Disposal at Sea permit application.

13.5.1.1.1.2 Sediment Dispersion Modelling - Vessel Maneuvering

Preliminary propeller scour modelling of the berthing and departure of an LNG carrier from the marine terminal, supported by four Voith Schneider 80 tonne tug boats, has been conducted for several low water and flood tide departure scenarios, for a winter period (January 18 to February 22). This period includes a large spring tide (i.e., a tide that occurs during the time of largest difference between high and low water), to provide predicted TSS results for a worst case scenario of TSS plume movements toward Flora Bank (Appendices G.7 and G.16). The model was developed using Coastal Modeling System Flow to predict local hydrodynamic conditions and a Particle Tracking Model to investigate the sediment fate, including deposition areas and levels of TSS above background.

13.5.1.1.2 Change in Fish Habitat

Change to fish habitat was assessed by identifying the location, area (m^2), and type of habitat that will be lost or altered as a result of project activities in marine riparian, intertidal and subtidal zones and then assessing such lost or altered habitat to determine if serious harm to fish and fish habitat would result.. The area (m^2) of eelgrass beds expected to be permanently destroyed or altered is identified separately due to its ecological importance, especially for out-migrating juvenile salmon and other species associated with Skeena River fisheries. Area (m^2) provides a surrogate measure for change in productivity, which is a complex value to measure directly, given that it reflects numerous functions and processes in a variety of habitat types and involving a wide range of species.

13.5.1.1.3 Direct Mortality or Physical Injury

Direct mortality or physical injury addresses any direct effects of project activities that result in the death or injury of individual fish or marine mammals. The effects of crushing or burial (for fish) are assessed based on the presence of the organism in the area affected and the ability of the organism to move away from these activities. This effect also addresses direct injury to marine mammals and fish in the vicinity during blasting, as well as pressure-related injuries to fish caused by noise impulses resulting from blasting, which are determined based on established thresholds, as described below and in detail in Section 13.5.3.

13.5.1.1.4 Physical Injury and Change in Behaviour Caused by Underwater Noise

Effects due to underwater noise are determined based on the timing, duration, and magnitude [linear decibel level (dB)] at a reference pressure of 1 µPa (micropascal) of predictive underwater acoustic modelling (see Appendix N). Because no behavioural thresholds exist for fish, the assessment of change in behaviour is qualitative in nature determined based on timing (seasonal) and duration. Results are compared to established underwater noise thresholds for injury and sensory disturbance, which are different for continuous (non-pulse) and impulsive (pulse) sounds. Decibels re: 1 µPa is the accepted standard for measuring underwater sound in relation to fish and marine mammals (Popper et al. 2006; Richardson et al. 1995; Southall et al. 2007).

Thresholds used are primarily broadband, applying generally to all species, as species-specific thresholds for marine mammals have been established only for northern resident killer whales (based on observed behavioural responses), as discussed in Section 13.5.4.

13.5.1.2 Assumptions and the Conservative Approach

Information used in this assessment is based on the description of construction, operations, and decommissioning activities provided in the Project Description (Section 2 of the EIS) and on data from baseline studies (Appendices K and L of the EIS). When detailed information is not available, a conservative approach is taken by assuming worst-case scenarios (i.e., scenarios where project effects would be of greater magnitude or duration). The following conservative assumptions were made:

- Sediment dispersion during dredging at the MOF and disposal of this sediment was modelled conservatively using the maximum potential dredge volume and assuming the entire dredge volume consists of sediment (expected volume of sediment to be dredged from the MOF is less than 200,000 m^3; volume of sediment used in dredging and disposal modelling was 615,000 m^3). Winter conditions, when currents, waves, and storm events are greatest, were modelled
- It is assumed that marine-based structures that have formed attachment sites for marine plants and animals will be left in place following decommissioning
- Important lifecycle stages will occur at the same time as project activities. If the timing of these activities is uncertain (e.g., juvenile salmon will be present on Flora Bank and adult salmon might be present throughout the LAA during construction activities), it is assumed that construction activities will occur during these important lifecycle stages
- The most conservative, publicly available thresholds are used to predict injury to fish and marine mammals from underwater noise (see Section 13.5.4.1)
- Modelling results for underwater noise are reported using the more conservative radius of R95% (encompassing 95% of the area over which sound levels exceed a threshold) (see Appendix N of the EIS)
- Modelling of underwater noise was undertaken to predict worst-case scenarios of pile installation and vessel berthing sound levels. Predictions for the marine terminal were made in shallow and deep areas. The shallow water construction scenario (source level depth of 0.5 m) is located approximately mid-way along the jetty-trestle, just to the northeast of the southwest anchor block and approximately 1.4 km from Lelu Island. The deep water scenario (source depth of 10 m), is located in Chatham Sound at the marine berth, approximately 2.8 km from Lelu Island. This deep water location is considered the worst-case location for sound propagation for activities other than shipping. Modelling locations are presented in Figure 1 of Appendix N of the EIS.

Several regulatory thresholds are conservative. For example, acoustic thresholds for marine mammals applied in the US are considered conservative (see Sections 13.5.4 and 13.5.5 for more detail). Similarly, Canadian ISQGs and PELs for dioxins and furans are intentionally conservative since they combine toxicity test results and endpoints from a wide range of aquatic species and apply ten-fold safety factors. The CCME ISQGs are generic guidelines for Canada and do not address areas that naturally contain higher levels of metals, like the north coast of British Columbia. They also typically incorporate tenfold safety factors. The ISQGs for metals, in particular, were derived from a review of sediment data and biological data (National Status and Trends Program approach) and do not incorporate toxicity testing, for example use of the spiked sediment toxicity tests, which would more clearly define toxicity thresholds.

13.5.2 Change in Sediment or Water Quality

13.5.2.1 Potential Effects

13.5.2.1.1 Total Suspended Solids

Various construction (e.g., dredging and disposal) and operations (e.g., vessel maneuvering during berthing) activities are expected to affect water quality through TSS levels elevated above background. Elevated TSS levels and sediment deposition are linked to potential effects on fish and marine mammals (discussed in Sections 13.5.4 and 13.5.5) and fish habitat (discussed in Section 13.5.3). No project activities during decommissioning are expected to result in adverse effects that cannot be addressed through use of codified practices, best management practices and adherence to regulations and permit conditions.

13.5.2.1.1.1 Construction

The MOF dredge area is shown in Figure 13-2 and Figure 13-3 and is approximately 60,000 m^2 (6 ha). The MOF will be dredged to a depth of 12.5 m, removing an estimated volume of 790,000 m^3 of material, of which approximately 590,000 m^3 will be rock and up to 200,000 m^3 will be sediment. The estimated volume is based on the area and bathymetry of the dredge area, and the water depth required for vessel operations in the area, and provides a maximum estimate of the total volume to be removed.

In-water construction for the MOF is expected to take approximately 13 months. Underwater blasting will be scheduled to occur within DFO's least risk timing window (approximately November 30, 2015 and February 15, 2016; exact dates to be refined to reflect local conditions, based on pre-construction field surveys and in consultation with DFO [See Section 13.7]). Construction methods reflect the current understanding of site conditions, including a need for considerable rock blasting. Methods may be further refined during the construction contracting process. The general order of activities identified in Appendix G.20 is as follows:

- Removal of 20,000 m^3 of sediment to expose rock prior to blasting, using a TSHD small enough to work in the shallow water of the MOF area, with sediment disposal at Brown Passage
- Blasting
- Removal of blasted rock and sediment using a backhoe dredge, placing the rock and sediment on a barge and depositing it as close to shore as possible, then using an excavator to work from the land to remove the material
- Use of the rock for construction on land and potential use of some rock for habitat offsetting work
- Additional sediment disposal at Brown Passage as needed to establish the final MOF dimensions.

The sediment release associated with dredging is estimated to be 1% for the TSHD (from bottom disturbance and release of overflow water from the hopper) and 3% for the backhoe dredge (for a mix of sediment and rock). Overall, the release rate should be similar to that modelled and presented in Appendix O assuming use of a clamshell dredge with 1% sediment release (half near the bottom and half during the ascent of the dredge bucket through the water column). For the TSHD, the greatest amount of sediment release will occur near the sediment-water interface where the dredge makes contact with sediment and deep in the water column where overflow water is released from the bottom of the TSHD hull (following settling of sediment). The overflow water is estimated to contain 100 mg/L TSS. For the backhoe dredge, it is assumed that 50% of the sediment loss will occur within 5 m of the bottom due to capturing the sediment, closing the bucket, and raising the bucket through the water column, with the remaining 50% loss assumed to be evenly distributed through the upper water column.

Sediment at the MOF consists, on average, of 17% clay, 23% fine silt, 14% coarse silt, 12% fine sand, 21% mid-sized sand, 9% coarse sand and 5% gravel (Appendix L and Appendix O). This information was used to model TSS plumes associated with dredging and sediment disposal.

Predicted sediment plumes and deposition were presented in Appendix O, assuming a total dredge volume of 615,000 m^3. As discussed in Section 13.5.1.1, the TSS plume predictions are considered to be the same for the current understanding of a maximum 200,000 m^3 dredge volume, but the final deposition thickness and extent is considered to be an overestimate, for both the MOF and the Brown Passage disposal site.

Predicted TSS concentrations at the MOF are shown for a typical tidal cycle in Figure 13-4 (for flood flow and flood slack tide conditions) and Figure 13-5 (for ebb flow and ebb slack conditions). On a flood tide, the sediment plume will flow northeastward into Porpoise Channel; on an ebb tide, it will flow southwestward away from Lelu Island. Within the active dredge area and in small areas to the north and south along Lelu Island, TSS concentrations are predicted to be higher than the 5 mg/L WQG for continuous activity, mainly near the bottom of the water column, with concentrations in surface waters predicted to be lower than the WQG. Outside the active dredging area (including over Flora Bank), TSS levels will typically not exceed background levels by more than 1 mg/L. Highest modelled TSS events are noted within the active dredge area, and include:

- Up to 17 mg/L above background on a flood flow and 42 mg/L on flood slack, with highest levels in the bottom 1.7 m of the water column
- Up to 16 mg/L above background on an ebb flow and 37 mg/L for ebb slack, with highest levels at about 9.7 m above the seabed.

Modelled sediment deposition at the MOF at the end of dredging is shown in Figure 13-6, rescaled from the original prediction to account for the 200,000 m^3 sediment volume. The maximum sediment thickness modelled is 21 mm, within the MOF area (this will be removed during dredging). Outside the dredge area, deposition areas have been identified in a bay to the north of the MOF (up to 7 mm thickness), in the channel north of Lelu Island (up to 3 mm thickness) and to the south of the MOF (1 mm thickness).

Blasting of the exposed rock will occur throughout the MOF dredge area. Blasting may result in minor, localized disturbances of sediment. Rock will be used for project construction and sediment will be disposed of at the previously used Brown Passage disposal site.

There will be an estimated 85 return trips to the ocean disposal site. Sediment will be released at or near the center point of the disposal site to minimize effects to water quality outside the one nautical mile (1.8 km) disposal site diameter. Predicted TSS plumes associated with sediment release at the previously used Brown Passage disposal site are presented in Appendix O and these predictions remain valid for a sediment volume of 200,000 m^3. Sediment dispersion was modelled for disposal activities at the disposal site throughout the 200 m water column at 0, 6, and 12 hours after sediment release from a barge (see Appendix O of the EIS, Figures 13, 14 and 15). Predicted TSS levels are compared to the CCME and BC WQG of 5 mg/L above background for activities lasting greater than 24 hours. Plume modelling for immediately after disposal is shown in Figure 13-6. TSS levels are predicted to be highest (1,100 mg/L above background) in deep waters (180 m) immediately following the release of sediment and to decrease quickly due to sediment settling and dilution. Maximum TSS values are concentrated at the disposal site, with concentrations 3 km from the site in any direction being below both the 5 mg/ L above background WQG (maximum values of 1.7, 2.5, and 4.3 mg/L above background at 0, 6 and 12 hours after a disposal event, respectively, as the plume drifts toward the 3 km radius).

The TSS levels closer to the surface are predicted to be lower than at depth, with near-surface levels generally less than 2.0 mg/L above background. Six hours after disposal, the minimum depth with TSS values greater than 5 and 25 mg/L are predicted to be at 37 m and 150 m, respectively. After 12 hours, the maximum TSS level for all depths in the entire model domain is 10.6 mg/L, and drops below 5 mg/L throughout the model domain within three days of the last disposal event, as suspended sediment settles out of the water column and is further diluted.

Levels of TSS higher than the 5 mg/L WQG within the disposal site are predicted to persist for three days, by which time another barge load of sediment will have arrived; as such, it is likely that the 5 mg/L WQG will be exceeded at some point in the water column within the disposal site for the duration of dredging operations. However, TSS values will be greatest in deeper waters, rather than at the shallower depths (surface to 100 m) most important for biological productivity.

Previous sediment deposition model results (Appendix O) have been scaled to account for the reduction in the volume of sediment to be dredged and disposed at sea, and the changed timing during which this will occur. Model rescaling accounts for the 200,000 m^3 sediment volume and dredging and disposal during Q4 2015 to Q1 2016 (originally modelled as January to June). Previous modelling results have been limited to the January to March period, which is expected to be similar to the October to December period. Updated predictions of the areal distribution of total sediment deposition at the Brown Passage disposal site are shown in Figure 13-8. Sediment is predicted to be deposited primarily at the disposal site (72% of material disposed) and to the east and south, to a thickness of 0.09 mm to 0.68 m. The maximum thickness of sediment outside the 1 nautical mile disposal site radius is predicted to be 12 mm in one area immediately outside the radius, with the majority of deposition outside the radius predicted to be in the 1 to 5 mm range.

13.5.2.1.1.2 Operations

During terminal operations, the maneuvering of LNG carriers and associated tugs at the LNG carrier berth will result in limited seafloor erosion, and thus some sediment dispersion, resulting in increased TSS levels during vessel arrivals and departures. Vessel maneuvering effects were modelled for mid-January to mid-February, covering a large spring tide (Appendix G.16). The study was conducted assuming 29 LNG carrier arrivals and 29 departures during a month that represents the most conservative conditions for generation of scoured sediment. Two scenarios were modelled: berthing of carriers with bows facing north, and berthing with bows facing south (this latter option is not considered further because of navigation constraints, and results are not discussed here). The resulting TSS levels were modelled at 26 locations on Flora Bank, though results at only two locations (labelled as traps 25 and 26, on the south edge of Flora Bank and not over eelgrass habitat; see Figure 7-2 of Appendix G.16) are discussed, since TSS levels for all other locations are predicted to be negligible. For vessels berthing with bows facing north, TSS was predicted to be measurable on one occasion during the modelling period at trap 25 (at just under 5 mg/L above background) and on seven occasions at trap 26 (three values between 5 and 25 mg/L above background and one value at 47 mg/L above background). At both locations, TSS levels would be elevated for about one hour during maneuvering. Negligible sediment deposition outside of the berth area from this elevated

TSS has been predicted, considering natural tidal currents and diel tidal cycles. The TSS generated from propeller wash may circulate associated with tidal currents, but is considered to be within normal variation presently exhibited in the area around Kitson Island and Flora Bank (Appendix G.16). As a result, no adverse effects on fish or fish habitat are predicted (1 hour duration at or above 25 mg/L TSS occasionally, no change in fish habitat due to sedimentation).

No need for maintenance dredging in the MOF has been identified. Modelling results indicate that sediment deposition of 0 to about 5 cm/year will occur, with the majority of the MOF dredge area is predicted to have sedimentation rates less than 0.5 cm/year, with a small area (< 100 m^2) at the northern shore of the MOF having the maximum sedimentation rate (Appendix G.4 and G. 19. Sedimentation in this area would not affect navigability in the MOF.

13.5.2.1.2 Dispersal of Contaminants in Sediment

The same construction and operations activities that result in elevated TSS levels will also result in dispersal of sediments and any associated existing contaminants. An overview of the sediment characteristics at the MOF and the Brown Passage disposal site is provided in Section 13.3.2.1. Sampling methods and results for sediment characterization are provided in Appendix L of the EIS. The 2013 sampling program fully characterized the chemical and physical composition of sediment in the current design for the dredge area.

Contaminants are present in MOF sediments at levels below the disposal at sea screening criteria (PAH, PCB, mercury, cadmium), below the Environment Canada draft guidelines for dioxins and furans (for sediments proposed for open water disposal at non-dispersive sites), or reflect natural occurrence (arsenic, copper). Disturbance of these contaminants in the suspended sediment plumes during dredging will result in short-term presence in the water column, and settling in an area of similar chemical composition. The levels are below levels that would pose a risk to aquatic life.

At and around the MOF, sediment containing legacy dioxins and furans will be disturbed during dredging. The dioxin and furan levels (0.06 to 2.64 pg/g TEQ in the surface 1.5 m, highest in the 0 to 0.2 m layer of subtidal sediment) reflect historical inputs from the closed WatCo pulp mill about 3 km from Lelu Island. All the surface and core sample results for dioxins and furans provided in Appendix L of the EIS have been used to evaluate dioxin and furan levels in the MOF dredge area, including all the small primary core samples taken at 0.2 m intervals to 1.0 m sediment depth (PCS01, PCS02, and PCS03; see Appendix L of the EIS, Figure 5) used to calculate the volume-weighted average for the entire dredge area. A worst-case scenario was also considered, assuming that only the surface 1.0 m, with maximum dioxin/furan concentrations, would be disposed of at Brown Passage prior to blasting. The volume weighted average would be 0.68 pg/g TEQ if only the surface 1 m of sediment was disposed (calculated weighting each 0.2 m sediment horizon as 20% of the overall volume, as previously described), rather than the full 12.5 m depth of sediment (2.5% for each 0.2 m sediment horizon from 0 to 1.0 m depth). The volume of the surface 1 m layer of sediment remains unchanged at approximately 40,000 m^3.

At the Brown Passage disposal site, contaminant levels in sediment were generally similar to those collected from the MOF dredge area, with the exception of lower arsenic, copper, and dioxin and furan levels at Brown Passage. The lower arsenic and copper levels at the Brown Passage disposal site likely reflect differences in coastal sediments (MOF sediment would be influenced strongly by natural sources from soil erosion) and offshore sediments, whereas the differences in dioxin and furan concentrations are related to proximity to human activities. Sediment from the Prince Rupert area has consistently contained arsenic and copper concentrations at levels higher than the ISQG, regardless of depth in sediment or location. This has been documented in sediment from the MOF (Appendix L of the EIS), the formerly considered marine berth facility (Technical Memorandum: *Follow-up Report on Sediment and Water Quality Associated with Construction of the Terminal Berth Area* submitted in June 2014), the Prince Rupert Gas Terminal pipeline approach to Lelu Island (Prince Rupert Gas Transmission 2014b), the Fairview Phase II Project (Stantec Consulting Ltd. 2009b), and the Canpotex Project (Stantec Consulting Ltd. 2011a, 2011b). These studies indicate that arsenic and copper are present at various depths in the sediment and occur naturally, not as a result of contamination. Although levels are higher than the CCME ISQGs, these levels are not considered to pose a risk to marine biota, as evidenced in the high levels of biological diversity and productivity of the marine environment in this area. Concentrations are well below the PELs, the thresholds above which adverse effects are more likely to occur. Although arsenic and copper levels are higher at the MOF than at Brown Passage, and disposal will result in an increase in concentrations at Brown Passage, this will not pose a risk to aquatic biota.

13.5.2.2 Mitigation

The current marine terminal design mitigation incorporates several elements to avoid or reduce the potential project effects on marine resources. This includes locating the marine berth terminal in deep water off Agnew Bank to avoid the need for dredging for the berth and to reduce potential effects on Flora Bank and Agnew Bank; using a suspension bridge to avoid any pile installation on Flora Bank; and using blasted rock on land for project construction to reduce the volume of dredged material to be disposed at sea.

The following mitigation measures will be implemented to reduce the potential for project-related changes in sediment or water quality during construction:

- A 30 m vegetation buffer will be retained around the perimeter of Lelu Island, except at access points (e.g., at the bridge, pioneer dock, MOF, trestle, and pipeline interconnection). Sediment and erosion control measures will be used (e.g., sediment fences) for land-based construction, particularly at the shoreline, to reduce TSS inputs into the water.
- Dredging operations will be conducted using methods and/or equipment that reduces sediment spill
- Turbidity will be monitored in real time during in-water construction activities (i.e., blasting, dredging, and ocean disposal) and compared to predicted TSS levels (through use of a turbidity-TSS calibration curve) and WQG. In the event that calculated TSS levels exceed modelled predictions outside of the active work area (defined as the immediate area surrounding operating construction equipment) or disposal site, the rate of the activity will be adjusted (e.g., slowed), or additional mitigation measures implemented (e.g., silt curtains) to minimize the spatial extent of elevated TSS
- In areas of low to moderate currents (≤ 1 knot), silt curtains will be installed around dredging and blasting activities if monitoring indicates that inferred TSS levels are greater than predicted (Appendix G.12). Studies suggest that effectiveness of silt curtains is reduced when currents exceed about 1 knot (Francingues and Palermo 2005). Silt curtains are expected to be most effective in the inner, sheltered areas of the MOF. Currents in Porpoise Channel (outer MOF) are likely to be too strong to permit effective use of silt curtains
- Dredging will occur at low tide, where possible

- Dredged sediment will be disposed of at or near the center point of the Brown Passage disposal site, to minimize effects on water quality outside the site.

To reduce TSS from vessel maneuvering, the following mitigation measure will be used:

- Tugs with less powerful propulsion systems (Voith Schneider tugs) have been evaluated and will be used.

Detailed EMPs will be developed and implemented prior to project construction. PNW LNG is committed to meeting the appropriate TSS WQG over the long-term during construction and operations.

13.5.2.3 Characterization of Residual Effects

13.5.2.3.1 Total Suspended Solids

13.5.2.3.1.1 Construction

The TSS plumes for the MOF, presented in Section 13.5.2.3 and shown in Figure 13-4 and Figure 13-5, do not consider the use of silt curtains, which will be used around the active work area in shallow water and slow currents to reduce TSS levels away from the active work area when monitoring indicates the inferred TSS levels are greater than predicted. The predicted TSS levels higher than the 5 mg/L WQG for continuous activity in the active work area and small areas to the north and south along Lelu Island are identified mainly for near the bottom of the water column, with concentrations in surface waters predicted to be lower than the WQG. Outside the active dredging area, TSS levels will typically not exceed background levels by more than 1 mg/L. The maximum concentrations (42 mg/L) occur for a short period, on a slack tide, when currents and dilution potential are lowest.

Porpoise Channel and Flora Bank already experience elevated TSS during the Skeena River spring freshet and at other times of year, due to current and wave action on the sediment. Fish and marine mammals in these areas are adapted to naturally high and fluctuating levels of turbidity and TSS. The elevated TSS levels will have low potential for effects on algal growth (phytoplankton and seaweeds), given the low primary production during the fall and winter period.

The areas with elevated TSS during dredging and with subsequent sediment deposition are not expected to result in effects on CRA fisheries (assessed in Section 15 of the EIS). No commercial fisheries are managed or permitted within the Porpoise Channel area and the MOF site. Recreational fisheries for salmon and crab are distributed throughout the project area and infrequently occur within the Porpoise Channel area (Figure15-12 and Figure 15-13). The PRPA harbor operations practices and procedures define that fishing is not allowed in navigation channels, including Porpoise Channel and the area adjacent to the MOF. Porpoise Channel is considered a navigation channel and fishing vessels less than 20 m are not allowed to impede larger vessel movement through active fishing or crab trapping. There is probability that limited recreational fishing will occur in Porpoise Channel. Any fishing activities will not be permitting by the PRPA in the active port area of the MOF, including areas with potential tidal current sediment deposition.

For dredging at the MOF, residual effects of TSS levels higher than the WQG are expected to be moderate in magnitude, local in geographic extent, occur over multiple regular events, with short-term duration and be reversible in an area expected to have high resilience (i.e., the area already experiences periods of high TSS associated with freshet).

For the previously used disposal site at Brown Passage, predicted TSS plumes presented in Section 13.5.2.1 do not reflect the use of mitigation measures such as reducing the rate of disposal, which will be implemented based on results of the turbidity monitoring program during disposal. The release of sediment at or near the center of the disposal site will minimize water quality effects outside the disposal site. Plume modelling (Figure 13-7) predicts the highest concentrations (1,100 mg/L above background) in deep waters (180 m) immediately following the release of sediment, with concentrations decreasing quickly due to sediment settling and dilution. The TSS levels closer to the surface are predicted to be lower than at depth, with near-surface levels generally less than 2.0 mg/L above background. Six hours after disposal, the minimum depth with TSS values greater than 5 and 25 mg/L are predicted to be at 37 m and 150 m, respectively. Concentrations 3 km from the site in any direction will be below both the 5 mg/L WQG (maximum values of 1.7, 2.5, and 4.3 mg/L above background at 0, 6 and 12 hours after a disposal event, respectively, as the plume drifts toward the 3 km radius). After 12 hours, the maximum TSS level for any depth is 10.6 mg/L, and within three days of a disposal event, TSS drops below the 5 mg/L WQG throughout the model domain, as suspended sediment settles and is further diluted. In practice, another barge load of sediment will have arrived within 18 hours, and it is likely that the 5 mg/L WQG will be exceeded at some point in the water column within the disposal site for the duration of dredging operations.

The TSS levels in shallower depths (surface to 100 m), which are the most important for biological productivity, will generally be either below the 5 mg/L WQG or above it for relatively short periods of time. The effects on fish are discussed in Section 13.5.4 and levels higher than the 5 mg/L WQG in deep waters (> 100 m) would be short-term in nature and are not expected to affect population viability, especially within the disposal site. The residual effects at the disposal site would be moderate in magnitude, local in geographic extent, occur over multiple regular events, and be short-term in duration and reversible in an area designated for disposal activities (expected to have high resilience).

13.5.2.3.1.2 Operations

Vessel maneuvering effects presented in Section 13.5.2.1 indicate that TSS levels could be higher than the 5 mg/L WQG for continuous exposure at one location on the south edge of Flora Bank for short periods of time (TSS levels for the majority of locations are predicted to be negligible throughout a 28 day tidal cycle) (Appendix G.16). This includes three values between 5 and 25 mg/L above background and one value at 47 mg/L above background, for about one hour during maneuvering. TSS levels of this magnitude and short term duration are not considered to pose a risk to marine life, which often are exposed to elevated TSS and turbidity on Flora Bank. Modelling indicates that negligible sediment will be deposited on Flora Bank eelgrass habitat (Appendix G-16). Effects of vessel maneuvering during berthing are expected to be moderate in magnitude, local in extent, continuous over the long-term, and reversible following operations, within an area considered to have high resilience to TSS fluctuations.

As described previously, maintenance dredging at the MOF is not anticipated (Appendix G.4). Given that there will be no need for capital dredging at the LNG carrier berth, no maintenance dredging will be required at this location either.

13.5.2.3.2 Dispersal of Contaminants in Sediment

Contaminants present in sediment at the MOF area could be disturbed and dispersed during construction activities that disturb the sediment and result in elevated TSS levels.

13.5.2.3.2.1 Construction

The levels of arsenic and copper in sediment from the MOF are not considered to pose a risk to marine life if disturbed and dispersed during dredging and during disposal at the Brown Passage site, as discussed in Section 13.5.2.1, as these levels are naturally occurring and reflect sources in soils from surrounding areas of the Skeena watershed, not related to human activity. As noted previously, the CCME ISQGs are generic guidelines for Canada and do not address areas that naturally contain higher levels of metals, like the north coast of British Columbia. They also typically incorporate tenfold safety factors. The ISQGs for metals, in particular, were derived from a review of sediment data and biological data (National Status and Trends Program approach) and do not incorporate toxicity testing, for example use of the spiked sediment toxicity tests, which would more clearly define toxicity thresholds.

For the levels of dioxins and furans described in Section 13.5.2.1 (0.06 to 2.64 pg/g TEQ) to pose a risk to ecological receptors, there must be both an exposure pathway and a toxic effect to receptor species. The exposure pathway is the same as the predicted sediment dispersal pathway.

The MOF sediments would be dispersed northeastward and southwestward (Figure 13-4 and Figure 13-5) and sediment would settle in areas with similar chemistry (Figure 13-5). With TSS levels outside the active dredging area predicted to be no more than 1 mg/L above background, little dioxin or furan will be resuspended and it will settle in areas of similar chemical composition. Thus, there is minimal potential of an exposure pathway for dioxins and furans to affect areas inside or outside the PDA, including the Flora Bank ecosystem, via dispersed sediments. Any dispersed dioxins and furans would not affect fish harvesting, given the low levels predicted for water, the short time period of dispersion, and the restrictions on commercial and recreational fishing in areas modelled to have elevated TSS or sediment deposition. Porpoise Channel, including the MOF and areas where sediment is predicted to be deposited, is a navigation channel. There is no commercial fishing allowed in that area and there is limited potential for recreational fishing, given that the area is a navigation channel (Figures 15-12 and 15-13 of the EIS).

Toxic effects on receptor species can be screened in terms of sediment guidelines and further evaluated through examination of toxicological literature. Appendix 5 of the Marine Sediment TDR (within Appendix L of the EIS) provides a discussion of various regulatory approaches used to evaluate dioxin and furan levels in sediment. Although concentrations at the MOF are higher than the CCME ISQG in some samples, they are below levels that pose a risk to aquatic biota or to humans that consume fish. There are ten-fold safety factors incorporated into the ISQG and PEL, and sediment concentrations are well below the concentrations identified in toxicological studies used to derive the guidelines. The sediment meets the criteria provided in the draft Environment Canada (2014) guidance on dioxins and furans in sediment for disposal at sea at non-dispersive sites (95% upper confidence limit of 3.2 pg/g TEQ compared to the LAL of 9 pg/g TEQ; volume weighted average of 0.22 pg/g TEQ compared to the OMO of 0.85 pg/g TEQ). A worst-case calculation, assuming that only the surface 1.0 m is disposed of at Brown Passage, yields a volume weighted average of 0.68 pg/g TEQ, which is below the OMO. Also, the maximum sediment concentration measured in MOF sediments (2.64 pg/g TEQ) is almost ten times lower than levels measured in 1995 (21.4 pg/g TEQ) in areas where the crab harvesting closure was lifted in Prince Rupert (British Columbia Ministry of Environment 2006). The dispersed dioxins and furans in sediment will settle quickly. Because dioxins and furans have very low solubility in water (they are hydrophobic) and bind preferentially with sediment and organic matter, they settle out and are not bioavailable in the water column (US EPA 1993).

At Brown Passage, including the disposal site, where dioxin and furan levels are lower than at the MOF, no toxicological risks to marine biota (including marine mammals) from disposal of the sediment are predicted because by meeting the levels identified in the draft guidance from Environment Canada (2014) for disposal of sediments containing dioxins and furans at non-dispersive sites (the LAL and OMO), the sediment is considered suitable for disposal at sea. Additional measures to mitigate risk posed by contaminants in sediment, such as strategic placement of sediment horizons, are not considered to be necessary during disposal of dredged material. The ecological implications of introducing low levels of dioxins and furans into Brown Passage are limited. Sediment dispersion modelling (Figure 13-7) predicts that a thin layer of sediment will be deposited outside the disposal site, mainly to the east and south, at a thickness of 1 to 5 mm, with a limited area adjacent to the disposal site boundary with up to 12 mm thickness. Water is about 200 m deep at and around the disposal site, and communities at this depth have lower diversity and abundance compared to shallower water. Marine resources at Brown Passage, including the disposal site, were characterized for the Fairview Phase II environmental assessment (Stantec 2010). While there are important benthos species in the general area (e.g., Dungeness crab, tanner crab and shrimp), important habitat areas do not appear to overlap with the disposal site. Dungeness crab, for example, is unlikely to use habitat at 200 m depth in the disposal site, as this species inhabits maximum depths of 180 m (DFO 2013h) and is typically found at depths shallower than 50 m (DFO 2001). There is some overlap of fisheries with the Brown Passage site, but with lower effort/catch for the main fisheries, compared to adjacent areas. The main fisheries in the general area, based on publicly available spatial catch data are shrimp, salmon, and groundfish including halibut and rockfish (DFO 2011). The ROV survey conducted in Brown Passage during July 2014 confirmed the disposal site and general area is dominated by soft bottom substrates with minimal rocky outcrops (Appendix G.21). The ROV survey identified similar habitat types and species at the disposal site as observed in other areas of Brown Passage and Chatham Sound. The dispersal of suspended sediment and deposition outside of the disposal site could introduce low levels of contaminants associated with dispersed sediments into these other areas; however, concentrations in water and sediment will be well below thresholds for effects on biota and on human and other mammalian consumers of the biota. Previously collected data on currents at 98 m depth indicate the disposal site is non-dispersive (i.e., sediment deposited on the bottom will not move over time); this will be re-evaluated using the results of ADCP deployment from October 2014 to April 2015. If the disposal site is identified as dispersive, Environment Canada has identified that disposal of sediment containing dioxins and furans at levels higher than 0.85 pg/g TEQ will not be allowed. However, even if the site is non-dispersive, it is not possible to prevent deposition of fine suspended sediment outside the disposal site, given the dynamic nature of the ocean.

The pathway from water to aquatic organisms is considered to be negligible. Dioxins and furans enter the food chain through absorption into the tissues of aquatic organisms by direct contact or ingestion of sediment particles in a process known as bioconcentration, which typically occurs in benthic organisms. When animals consume these benthic organisms, dioxins and furans can biomagnify in the tissues if the rate of uptake exceeds the rate of metabolism and excretion.

Further information about potential bioaccumulation concerns related to dioxins and furans is provided in Appendix L of the EIS. While dioxins and furans are harmful to vertebrate species such as birds, fish, and mammals (CCME 2001), they are not known to be toxic to invertebrates, including the species that inhabit Flora Bank and Agnew Bank, and live in close contact with sediment, such as Dungeness crabs and Pandalus shrimp. Concentrations in invertebrate species are not expected to bioaccumulate to levels of concern for the vertebrates and humans that consume these prey species. This is discussed further in the assessment of effects on Human and Ecological Health (Section 19), which includes an evaluation of potential risks from exposure to country foods, such as crabs and other seafood that contains dioxins and furans.

The Human Health Risk Assessment (Section 19) includes an evaluation of potential risks from exposure to country foods, such as crabs and other seafood that contain dioxins and furans.

The effects of contaminant dispersal are predicted to be low in magnitude (in the range of natural variability) resulting from dredging at the MOF and low to moderate in magnitude (above the range of natural variability, but well below sediment guidelines) for disposal at the Brown Passage site. In both areas, the effects are considered to be local in geographic extent, will occur over multiple regular events, and short-term in duration in an area of high resiliency (similar sediment chemistry).

13.5.2.3.2.2 Operations

Vessel maneuvering at the marine berth will result in small short term sediment dispersal events, but is not expected to result in elevated levels of contaminants, which are expected to be low and reflective of conditions within the surrounding area. The effects of contaminant dispersal as a result of these activities are expected to be low in magnitude, local in geographic extent, reversible, long-term and continuous throughout operations (for vessel maneuvering), and in an area of similar sediment chemistry (high resilience). Modelling indicates that negligible sediment deposition outside of the berth area is expected, given the natural tidal currents and diel tidal cycles. TSS generated from propeller wash may circulate associated with tidal currents, but is considered within normal variation presently exhibited in the area around Kitson Island and Flora Bank (Appendices G14 and G16). There will be spatially localized and small predicted increase in TSS levels over a one hour interval daily (seven occasions during a 29 day cycle at modelling point (trap) 26, at the southeast edge of Flora Bank, with three values between 5 and 25 mg/L above background and one value at 47 mg/L above background).

No maintenance dredging is anticipated at the MOF or marine terminal (Appendix G.4), and thus, no associated sediment dispersion will occur.

13.5.2.4 Likelihood

The likelihood of a residual effect from project activities on sediment and water quality is high due to the type of disturbance from dredging and disposal and recognized dispersal of sediments.

13.5.2.5 Determination of Significance of Residual Effects

Residual effects on sediment and water quality are considered to be not significant, as they will not result in an increased toxicological risk for marine organisms. It is not relevant to assess significance of a change in sediment or water quality in terms of the thresholds for residual effects on population viability of fish or marine mammals or on mortality to species at risk, as the toxicological threshold is protective of individuals and populations.

Residual effects associated with dredging during the construction period include TSS levels higher than the WQG over the six month dredging period, mainly within the active dredge and disposal areas. These effects are considered to be low to moderate magnitude, short-term changes. Contaminants associated with dispersed sediment from any project activity (dredging, disposal at sea, and vessel maneuvering at the berth) are not expected to pose toxicological risks to marine biota (including marine mammals), given concentrations in MOF sediments are related to background levels (arsenic and copper), or are below disposal at sea screening criteria (other metals, PCBs, and PAHs), or are below the Environment Canada LAL and OMO (dioxins and furans). TSS concentrations during operations (i.e., vessel berthing) are predicted to be higher than the 5 mg/L above background WQG in some areas for less than an hour at a time and are not predicted to exceed the WQG for continuous exposure (25 mg/L).Confidence and Risk

Confidence is high that effects of the Project on sediment and water quality are not significant for the following reasons:

- Dredging activities will be in compliance with legislation (*Fisheries Act, CEPA*) and established guidelines and thresholds (CCME for sediment and water quality, Disposal at Sea Regulations), except for elevated TSS levels in the immediate dredging area
- Baseline information is well understood, enabling effective characterization of effects
- Conservative assumptions were incorporated in the model used to characterize sediment dispersion resulting from dredging and sediment disposal
- Although project design and operational details are subject to change, the goals of maintaining water and sediment quality described in this assessment will apply
- Mitigation measures are known to be effective.

Since the confidence in this prediction is not low, no additional risk analysis has been conducted.

13.5.3 Change in Fish Habitat

13.5.3.1 Potential Effects

Project activities expected to interact with marine fish habitat include:

- Marine riparian infilling and/or vegetation removal
- Pile installation and scour protection
- Suspension bridge southwest tower and anchor platforms and scour protection
- Marine vessel berthing platforms
- Propeller scour
- Sediment deposition associated with marine infrastructure
- Habitat offsetting
- Dredging and disposal at sea.

These activities are associated with the following project marine infrastructure: the marine terminal, materials off-loading facility (MOF), Lelu Island access bridge, and pioneer dock. The total project area associated with the identified project marine infrastructure is approximately 157,998 m^2. Table 13-10 below provides a detailed breakdown of the overall project area resulting in alteration quantifiable change in marine fish habitat. An assessment of serious harm associated with habitats within the project development area is presented in Section 13.5.3.3.

Table 13-10 Detailed Breakdown of the Overall Project Development Area Resulting in a Quantifiable Change in Marine Fish Habitat

Project Activity	Marine Terminal (m^2)	MOF (m^2)	Lelu Island Access Bridge (m^2)	Pioneer Dock (m^2)	Lelu Island (m^2)	Total Area (m^2)
Loss of Eelgrass resulting from Dredging[1]	0	1,830	0	0	0	1,830
Effect to Eelgrass from Marine Structure Deposition	54,000 Modelled increase in sediment deposition on Flora Bank	0	0	0	0	54,000
Marine Riparian Area Infilling and/or Vegetation Removal[2]	1,572	19,825	3,322	537	0	25,256
Pile Area[3]	430 Pile Diameter: 1.22 m Pile Cross-Section Area: 1.131 m^2 Number of Piles: 380	51 Pile Diameter: 1.0 m Pile Cross-Section Area: 0.785 m^2 Number of Piles: 65	8 Pile Diameter: 0.6 m Pile Cross-Section Area: 0.283 m^2 Number of Piles: 20	8 Pile Diameter: 0.914 m Pile Cross-Section Area: 0.656 m^2 Number of Piles: 10	0	497
Pile Scour Protection	3,712 Scour Protection Diameter: 3.72 m Scour Protection Cross-Section Area (Pile and Scour Protection: 10.9 m^2 Number of Piles: 380	0	0	0	0	3,712

Project Activity	Marine Terminal (m^2)	MOF (m^2)	Lelu Island Access Bridge (m^2)	Pioneer Dock (m^2)	Lelu Island (m^2)	Total Area (m^2)
LNG carrier Berthing Platform	2,140	0	0	0	0	2,140
Suspension Bridge southwest tower (720 m^2) and anchor (1,980 m^2) platforms and pilings footprints	7,200	0	0	0	0	7,200
Suspension Bridge southwest tower (1,664 m^2) and anchor (3,750 m^2) platforms and pilings scour protection footprint.	5,414	0	0	0	0	5,414
Habitat Offsetting	0	0	0	0	24,080	24,080
Dredge Area Soft substrate area within dredge footprint (not including hard bottom algae and eelgrass habitats)	0	31,569	0	0		38,369
Dredge Area Hard bottom algae area within dredge footprint	0	6,800	0	0	0	6,800
Total	69,968	60,075	3,330	545	24,080	157,998

NOTES:

[1] The anticipated dredging area was overlaid on mapped eelgrass beds and areas were calculated by GIS

[2] A riparian zone was attributed to Lelu Island extending 10 m inland from the high water mark. Project components were mapped and the project development area interaction with riparian areas was calculated using GIS

[3] Pile area was calculated by multiplying cross-sectional area of each pile by number of piles.

[4] Development area of the southwest (southwest) tower and anchor platforms were determined by GIS

13.5.3.1.1 Marine Terminal

Construction of the marine terminal and berth includes a 2.7 km jetty supported by a 1.6 km clear span suspension bridge over Flora Bank from Lelu Island to Agnew Bank, and a 1.1 km conventional pipe pile trestle from the suspension bridge to the LNG carrier berth (Figure 13-9). The suspension bridge includes a 128 m approach structure from Lelu Island, a 1.2 km suspended span over Flora Bank, and a 320 m suspended span over Agnew Bank. The bridge is supported by two 128 m tall prefabricated steel towers designed as an aerodynamic, steel orthotropic box for wind stability. The towers sit on a cast-in-place concrete base (up to 11.6 m tall). Each tower foundation is a rectangular (36.4 by 20.2 m) concrete footing supported by 28 steel pipe piles; the outer piles are battered to provide lateral support (Figure 13-9). The southwest tower will be located within the marine environment (including associated tower and anchor foundations). The northwest tower will be located on Lelu Island and will not be considered in the assessment of effects on the marine environment. The marine terminal and berth have been sited away from Agnew Bank and out into deep water in Chatham Sound. The LNG carrier berth location is approximately 2.7 km southwest of the northwest corner of Lelu Island. No dredging, slope armouring, or breakwaters will be required for the marine terminal.

Marine habitats found within the development area of the marine terminal are described in Appendix M of the EIS, Section 4.1 (Intertidal Habitat Characterization), Section 4.2 (Subtidal Habitat Characterization), Section 4.3 (Flora Bank Eelgrass Assessment). In addition, Stantec prepared the Technical Memorandum: *Species Use of Marine Habitats in the Local Assessment Area* submitted in June 2014, with detailed description of species use of marine habitat within the local assessment area. A summary is provided below:

- Intertidal and shallow subtidal environment along an exposed shoreline
- Predominately soft sediment (silty sand at the surface and clay and fine silt in deep sediment samples) in subtidal areas
- Predominately rocky shoreline with some intertidal soft sediment present at the suspension bridge abutment with Lelu Island
- Relatively low diversity of vegetation and fauna throughout the soft bottom habitat of Flora and Agnew banks. Higher diversities of vegetation and fauna on the boulder and bedrock areas of Porpoise Channel along the northwest side of Lelu Island.
- No SARA listed marine plants are found within the marine terminal footprint.
- Flora Bank eelgrass bed, large size, located southeast of the suspension bridge and is known to support numerous CRA and forage fish species.

Flora Bank is recognized as a biologically rich area, and an important resource for Skeena River and Nass River salmon (Department of the Environment 1973a; DFO 1985; Higgins and Schouwenburg 1973). As such, intertidal and subtidal surveys of Flora Bank were conducted along with surveys of eelgrass. The surveys indicate eelgrass beds have a patchy distribution of various sizes and densities, interspersed by extensive areas of no vegetation. No evidence was found of other vascular marine species in the assessment area. Aside from eelgrass, Flora Bank was almost completely devoid of structuring habitat except for small pockets of green (*Ulva. Sp.*), red, and brown algae (*Alaria sp., Laminaria sp.*) found in sub-tidal areas surrounding the bank.

Eelgrass on Flora bank is predominantly the native Zostera marina species and grows extensive thick rhizomes with shoots and leaves in lengths greater than 0.5 m. Flora Bank eelgrass has been observed distributed in conditions on the bank exposed to normal tidal currents > 1 m/s, low light levels (transparencies < 0.25 m), water turbidity > 25 mg/L TSS, and tidal cycles which vary by greater than 7 m within a 24 hour period.

Dense eelgrass patches (eelgrass cover > 70%) are distributed on Flora Bank in areas of higher elevation (shallow bathymetry, > -0.5 m) and lower tidal currents relative to other portions of the bank. The dense eelgrass patches grow in local conditions of lower tidal current velocities immediately adjacent to Lelu Island and Kitson Islet (see Appendix G.16, Figures 6-1, 6-2), and in shallower areas of the bank with greater exposure to direct sunlight. Eelgrass on Flora Bank is not distributed in lower intertidal areas (> -1.0 m depths) or in subtidal areas. Eelgrass growth and survival on Flora Bank would appear to be dependent on its being adapted to maximize photosynthetic capacity and carbohydrate production while exposed during low tide cycles in daylight hours over the spring/summer growing season. Eelgrass density and distribution, as well as seed survival and nutrient provision, are anticipated to be positively influenced by annual and seasonal sediment deposition onto Flora Bank. These results are consistent with other areas of the Skeena estuary (Faggetter 2013), Fisheries and Oceans Canada regulatory guidance (Vandermeulen et al. 2012) and other studies around North America (Marion and Orth 2012; reviewed by Vandermeulen, H., J. Surette, and M. Skinner. 2012).

The primary activity associated with construction of the suspension bridge, trestle and LNG carrier berth is the installation of piles (including tower/anchor platforms and scour protection) and removal/infilling of marine riparian areas. In addition to the primary construction activities, propeller scour associated with LNG vessels and changes to depositional patterns associated with constructed marine infrastructure may contribute to increased sediment deposition and TSS concentrations on Flora Bank. The primary activities will result in a change in fish habitat of 69,968 m^2 (Table 13-10), including:

- 1,572 m^2 of marine riparian vegetation
- 54,000 m^2 of eelgrass habitat on Flora Bank associated with changes to depositional patterns from marine infrastructure, used by juvenile salmonids and other CRA and forage fish
- 10,254 m^2 of subtidal soft substrate habitat associated with the southwest tower and anchor platforms and marine vessel berthing platform, primarily used by Dungeness crab and local flatfish species
- 4,142 m^2 of intertidal and subtidal soft substrate habitat associated with pile installation and scour protection, primarily used by Dungeness crab and local flatfish species.

The suspension bridge, trestle and berth footprints have been designed to avoid Flora Bank. Field surveys, complemented with remote-sensing-based mapping, indicate that infrastructure footprints (e.g. suspension bridge, marine trestle) and associated scour will not affect eelgrass. It is anticipated scour protection (rip-rap) associated with pile construction will increase the availability of hard substrate for algae to attach and grow. Although infrastructure footprints and scour is not anticipated to effect Flora Bank, preliminary model results of depositional patterns after the construction of marine structures indicates that 290,000 m^2 (54,000 m^2 of eelgrass habitat) on the northwest corner of Flora Bank will experience an increase in sediment deposition (Appendix G.18) at a rate of 0 cm/yr to 5 cm/yr in areas with eelgrass.

Sediment discharge from the Skeena River is estimated to range from 2 to 5 million m^3/year (Conway et al. 1996). Given an average sediment discharge of 3 million m^3/year, sand composition and deposition of at least 75% of this sediment (Conway et al. 1996), approximately 10 cm/year of sediment can be deposited over the main Skeena River estuary, with smaller levels of deposition ranging from 2 cm/yr to 10 cm/yr reaching Smith Island and near Lelu Island. Therefore, sediment deposition around Lelu Island and Flora Bank is normally expected (without project infrastructure) to be greater than the predicted increase of 0 cm/yr to 5 cm/year.

Sediment deposition around marine structures is expected to be localized, and within 50 m to 100 m of the southwest anchor block and tower platforms, predominately during storm periods in the fall and winter outside the marine summer growing season. Changes in sediment re-suspension and deposition patterns are not expected to alter or destroy fish habitats or cause death of fish in proximity to the project marine terminal structures. The rate of sediment deposition and changes within the area are predicted to be within the range of existing sediment deposition originating from the Skeena River sediment transport. The predicted changes in sediment deposition onto vegetated or growing areas of Flora Bank are expected to be reduced to negligible levels during growing season based on limited changes in tidal current velocities. Therefore, eelgrass survivability is expected to be high and densities are not anticipated to be affected..

During normal operations, propeller derived sediment movement during LNG carrier maneuvering and berthing may increase TSS levels on the north end of Flora Bank. Potential propeller scour will create a scour pocket immediately adjacent to the berths and maintain this pocket at equilibrium within approximately two to five years. Sediment movement associated with propeller scour will be mitigated by use of VSP tugs, low RPM propeller rotation for LNG carriers adjacent to the berth, maneuvering with use of four tugs, and deep berths sited outside the scour potential (greater than 30 m deep) of LNG carrier propeller wash. Sediment moved from propeller wash has been modelled to move at distances up to 300 m from the berth at a rate of 0 to 2 mm per month (29 vessel movements). Sediments will be moved and deposited immediately adjacent to the berth (Appendix G16, Figure 8-2 and 8-5). Fish habitat around the berth is considered widely distribution, soft silt-clay – mud like sediment with no cover and uniform substrates. No life process dependent fish habitats have been observed in these areas.

TSS potentially generated by propeller wash has been modelled and is not expected to be distributed to sensitive eelgrass areas and is not expected to impact fish and fish habitats. Models have presently used very conservative vessel maneuvering scenarios. Maneuvering for LNG carriers is expected to not engage full trust from the carriers, maintain low RPM (less 60) and rely on VSP low propeller wash tugs for maneuvering and berthing. Based on natural tidal currents and diel tidal cycles, TSS is not predicted to be deposited onto sediments. TSS generated from propeller wash may circulate associated with tidal currents, but is considered within normal variation presently exhibited in the area around Kitson Island and Flora Bank (Summary in Appendix G14, G16, and ASL 2014).

LNG carrier maneuvering and berthing will be planned and adaptively managed to limit propeller wash derived scour and generated TSS and sediment movement. TSS and changes in bathymetry (sediment elevation) will be monitoring around the berth areas and during vessel berthing to avoid and limit generated TSS and sediment scour.

Southwest Tower and Anchor Platforms

The jetty, vessel berth and southwest tower area are predominately comprised of soft silt-clay sediments. The habitats are defined by low densities of fish including, shrimp, crab, eelpout, and flatfishes. Construction of the southwest tower, including tower and anchor platforms, piles, and scour protection, will result in the permanent loss of subtidal soft substrate habitat, primarily used by Dungeness crab and local flatfish species

13.5.3.1.2 Materials Offloading Facility

The MOF is located within a small cove on the north side of Lelu Island, oriented parallel to Porpoise Channel. Construction of the MOF and the associated turning basin requires dredging approximately 790,000 m^3 of marine substrates (i.e., 200,000 m^3 soft sediment and 590,000 m^3 rock). The dredging covers an area of about 6.0 ha, to a depth of 10 m, with slope angles of 2 horizontal to 1 vertical. Additional overdepth dredging will be to 12.5 m, with vertical sides. Construction of the MOF will also require 65 drilled piles.

Marine habitats found within the development area of the MOF are described in Appendix M of the EIS, Sections 4.1.2 (marine riparian and intertidal habitat) and 4.2.3 (subtidal habitat). The intertidal zone within the MOF area contains two large soft sediment basins with patches of eelgrass (primarily *Zostera marina* with lesser amounts of *Z. japonica*) (see Figure 12, Appendix M of the EIS). No SARA listed marine plants are found within the MOF. Infaunal communities in these areas include *nemerteans*, *polychaetes*, macoma clams, and bay ghost shrimp. Rocky outcrops are found along the shorelines of the MOF area and in the deeper areas of Porpoise Channel. Rocky substrates in the intertidal and subtidal zones support diverse communities of algae and invertebrates, and are suitable for kelp establishment and growth. Blasting will occur in existing intertidal and subtidal habitats. Marine riparian habitats surrounding the MOF will be cleared. Blasting will result in the mortality of immobile and slow-moving organisms within the MOF area, including algae, eelgrass, invertebrates and some demersal fish (e.g., sculpin, gunnel, prickleback) (see Section 13.5.4.1).

Marine species and life stages with a high dependence on the habitats associated with the MOF include: juvenile salmon (pink, chum, coho, chinook, sockeye, and steelhead), eulachon larvae and juveniles, juvenile Pacific herring, juvenile English sole, starry flounder (all life stages), and Dungeness crab (all life stages). The Technical Memorandum: *Species Use of Marine Habitats in the Local Assessment Area* submitted in June provides a complete discussion of species (CRA fisheries, invertebrates, and marine mammals) and life-stage use of habitats associated with the MOF.

The primary activities associated with MOF construction are dredging, blasting, pile installation and removal/infilling of marine riparian areas. These activities will result in a change in fish habitat of 60,075 m^2 (Table 13-10), including:

- 1,830 m^2 of eelgrass potentially used by juvenile salmon, eulachon juveniles and larvae, Pacific herring juveniles and flatfish species
- 19,825 m^2 of marine riparian vegetation removal
- 38,420 m^2 of intertidal and subtidal rocky and soft substrate habitat potentially used by juvenile salmon, eulachon juveniles and larvae, Pacific herring juveniles, Dungeness crab and local flatfish species. Destruction/alteration of this habitat is associated with dredging and pile installation.

Dredging activities will result in the permanent loss of 6,800 m^2 of hard bottom brown algae habitat and 1,830 m^2 of eelgrass habitat, used as foraging and nursery habitat by juvenile salmonids, herring, surf smelt, sandlance and crab. Dredging (including sediment deposition outside of the MOF as a result of dredging) and disposal of dredged material at sea (Brown Passage) will also result in temporary alteration of fish habitat; however, it is not expected to result in permanent alteration or destruction of fish habitat as no life process dependent habitats will be affected. Deposition of re-suspended sediments associated with dredging activities would primarily occur within the dredge area on the northwest side of Lelu Island, at the junction of channels to the northeast of Lelu Island, and along the southwest coast of Port Edward (see Figure 13-6, which has been rescaled to account for the reduced dredge volume compared to that which was originally modelled). Habitats associated with these areas are predominately soft silts and clay used by low densities of crab and flatfish. Deposition of re-suspended sediments will not change the quality of available habitat or limit species diversity and life-stage use. Stressed environments, similar to Brown Passage, which has been used periodically for sediment disposal since 1972, generally recover within nine months (Bolam and Rees 2003). Re-colonization may occur via vertical migration of buried benthic organisms through the disposed material, horizontal migration from neighboring areas by migrating adults or post-larval individuals, and larval recruitment (Bolam and Rees 2003).

13.5.3.1.3 Pioneer Dock

A temporary pioneer dock for initial off-loading of construction equipment (prior to construction of the MOF) will be developed north of the MOF. The dock will consist of floating pontoons secured with piles, a rock/gravel ramp to land and a gangway. The site will be decommissioned once the MOF and bridge are complete. Further details concerning construction of the pioneer dock are outlined in Section 2.3.1.5.

Dominant habitat types associated with the pioneer dock location comprise a mix of rocky shore and mudflats with protected bays and channels. The main bay is exposed at low tide and is predominately muddy with gravel-based substrate at the head. A small stream runs through the middle of the bay and contains large woody debris. Two eelgrass beds containing *Zostera japonica* were delineated at the pioneer dock site. No SARA marine plant species are found within the pioneer dock footprint.

Marine species and life stages with a moderate to high dependence on the habitats associated with the pioneer dock include: juvenile salmon (pink, chum, coho, chinook, sockeye, and steelhead), eulachon larvae and juveniles, juvenile Pacific herring, juvenile English sole, starry flounder (all life stages), and Dungeness crab (all life stages). The Technical Memorandum: *Species Use of Marine Habitats in the Local Assessment Area* submitted in June provides a complete discussion of species (CRA fisheries, invertebrates, and marine mammals) and life-stage use of habitats associated with the pioneer dock.

Pile installation for the pioneer dock will result in the loss of 545 m^2 of habitat, comprised of 537 m^2 marine riparian habitat and 8 m^2 intertidal and subtidal habitats . Pile installation would be temporary and would result in the creation of 29 m^2 of habitat (wetted and surface area of piles), which would provide attachment substrate for algae and invertebrates.

13.5.3.1.4 Lelu Island Access Bridge

The facility on Lelu Island will be accessed from the mainland via a multi-span bridge connecting the northeastern edge of the island to Skeena Drive (Highway 16). The bridge will also pass over the CN rail line at this location.

As outlined in Appendix G.10, marine riparian habitat will be cleared in areas where infrastructure encroaches within 30 m (horizontal distance) of the high water mark. This will include 3,322 m^2 for the access bridge. The bridge will be supported by footings (steel piles) which will result in the destruction of 8 m^2 of intertidal habitat. Total habitat affected as a result of bridge construction will be 3,330 m^2 (Table 13-10). The bridge area is intertidal (exposed at low tide), and is dominated by soft substrate and *Ulva* spp. with very few patches of eelgrass that will not be affected (see Appendix M, Section 4.1.2, of the EIS). Based on recent field surveys, this area has the lowest diversity of invertebrates, fish, and algae of all areas surveyed within the LAA.

13.5.3.1.5 Lelu Island

Habitat offset measures have been proposed along intertidal and subtidal habitats surrounding Lelu Island. The currently presented habitat offsets include approximately 24,080 m^2 of constructed eelgrass and algae habitats comprising five sites constructed as benched raised beds, and sloping intertidal reefs both planted using donor stock (eelgrass and algae). Habitat offsets are conceptually sited at existing rocky intertidal bays south and west of the MOF. The sites are situated within existing locations which have industrial debris (abandoned vessels, logging debris), have observed limited existing habitat complexity or diversity (existing mud, silt-clay habitats) and are widely available habitat types (coastal rocky areas, isolated mud foreshores). Benthic invertebrate densities were low and no clam (infauna) beds were identified in the potential offset habitat areas.

The habitat offsetting plans are designed to enhance existing habitat complexity and thereby increase species diversity and life-stage use at the identified offset locations; existing high quality habitat found within the potential offset locations will not be impacted. These enhancement techniques are not anticipated to limit or prevent species and life-stage use occurring under baseline conditions.

13.5.3.2 Mitigation

As noted previously, the marine terminal design was revised to avoid or reduce potential effects on marine resources, including fish habitat. In addition, the following mitigation measures are presented to reduce changes to fish habitat caused project activities:

- No offset habitats will be located on Flora Bank and Agnew Bank
- Planned scour protection will be placed around tower platform below mud line through use of slightly larger substrate sized materials around the perimeter of tower platform based on 2D and 3D model outputs
- Hard multi-facetted shoreline protection material (e.g., rip-rap boulders) will be used where needed (e.g., trestle abutment) to promote colonization by marine biota
- A Habitat Offsetting Plan will be developed and implemented to maintain productivity within the LAA
- Beneficial re-use of rock for construction of fish habitat offset is being considered and will be determined in consultation with Fisheries and Oceans Canada

In addition, detailed Environmental Management Plan(s) will be prepared to mitigate potential effects associated with construction. Appendices J.1 to J.16 outline the various EMPs that are presented for construction activities.

13.5.3.3 Characterization of Residual Effects

Change in quantity and quality of the physical and biological attributes of fish habitat (including marine vegetation) will occur as a result of project activities during construction, operations and decommissioning. Project activities expected to result in quantifiable changes to fish habitat include dredging, blasting, excavation of intertidal and subtidal habitats within the MOF, pile and bridge foundation (i.e. southwest anchor block and southwest tower) installation, and sediment deposition from vessel maneuvering at the berths during operations.

Of the overall footprint associated with the project activities (157,998 m^2), changes in marine fish habitat resulting in serious harm are considered localized to the MOF area, the southwest suspension bridge tower and bridge anchor areas and piles including scour protection totaling 23,026 m^2. Serious harm to fish habitat includes 14,396 m^2 soft silt-clay substrates (used by Dungeness crab and flatfish species), 6,800 m^2 of hard bottom brown algae habitat and 1,830 m^2 of eelgrass habitat (used as forage and nursery habitat by juvenile salmonids, herring, surf smelt, sandlance and crab).

A project-related *Fisheries Act* authorization for habitat destruction and offsets will be required for serious harm to fisheries and forage fish and habitats at the population level including local habitats used for specific population dependent life history stages. A summary of serious harm to fish habitat is provided in Table 13-11. Detailed rational for the assessment of serious harm is provided in the Habitat Offsetting Plan (Appendix G.10; see also Appendix G.9).

Residual adverse effects to fish habitat (including marine vegetation) as a result of the Project will be negligible. Habitat offsetting measures pursuant to Section 35(2) of the Fisheries Act will maintain productivity throughout the LAA.

Table 13-11 Summary of Serious Harm to Fish and Fish Habitat

Project Footprint (m^2) and Area	Serious Harm to Habitats (m^2)	No Serious Harm to Habitats (m^2)
Marine Terminal (Suspension Bridge, Trestle and LNG Carrier Berth) | Total Footprint: 69,968 m^2		
54,000 m^2 Marine structure deposition	0 m^2	54,000 m^2 Sediment deposition rates and patterns of distribution resulting from placement of marine terminal structures fall within normal variation and ranges of annual sediment deposition onto Agnew and Flora Bank. Sediment deposition around marine structures is expected to be localized, predominately during storm periods in the fall and winter outside the summer growing season. Changes in sediment re-suspension and deposition patters are not expected to alter or destroy fish habitats.
1,572 m^2 A Riparian area infilling and/or vegetation removal on Lelu Island	0 m^2	1,572 m^2 No serious harm predicted on marine riparian areas. Riparian areas have been assessed as not supporting life process dependent habitats for salmonids and forage fish species (sandlance and surf smelt); intertidal habitats at Lelu Island comprise mud or rock shoreline. No riparian shaded beach spawning habitats were observed in the PDA.

Project Footprint (m^2) and Area	Serious Harm to Habitats (m^2)	No Serious Harm to Habitats (m^2)
430 m^2 Trestle and LNG carrier berth pile footprint (380 piles with a 1.22 m diameter)	430 m^2 Permanent alteration of soft silt – clay subtidal substrate. Added rip rap scour protection around individual piles. Foraging habitats used by shrimp, Dungeness crab and local flatfish species	0 m^2 No additional serious harm predicted from marine terminal individual pile footprint. Habitats presently used at low density by shrimp and flatfish in depths greater 5 m, and by flatfish and crab in shallower depths. Scour and accretion will not prevent shrimp, Dungeness crab or flatfish from using existing soft substrate habitats to carry out life processes.
3,712 m^2 Trestle and LNG carrier berth individual pile and scour protection footprint	3,712 m^2 Permanent alteration of soft silt – clay subtidal substrate. Added rip rap scour protection around individual piles. Foraging habitats used by shrimp, Dungeness crab and local flatfish species	0 m^2 No additional serious harm predicted from marine terminal piling scour protection armouring footprint. This protective armouring will be applied during construction to avoid and limit pile scour in widely distribution soft substrate at Agnew Bank and outside the bank. Habitats presently used at low density by shrimp and flatfish in depths greater 5 m, and by flatfish and crab in shallower depths. Scour and accretion will not prevent shrimp, Dungeness crab or flatfish from using existing soft substrate habitats to carry out life processes.
2,140 m^2 LNG carrier berth platform with grouped pile scour protection footprint	2,140 m^2 Permanent alteration of soft silt – clay subtidal substrate. Added rip rap scour protection around grouped piles. Foraging habitats used by shrimp, Dungeness crab and local flatfish species	0 m^2 No additional serious harm predicted from marine vessel berthing platform piling footprint and grouped scour protection (armouring) footprint. Scour protection (rip rap armouring) will be applied during construction to avoid and limit pile scour in widely distribution soft substrate at Agnew Bank and outside the bank. Habitats presently used at low density by shrimp and flatfish in depths greater 5 m, and by flatfish and crab in shallower depths. Scour and accretion will not prevent shrimp, Dungeness crab or flatfish from using existing soft substrate habitats to carry out life processes.
2,700 m^2 Suspension bridge: southwest tower (720 m^2) and anchor (1980 m^2) platforms and pilings footprints	2,700 m^2 Permanent alteration of soft silt – clay subtidal substrate habitat through southwest tower and anchor platforms and pilings. Existing habitats used for foraging by Dungeness crab and local flatfish species.	0 m^2 No additional serious harm predicted from southwest tower and anchor platforms and pilings footprints. Habitats presently used at low density by shrimp and flatfish in depths greater 5 m, and by flatfish and crab in shallower depths. Scour and accretion will not prevent Dungeness crab or flatfish from using existing soft substrate habitats to carry out life processes.
5,414 m^2 Suspension bridge: southwest tower (1664 m^2) and anchor (3750 m^2) platforms and pilings scour protection footprints	5,414 m^2 Permanent alteration of soft silt – clay subtidal substrate through addition of rip rap scour protection around platforms and piles. Foraging habitats used by Dungeness crab and local flatfish species	0 m^2 No additional serious harm predicted from additional scour protection (armouring) footprint. Scour protection (rip rap armouring) will be applied during construction to avoid and limit pile scour in widely distribution soft substrate at Agnew Bank and outside the bank. Habitats presently used at low density by shrimp and flatfish in depths greater 5 m, and by flatfish and crab in shallower depths. Scour and accretion will not prevent Dungeness crab or flatfish from using existing soft substrate habitats to carry out life processes.

Project Footprint (m^2) and Area	Serious Harm to Habitats (m^2)	No Serious Harm to Habitats (m^2)
Materials Offloading Facility | Total Footprint: 60,075 m^2		
1,830 m^2 Soft bottom eelgrass area	1,830 m^2 Destruction of intertidal eelgrass used as foraging and nursery habitats by juvenile salmonids, herring, surf smelt, sandlance and crab.	0 m^2
19,825 m^2 A riparian area infilling and/or vegetation removal on Lelu Island	0 m^2	19,825 m^2 No serious harm predicted on marine riparian areas. Riparian areas have been assessed as not supporting life process dependent habitats for salmonids and forage fish species (sandlance and surf smelt); intertidal habitats at Lelu Island comprise mud or rock shoreline. No riparian shaded beach spawning habitats were observed in the PDA.
51 m^2 Marine pile footprints	0 m^2	51 m^2 No serious harm predicted from piling footprint. Piles will be placed in dredged MOF footprint.
31,569 m^2 Soft substrate area within dredge footprint (not including hard bottom algae and eelgrass habitats)	0 m^2	31,569 m^2 No serious harm predicted in intertidal soft mud habitats within the MOF area. Intertidal mud areas are widely distributed around Lelu Island and the outer Skeena River estuary. These are sloping mud intertidal areas and predominantly in a low water or dry state. The habitats have been assessed as not supporting life process dependent habitats for juvenile salmonids, crab, and forage fish species.
6,800 m^2 Hard bottom algae area	6,800 m^2 Destruction of intertidal hard bottom brown algae area, used as foraging and nursery habitat by juvenile salmonids, herring, surf smelt, sandlance and crab	0 m^2
Access Bridge to the Mainland | Total Footprint: 3,330 m^2		
3,322 m^2 A riparian area infilling and/or vegetation removal on Lelu Island	0 m^2	3,322 m^2 No serious harm predicted on marine riparian areas. Riparian areas have been assessed as not supporting life process dependent habitats for salmonids and forage fish species (sandlance and surf smelt); intertidal habitats at Lelu Island comprise mud or rock shoreline. No riparian shaded beach spawning habitats were observed in the PDA.
8 m^2 Marine pile footprints	0 m^2	8 m^2 No serious harm predicted from Lelu Island bridge piling footprint. Slough areas are predominantly dry during high to low tide cycles with the exception of a centre wetted channel. The slough is comprised of fine silt-clay mud areas and is used by fish as tidal passage between ebb and flood periods. No habitats were identified in the slough as dependent for life process for fish species.

Project Footprint (m^2) and Area	Serious Harm to Habitats (m^2)	No Serious Harm to Habitats (m^2)
Pioneer Dock / Roll-on roll-off barge ramp| Total Footprint: 545 m^2		
537 m^2 A Riparian area infilling and/or vegetation removal on Lelu Island	0 m^2	537 m^2 No serious harm predicted on marine riparian areas. Riparian areas have been assessed as not supporting life process dependent habitats for salmonids and forage fish species (sandlance and surf smelt); intertidal habitats at Lelu Island comprise mud or rock shoreline. No riparian shaded beach spawning habitats were observed in the PDA.
8 m^2 Marine pile footprints	0 m^2	8 m^2 No serious harm predicted from piling footprint. No soft sediment habitats in the pioneer dock areas were identified as dependent for fish life processes.
Habitat Offsetting | Total Footprint: 24,080 m^2		
24,080 m^2	0 m^2	24,080 m^2 No serious harm predicted from habitat offsetting. Habitat offsets will be designed to limit the destruction of any existing high quality habitats and will focus on the enhancement of physical and biological habitats that support CRA fish and forage fish species consistent with those habitats altered or destroyed by the Project.
Totals		
157,998 m^2	**23,026 m^2**	**134,972 m^2**

Project changes and mitigations minimize the loss of fish habitat wherever possible. Where serious harm to fish habitat is unavoidable, habitat offset measures are identified to replace lost habitat types (eelgrass and hard substrate algae / kelp habitats) with similar new habitats. Offset habitats will be carefully sited and designed with input from DFO and Aboriginal groups to maintain local fisheries productivity. The offset plans will be presented in a detailed Request for Authorization under Section 35(2) of the *Fisheries Act* and will incorporate preferred offset plans refined for location, size, design feasibility, effectiveness and follow-up monitoring. The project preference will be to create offset habitats in advance or parallel to project construction works, if feasible, to limit lag time between loss and development of productive habitats. Details associated with the presented habitat offsets are described in (Appendix G.10).

Overall, project construction and operations will result in permanent and temporary changes to fish habitat; however, habitat offsetting will result in the enhancement of existing widely distributed rocky habitat to high-value habitats for salmon and other CRA fishery species. The net result will be a negligible change in fish habitat, maintaining productivity within the LAA. The ecological context in which these changes will occur is expected to be moderate, as marine resources within the LAA have been exposed to anthropogenic effects causing changes to fish habitat (see Section 13.6 for specific projects) and communities are expected to recolonize affected areas rapidly. The effects are expected to be of moderate magnitude, as this will cause a measurable change outside the range of natural variability, but will not pose a risk to population viability as habitat offsetting features will benefit species potentially affected, including salmon. Project effects on marine fish habitat will occur within the LAA, constituting one-time events causing negligible change which are long-term, permanent, and reversible, with an overall benefit through gains in productivity via habitat offsetting.

13.5.3.4 Likelihood

The Project will affect marine fish habitat, particularly during the construction phase. While immediate effects of construction are expected to be adverse (e.g., loss or alteration of habitat), the implementation of offsetting measures will maintain the productivity of fish habitat. Following the application of mitigation measures (including offsetting), there is low likelihood of an adverse residual effect on change in fish habitat.

13.5.3.5 Determination of Significance of Residual Effects

Effects associated with dredging, blasting, excavation of intertidal and subtidal habitats within the MOF, pile and bridge foundation (i.e. southwest anchor block and southwest tower) installation, and sediment deposition from vessel maneuvering at the berths during operations were assessed for potential serious harm to fish habitat. Where the potential for serious harm was identified, habitat offset measures are presented to maintain the overall productivity within the LAA. Residual effects on fish habitat are considered to be not significant, as they will not affect the population viability of fish or cause mortality to a species at risk. The residual effects to marine vegetation, specifically depositional effects on the northwest corner of Flora Banks, are considered to be not significant, as survivability is expected to be high and density of eelgrass is not anticipated to be effected.

With the implementation of habitat offsetting, project-related effects to fish habitat are expected to be negligible. Habitat offsets are presented to counterbalance identified serious harm to marine fish habitats used for life dependent processes by fish that are part of, or support, CRA fisheries. The habitat offsets plans are designed to offset project-related series harm to eelgrass, hard bottom brown algae and soft sediment habitats used by juvenile salmonids, herring, crab and forage fish species during sensitive life history stages. The habitat offsets are described in Appendix G.10. The project preference will be to create habitat offsets in advance or parallel to project construction works to limit lag time between serious harm resulting from construction and development of enhanced habitat offsets.

Effects of the Project have been assessed for each SARA and COSEWIC-listed species at risk, including marine fish and marine mammals. These species-specific assessments are presented in Appendix F.4.

13.5.3.6 Confidence and Risk

The confidence in the significance prediction and mitigation measures is considered high. While an inherent amount of uncertainty exists in every prediction of future changes to fish habitat, the approach and methods used to assess the effects incorporates quantitative data (habitat areas, species composition and densities) from baseline reports and literature reviews and analyses using scientific models. The confidence level in the identified mitigation measures and habitat offsetting is also high based on the following:

- The baseline fish and fish habitat information is robust and well understood within the identified areas of impact (specifically the MOF) enabling an effective characterization of effects
- Mitigation measures are known to be effective

- The habitat offset measures presented for the final Habitat Offsetting Plan will result in neutral change to fish habitat and are proven to be successful with appropriate design and follow up monitoring.

Since the confidence in this prediction is high, no additional risk analysis has been conducted.

13.5.4 Direct Mortality or Physical Injury to Fish or Marine Mammals

13.5.4.1 Potential Effects

Project construction could cause direct mortality or physical injury to fish or marine mammals. Blasting can cause permanent pressure-related injuries to tissue or organs (i.e., barotrauma) in fish (Popper and Hastings 2009), direct mortality to marine mammals, and the impulsive underwater noise from blasting can cause temporary or permanent auditory injury to marine mammals (Popper and Hawkins 2012; Richardson et al. 1995). Marine construction activities and vessel maneuvering at the berths may result in injury or mortality to fish by burial, crushing or smothering caused by sediment deposition. Increased TSS (from dredging, disposal at sea, and vessel maneuvering at the berths) may also result in TSS levels that can cause injury or mortality to fish and invertebrates.

Construction activities may increase the likelihood of fish or marine mammal injury or mortality through the following mechanisms and project activities:

- Injury or mortality to fish
- Blasting (direct physical injury or barotrauma)
- Crushing or burial (during dredging, disposal of sediment at sea, other marine construction, and vessel maneuvering at the berths)
- Increased TSS (from dredging, disposal at sea, and vessel maneuvering at the berths)
- Underwater noise from blasting or impact pile driving (temporary or permanent auditory injury).
- Injury or mortality to marine mammals
- Blasting (direct physical injury)
- Underwater noise from blasting or impact pile driving (temporary or permanent auditory injury).

13.5.4.1.1 Blasting

Blasting will be required to remove bedrock from the MOF, but is not required for the marine berth area. Underwater blasting will be scheduled to occur within DFO's least risk timing window (approximately November 30, 2015 and February 15, 2016; exact dates to be refined to reflect local conditions, based on pre-construction field surveys and in consultation with DFO [See Section 13.7]). Unmitigated, blasting has the potential to injure or kill animals within close range of the blast area through direct physical impact or barotrauma (potential effects of underwater noise are discussed in a subsequent subsection). The primary effect of blasting will be on fish and invertebrates that inhabit the rocky subtidal and intertidal areas. The sudden nature of blasting means that species are unlikely to be able to evade the effects. Pricklebacks are the dominant fish in these habitats year-round, while several species of importance to CRA fisheries might be found in the area at certain times of the year. For example, juvenile salmon use Flora Bank eelgrass habitats from March to July (see Appendix M of the EIS), which is outside DFO's least risk timing window for blasting (approximately November 30, 2015 and February 15, 2016; exact dates to be refined to reflect local conditions, based on pre-construction field surveys and in consultation with DFO [See Section 13.7]).

Dungeness crab, which is an important fisheries species, is also likely to be exposed to blasting. However, this species is rare in the MOF compared to Agnew Bank, where it is abundant. Intertidal species that inhabit rocky areas and that could be affected as a consequence of blasting are likely to recolonize the rip-rap habitat created beneath the MOF loading dock upon completion of construction. Marine mammals could be injured (Richardson et al. 1995) or killed by blasting if they come within close range (see Section 13.5.4.2 for mitigation measures to prevent this). Management measures for both terrestrial and underwater blasting will be outlined in a Blasting Management Plan (see Appendix J.11), which will include methods to reduce the risk of mortality and injury to marine life. The plan will be based on DFO's Blasting Guidelines (Wright and Hopky 1998) and will be developed in consultation with DFO.

13.5.4.1.2 Crushing or Burial

13.5.4.1.2.1 Dredging

Dredging has the potential to bury or crush benthic or demersal fish and invertebrates (Newell et al. 1998) within intertidal and subtidal areas adjacent to Porpoise Harbour at the MOF, potentially affecting site-specific abundance and biomass of benthic organisms.

A range of fish and commercially harvestable invertebrates occur within the MOF dredge area. Dominant finfish species observed within the dredge area during field surveys were flatfish (Pleuronectidae), pricklebacks (Stichaeidae), northern ronquil (*Ronquilus jordani*), and eelpouts (*Lycodes* spp.) (see Appendix M of the EIS). During intertidal surveys, the dominant infaunal species observed were *Macoma* spp. (clams), bay ghost shrimp (*Neotrypaea californiensis*), and polychaete and nemertea worms. Commercially important Dungeness crab, echinoderms (predominantly sea urchins and sea cucumbers), and bivalves (predominantly *Macoma* spp.) also inhabit the area. Salmon may also be found in the area during adult spawning migration or juvenile out-migration from the Skeena River, despite the absence of observations during field surveys.

Vulnerability of species within the dredge area largely depends on their mobility. Echinoderms and intertidal invertebrates, especially infauna species, are more likely to experience injury or mortality from dredging, as they are slow-moving or sessile. Flatfish are unlikely to move away from dredging activity as they tend to remain stationary when threatened and rely on camouflage to evade detection (Ryer et al. 2008), although they may eventually swim away from imminent danger. Most fish and crabs will perceive the equipment as a potential threat and will retreat and avoid dredging activities.

13.5.4.1.2.2 Disposal of Sediment at Sea

Disposal of the dredged sediment at sea has potential to increase the likelihood of injury or mortality to organisms living on or in the seafloor at the disposal site as a result of burial, smothering, or crushing (Bolam and Rees 2003). Most mobile species (such as fish and crabs) can avoid burial and shed small amounts of settling sediment, for example, halibut live at the sediment-water interface and often are partially buried in sediment; however, epibenthic species will be covered. During ROV surveys, no large rocky outcrops (the preferred habitat for rockfish) were observed at the disposal site and halibut and rockfish were only observed in low numbers. Ratfish and pricklebacks were the most commonly observed fish species, while eulachon were observed only south of the previously used disposal site (see Appendix G.21). TSS values will be greatest in deeper waters, rather than at the shallower depths (surface to 100 m) that are most important for biological productivity. TSS levels higher than the 5 mg/L WQG in deep waters (> 100 m) would be short-term in nature and are not expected to affect population viability, especially within the disposal site. Benthic animals have been shown to migrate vertically to the surface (Bolam and Rees 2003) following burial, even when buried by more than 30 cm of sediment (Newell et al. 1998). Brown Passage has been used for ocean disposal within the last ten years as a federally regulated site. The species that inhabit the disposal site can either avoid or withstand such burial (e.g., most fish) or can quickly recolonize the newly laid sediment (e.g., invertebrates). It is anticipated that the disposal site will rapidly return to a similar condition once disposal is complete.

13.5.4.1.2.3 Vessel Maneuvering at the Berths

Vessel maneuvering from LNG carriers and tugs during berthing and departure is likely to result in some deposition of sediment; however, the modelled deposition patterns indicate that most of the sediments are deposited around the LNG terminal area, independently of the path used by the LNG tankers. Only a negligible fraction is predicted to deposit on the southern edge of Flora Bank (see Appendix G. 7, and Appendix G.16 for further details and modelling results). As previously discussed, benthic animals can migrate vertically to the surface (Bolam and Rees 2003) following burial, even when buried by more than 30 cm of sediment (Newell et al. 1998).

13.5.4.1.3 Increased TSS

Construction of the MOF will require dredging of approximately 790,000 m^3 of material, less than 200,000 m^3 of which is marine sediment (the remaining material is rock). Dredging at the MOF will result in resuspension of marine sediment, leading to increases in TSS levels (potential for dispersal of contaminants from sediment is assessed in Section 13.5.2).

Within the LAA, salmon and herring are the most sensitive CRA species to injury or mortality from high TSS concentrations; whereas Dungeness crab (McFarland and Peddicord 1980; Peddicord and McFarland 1976) and bivalve molluscs (Wilber and Clarke 2001) exhibit higher tolerances. Lethal and sublethal effects on salmon as a result of high TSS levels vary widely according to the duration of activities and TSS concentrations, and juveniles are more susceptible to mortality compared to adults (McFarlane and King 2003; Newcombe and Jensen 1996; Wilber and Clarke 2001). High levels of TSS (generally > 1,000 mg/L for a duration greater than 1 day) can result in salmonid (Wilber and Clarke 2001) and herring (Boehlert and Morgan 1985) mortality, while lower levels (< 1,000 mg/L for a duration less than 1 day) may cause chronic effects to salmonids (i.e., loss of foraging capability, reduced growth, increased susceptibility to disease, increased stress, interference with homing and migration, decreased incubation success, gill clogging) (Bash et al. 2001; Bilotta and Brazier 2008; Greig et al. 2005; Lazar et al. 2010; Shrimpton et al. 2007; Wilber and Clarke 2001). As described in the Technical Memorandum: *Follow-up Report on Sediment and Water Quality Associated with Construction of the Terminal Berth Area* submitted in June 2014, benthic-dwelling organisms such as Dungeness crab, bivalve molluscs, and halibut are less sensitive to elevated TSS levels, as they live and forage just above the seafloor where sediment is easily disturbed.

Adult fish and highly mobile invertebrates typically avoid areas with elevated TSS levels (Martens and Servizi 1993; Newcombe and Jensen 1996; Wilber and Clarke 2001) and therefore exposure durations are generally limited to minutes or hours (Newcombe and Jensen 1996; Wilber and Clarke 1998). TSS concentrations from dredging at the MOF and disposal of MOF sediment are expected to be below levels associated with gill abrasion, fish mortality, or sublethal effects, with the majority of depths and locations having TSS levels well below these limits (Appendix O of the EIS) and, therefore, gill abrasion or mortality to fish species (including invertebrates) is not expected. At

Brown Passage, levels will be highest near the bottom and they will decrease rapidly throughout the water column following disposal (Section 13.5.2.3).

The TSS effects associated with construction of the marine terminal (i.e., from pile installation) near Flora Bank are expected to be minimal due to highly localized sediment displacement and are likely to be largely masked by the large natural amount of sedimentation on Flora Bank.

Potential increases in TSS as a result of vessel maneuvering were predicted based on sedimentation fate modelling of 29 arrivals and departures of an LNG carrier assisted by four Voith Schneider Propeller (VSP) tugs (i.e., approximately one month of berthing and departure operations). TSS concentrations at 24 of 26 traps located along Flora Bank were predicted to be almost negligible (Appendix G.16). At the remaining two trap sites at the southern edge of Flora Bank, under all cases modelled, the peak TSS values were below, or decreased to below the TSS threshold limit for clear flow of 5 mg/L above background within one hour. Salmonids can experience lethal effects when exposed to TSS concentrations of 1,000 mg/L for durations greater than 1 day (Wilber and Clarke 2001), values far higher than those predicted by modelling.

13.5.4.1.4 Underwater Noise

With respect to underwater noise, the EIS uses the term 'injury' to refer to permanent auditory damage (i.e., a permanent threshold shift [PTS]) to be consistent with the use of this term by Southall et al. (Southall et al. 2007) (i.e., "We define the minimum exposure criterion for injury as the level at which a single exposure is estimated to cause onset of permanent hearing loss (PTS)", pp.412) and the National Oceanic and Atmospheric Administration (NOAA 2013) (i.e., "NOAA equates the onset of permanent threshold shift (PTS), which is an auditory injury [...]" and "NOAA does not consider temporary threshold shift (TTS) to be an auditory injury [...]" pp.20). PTS and TTS are commonly measured using two metrics, sound pressure level (SPL) and sound exposure level (cumulative - SEL_{cum} or root mean square - SEL_{rms}). These metrics are further explained in Appendix N of the EIS.

Loud underwater noises can cause auditory injury leading to permanent hearing loss or impairment (Ketten 2012). Continuous (often referred to as non-pulse) sounds such as those produced by shipping (including disposal at sea activities) and dredging are not likely to cause mortality or injury to marine mammals, as they lack the rapid rise-time to maximum pressure that characterizes pulse noises. Sound source levels (SLs) from dredging and shipping are below published thresholds for injury (see Section 13.5.5.3 for underwater sound profiles of these activities). Modelled sound levels from project shipping activities (LNG carrier plus accompanying tugs) do not exceed NOAA (2013) PTS thresholds at any distance under any scenario. Further, PNW LNG is not aware of any studies linking routine shipping or dredging operations with demonstrated PTS in marine mammals. Underwater noise produced during vessel transit may, however, cause behavioural effects (discussed in Section 13.5.5).

Blasting and impact pile driving produce sudden, intense noises. These pressure pulses can cause auditory injury (i.e., PTS) or pressure injuries to fish and marine mammals close to the sound source. The distance over which injury might occur depends on a variety of oceanographic factors that attenuate sound (e.g., depth, water temperature) and the sensitivity of the receiver to the noise being emitted.

In fish with swim bladders (e.g., salmon, herring, rockfish), pressure waves created by concussive impacts (e.g., impact pile driving) can rupture the swim bladder and/or damage other internal organs and tissue. Vulnerability to and the potential implications of such injuries, depend on the type of swim bladder a species possesses (Halvorsen et al. 2012). Beyond this effect, auditory effects of underwater noise on fish are poorly understood (Popper and Hawkins 2012).

Construction of the materials off-loading facility (MOF) and marine terminal (including the suspension bridge and trestle) will use drilled piles and will occur year round until complete. Use of low noise pile installation techniques (e.g., vibratory hammers) will reduce the risk of physical injury to marine mammals and fish. Due to the depths of soft sediment in the area, low noise pile installation techniques can (and will) be the primary method of pile installation; these methods are not expected to cause physical injury and are discussed under 'Change in Behaviour' (Section 13.5.5). Impact pile driving will likely only be used to seat the piles into bedrock; potential effects of impact pile driving are discussed below.

The vulnerability of individuals to PTS and the potential implications of associated injuries depend on a wide range of variables including the species, pre-existing injuries, distance from source, local bathymetry, and sound frequency (Ketten 1995). Consequently, the effects of noise on marine mammals are highly context dependent and difficult to predict, and may vary substantially between species and individuals. Due to this uncertainty, mitigation measures consider the maximum possible threshold exceedances for underwater noise to cetaceans (see Section 13.5.4.2).

13.5.4.1.4.1 Injury Thresholds for Marine Mammals

There are no regulatory thresholds or guidance in Canada to assess the effects of underwater noise on marine mammals.

Published thresholds used in this assessment (presented in Table 13-12) include:

1. Southall et al. (Southall et al. 2007) cumulative injury criteria (potentially causing PTS) for pinnipeds and cetaceans measured in SPL_{peak} and SEL levels.
2. The National Oceanic and Atmospheric Administration (NOAA) interim sound threshold guidance on injury criteria (potentially causing PTS) for pinnipeds and cetaceans measured in SPL_{rms} (NOAA 2013).

Table 13-12 Permanent Auditory Injury Criteria for Marine Mammals (PTS)

Species Group	Southall et al. (2007)			NOAA
	SPL_{peak} (dB re: 1 µPa)	SEL_{cum} (dB re: 1 µPa^{2}s)		SPL_{rms} (dB_{RMS} re: 1 µPa)
Pinnipeds	218	186 (pulse)	203 (non-pulse)	190
Cetaceans	230	198 (pulse)	215 (non-pulse)	180

NOTES:

SPL_{peak} values apply to single, multiple, and non-pulse sound sources. SPL_{RMS} do not specifically distinguish between different types of sound sources.

Detailed information on how these thresholds are determined and their limitations are described in Appendix N of the EIS. This assessment considers both sets of guidelines and conclusions are based on the more conservative result. Exceeding any of these criteria would constitute a high potential for auditory injury to marine mammals.

As TTS relates to temporary auditory fatigue and not permanent injury, marine mammals are expected to recover from this effect shortly after exposure; therefore, Southall et al. (2007) TTS criteria are not used in this assessment but are discussed qualitatively. In addition, NOAA regulatory thresholds for injury only consider PTS.

13.5.4.1.4.2 Injury Thresholds for Fish

Despite the lack of information on auditory effects (injury) on fish, interim guidance criteria have been developed (Popper et al. 2006) and adopted by the Fisheries Hydroacoustic Working Group (2008) for exposure to noise generated by pile driving (Ketten 2012; Popper et al. 2006).These criteria (onset threshold for physical injury of SPL_{peak} of 206 dB re: 1 µPa; and SEL_{cum} of 187 dB re: 1 μPa^2s) are not species-specific and do not distinguish between hearing specialists (e.g., herring) and generalists (e.g., salmon). This assessment considers exceeding these criteria to constitute a high potential for injury or mortality to fish.

13.5.4.1.5 *Sound Profiles of Key Project Activities*

Blasting, pile installation and dredging are the three main construction activities that will produce underwater noise. Blasting triggers momentary pulses of very high pressure that quickly diminish to background levels. Pile installation and blasting will follow DFO guidelines, as described under mitigation measures in Section 13.5.4.2.

Peak sound levels generated by blasting activities depend on the construction regime (e.g., charge size and type of explosive, depth and configuration of blast holes, blast delay pattern and timing); detailed engineering design concerning blasting activities and likely peak sound levels was not available at the time of writing.

Likewise, noise levels generated from pile installation activities depend on the type of pile being installed (e.g., wood, steel), its diameter (larger piles have larger SPL_{peak} and SEL_{cum}), the method of installation (e.g., impact hammer vs. vibratory driver), and the size of the hammer (Illingworth & Rodkin 2007). Propagation of sound in the water column depends on the water depth (i.e., deeper water results in greater propagation), bathymetry, geology, and presence of other in-water structures (ICF Jones and Stokes and Illingworth and Rodkin Inc 2009).

Current engineering designs for the Project specify the use of 600-1,400 mm diameter steel piles for the MOF, marine terminal, and bridge. Given the abundance of soft sediment in the area, it is likely that a vibratory hammer can be used at most, if not all, locations for construction. Although example sound levels are available for pile installation in the literature (e.g., Hildebrand 2009; Illingworth & Rodkin 2007), more representative predictions are determined by modelling (Appendix N of the EIS). Modelling assumed that one hammer will be used at a time; the addition of one or more hammers working simultaneously would result in an increase in the extent and intensity of underwater noise.

The modelling results predict sound levels (dB) and extent (in km) of underwater noise from impact and vibratory pile installation (with and without bubble curtains as mitigation) compared to the previously discussed thresholds known to affect marine mammals and fish. The sound was modelled at the MOF and two locations at the marine terminal to assess potential for injury and changes in behaviour. The marine terminal sites included a deep water site (pile installation source depth of 10 m) and a shallow water site (pile installation source depth of 0.5 m). Modelling scenario locations are presented in Table 1 of Appendix N of the EIS. Acoustic results from the MOF are used to infer the extent of noise from pile installation at the bridge, and are considered conservative as the bridge is located over a very shallow area where propagation is likely to be less extensive.

Sound levels from vibratory hammers are lower than for impact pile drivers (Illingworth & Rodkin 2007). Modelling results support this, showing that the use of a vibratory hammer decreases sound levels (relative to impact drivers) to below NOAA injury criteria for cetaceans and pinnipeds at all modelled locations. Vibratory pile installation exceeds Southall et al. (2007) PTS injury criteria (using the SEL_{cum} metric) only at close proximity to the sound source. To experience PTS, an animal would need to be in close proximity of pile installation for an entire 24 hour period, which is highly unlikely (see Appendix N of the EIS). For impact pile driving, the predicted extent (in km from the sound source) of potential PTS-inducing sound levels is summarized in Table 13-13 for each marine mammal functional hearing group, under both unmitigated and mitigated (i.e., bubble curtain) scenarios for comparison. As Southall et al. (2007) thresholds are more conservative (198 dB re 1 µPa2•s for cetaceans and 186 dB re 1 µPa2•s for pinnipeds), only these are presented in Table 13-10 and used in the assessment of potential effects. Exceedances of NOAA thresholds (190 dB re 1 µPa for cetaceans and 180 dB re 1 µPa for pinnipeds) occur over smaller areas, with a maximum radius of 0.41 km for impact pile driving at the marine terminal, even without a bubble curtain (see Appendix N of the EIS).

Dredging at the MOF is expected to occur over a period of approximately 6 months and is not expected to occur simultaneously with pile installation at the marine terminal. Current engineering design suggests that sediment in the 0 to 8 m water depth will be dredged by backhoe dredge (BHD) and sediment in the 8 to 15.6 m water depth will be dredged by trailing suction hopper dredge (TSHD). It is conservatively assumed that both the BHD and TSHD are operating simultaneously for four months of the summer season (including August 2015), even though this has not been confirmed.

In a recent study characterizing underwater sound levels of three TSHDs (the louder of the two dredging methods), SLs were found to range from 161 to 177 dB_{rms} re: 1µPa @ 1m (Reine et al. 2014). These values are below the NOAA interim permanent auditory injury thresholds of 190 and 180 dB_{rms} for pinnipeds and cetaceans, respectively (Table 13-13), and will decrease rapidly with distance from the source. As such, underwater noise produced by dredging at the MOF is not likely to cause physical injury to marine mammals, but may cause behavioural change (see Section 13.5.5.3). Similarly, underwater noise produced during vessel transit and disposal at sea activities (including vessel transit) is not likely to cause mortality or physical injury to marine mammals.

Table 13-13 Predicted Extent (km) of Potential Injury to Marine Mammals from Impact Pile Driving based on Southall et al. (2007) Thresholdsa

Impact Pile Driving Location	Low-Frequency Cetaceans (mysticetes, baleen whales)	Mid-Frequency Cetaceans (some odontocetes, toothed whales)	High-Frequency Cetaceans (specialized odontocetes)	Pinnipeds
	198 dB re 1 µPa2·s			186 dB re 1 µPa2·s
Deep scenario (unmitigated)	4.1 km	3.8 km	3.7 km	16 km
Deep scenario (bubble curtain)	0.96 km	0.65 km	0.61 km	5.0 km
Shallow scenario (unmitigated)	2.6 km	2.6 km	2.5 km	21 km

Impact Pile Driving Location	Low-Frequency Cetaceans (mysticetes, baleen whales)	Mid-Frequency Cetaceans (some odontocetes, toothed whales)	High-Frequency Cetaceans (specialized odontocetes)	Pinnipeds
	198 dB re 1 µPa2·s			186 dB re 1 µPa2·s
Shallow scenario (bubble curtain)	0.83 km	0.81 km	0.80 km	4.1 km
MOF (unmitigated)	0.75 km	0.71 km	0.72 km	1.1 km
MOF (bubble curtain)	0.60 km	0.50 km	0.47 km	0.80 km

NOTES:
Source: Appendix N of the EIS.
[a] Based on cumulative SEL, calculated by adding the SEL of all sound sources an animal could be exposed to over a 24-hour period (for instance, each separate impact pile driving strike) (see Appendix N of the EIS).

13.5.4.2 Mitigation

The following mitigation measures will be implemented year-round (as applicable) to reduce the potential for injury or mortality to fish and marine mammals. Mitigation measures may be refined over the course of the Project, as the result of information learned through follow-up and monitoring programs (see Section 13.7) and ongoing discussions with regulators and Aboriginal groups.

13.5.4.2.1 Burial, Crushing, or Blasting

- A Blasting Management Plan which outlines management measures for both terrestrial and underwater blasting will be implemented (Appendix J.11 of this EIS Addendum)
- Fisheries and Oceans Canada's Blasting Guidelines (Wright and Hopky 1998) will be implemented, including enforcing a safety radius of 500 m, and ensuring marine mammals are not present in the safety radius prior to blasting. A marine mammal observation program will be implemented and marine mammal observers (MMOs) will terminate blasting activities if cetaceans or marine mammals listed under the *Species at Risk Act* (SARA) enter the 500 m blasting safety radius (detailed below under 'underwater noise')
- Blasting will be conducted within DFO least-risk timing windows (approximately November 30 to February 15); exact dates to be refined to reflect local conditions, based on pre-construction field surveys and in consultation with DFO to reduce mortality to fish during important lifecycle stages
- The blasting design will consider appropriate measures to reduce overpressure, through the optimum use of explosives for rock blasting. Where possible (i.e., if low tides occur during daytime hours), blasting will be timed with low tides to reduce the number of detonations that occur underwater
- Dungeness crabs will be relocated from construction zones using proper handling techniques and strategies that limit stress
- In areas of low to moderate currents (≤ 1 knot), silt curtains will be installed around blasting activities if monitoring results indicate inferred TSS levels will be higher than the WQG outside the active work area. Studies suggest that effectiveness of silt curtains is reduced when currents exceed about 1 knot (Francingues and Palermo 2005). Silt curtains are expected to be most effective in the inner, sheltered areas of the MOF. Currents in Porpoise Channel (outer MOF) are likely to be too strong to permit effective use of silt curtains.

13.5.4.2.2 Turbidity and TSS

Mitigation measures discussed in Section 13.5.2.2 (Change in Sediment or Water Quality) to reduce effects from vessel maneuvering at the marine berth will also reduce the potential for injury and mortality of fish resulting from elevated TSS and burial by sediment deposition. The following mitigation measures are presented:

- Dredging operations will be conducted using methods and/or equipment that reduces sediment spill
- Dredged sediment will be disposed of at or near the center point of the Brown Passage disposal site, to minimize effects on water quality outside the site
- Turbidity levels in accessible areas of the water column will be monitored during disposal
- Turbidity will be monitored in real time during in-water construction activities (i.e., blasting, dredging, and ocean disposal) and compared to predicted TSS levels (through use of a turbidity-TSS calibration curve) and WQG. In the event that calculated TSS levels exceed modelled predictions outside of the active work area (defined as the immediate area surrounding operating construction equipment) or disposal site, the rate of the activity will be adjusted (e.g., slowed), or additional mitigation measures implemented (e.g., silt curtains) to minimize the spatial extent of elevated TSS.

13.5.4.2.3 Underwater Noise

- A Marine Pile Installation Management Plan (see Appendix J.12) which outlines the reduced noise pile installation techniques that will be used when low noise installation methods are not technically feasible (e.g., due to unfavourable substrate) will be implemented
- Low noise pile installation techniques (i.e., vibratory installation methods) will be used except during seating of some piles into bedrock
- In instances when an impact pile driver is required (e.g., during pile seating), bubble curtains with bubble-containment casing will be used and the impact hammer will be constructed of sound absorbent material. To mitigate for behavioural effects, a bubble curtain will also be used during low noise pile installation (see Section 13.5.5.2)
- In instances when the efficacy of bubble curtains is diminished by high currents, isolation casings that contain bubbles will be used in lieu of bubble curtains
- Bubble curtains will be used during pile installation (i.e., vibratory and impact) at the inner MOF. The exact style of bubble curtain and/or casing used will be determined on a case by case basis, taking into consideration the type of activity (and predicted sound levels) and oceanographic conditions (e.g., current speed). In situ field validation of the effectiveness will be measured/monitored during the first seven days of each style of curtain/casing implemented to confirm underwater sound levels produced following implementation of this mitigation
- If it is determined that pile installation and dredging need to occur simultaneously, potential underwater noise levels will be modelled to inform mitigation measures, and a monitoring program will be developed.
- During all pile installation activities, a marine mammal observation program will be implemented. Marine mammal observers will monitor a safety radius (i.e., exclusion zone) around pile installation, including during pile seating, and will halt the activities if cetaceans (of any species) or other marine mammal species that are listed under SARA enter this zone
- The Environmental Monitoring Management Plan will detail the duties and responsibilities of the MMOs, and will include the following protocols:

- Prior to commencement of impact pile installation activities and any time there is a pause in impact pile installation for more than 30 minutes, the safety zone will be surveyed visually by the MMO, and impact pile installation will not commence until (i) any observed cetacean or SARA-listed marine mammal is seen leaving the safety zone, or (ii) none have been detected in the safety zone for a period of 30 minutes
- Upon commencement of impact pile installation activities or recommencement after a delay of 30 minutes or more, pile installation will ramp-up by starting with slower, quieter strikes. This is designed to enable any marine mammals in the area time to leave the area prior to attainment of underwater noise levels capable of causing injury
- During conditions of low visibility (i.e., when the safety zone cannot be monitored, during foggy conditions or darkness), if pile installation activities have ceased for more than 30 minutes, the MMO will delay recommencement of start-up until conditions improve. Once conditions improve, the safety zone will be monitored for cetaceans (of any species) or other SARA-listed marine mammals for 30 minutes before commencing impact pile installation
- Underwater sounds levels will be measured/monitored in situ during the first seven days of underwater blasting and impact pile driving to acquire baseline data on sound pressure levels produced during each activity, and to field-validate the effectiveness of bubble curtains and the size of the safety zone (currently set at 500 m and 1.0 km respectively). Monitoring will be conducted at the sound source and at the edge of the marine mammal safety radius (i.e., exclusion zone). Measurements for source levels are made close to the source, typically at a distance of 10 to 100 m. The exact distance and location will depend on several factors, such as source type and amplitude, and water depth. Measurements may be taken at multiple distances simultaneously to assist with confirming the back-propagation function. Should the construction equipment or technique change notably over the course of construction (e.g., pile installation method or material, blasting charge etc.), such that source levels measured at the onset are unlikely to remain representative, new source levels will be acquired. In addition:
    - If monitoring indicates pressure levels in excess of 30 kPa or a fish kill is observed during vibratory or impact pile driving, the activity will cease and DFO will be notified. The activity will resume after additional mitigation measures are implemented
    - If monitoring indicates pressure levels in excess of 100 kPa or a fish kill is observed during underwater blasting, the activity will cease and DFO will be notified. The activity will resume after additional mitigation measures are implemented
    - If monitoring indicates sound levels in excess of 160 dB at the edge of the marine mammal safety (exclusion) zone for any activity, the activity will cease and DFO will be notified. The activity will resume after additional mitigation measures are implemented. Additional measures could include type/configuration of bubble curtain and size of safety radius for marine mammals
    - If monitoring indicates sound levels at or below 160 dB are being achieved at a distance of 500 m or less, the marine mammal safety (exclusion) zone for that activity may be reduced to 500 m
- Pile driving planning and operation will adhere to the Best Management Practices Policy for Pile Driving and Related Operations developed by the BC Marine and Pile Driving Contractors Association and DFO (BC Marine and Pile Driving Contractors Association 2003), wherever and whenever feasible.

13.5.4.3 Characterization of Residual Effects

13.5.4.3.1 Blasting

According to DFO's blasting guidelines, sounds produced by a 100 kPa blast are unlikely to harm marine mammals that are at least 500 m from the source (Wright and Hopky 1998). Although detailed engineering design concerning blasting activities and likely peak sound levels was not available at the time of writing, appropriate mitigation measures have been developed to reduce the likelihood that marine mammals are exposed to potential injury. As detailed in Section 13.5.4.2, a marine mammal observation program will be implemented, through which trained MMOs will monitor an exclusion zone around the blasting area for thirty minutes prior to the start of blasting, and throughout blasting operations. The MMOs will be authorized to delay the start or temporarily terminate blasting activities if cetaceans (of any species) or other marine mammals that are listed under SARA enter the blasting safety radius (i.e., exclusion zone). Blasting will not recommence until the exclusion zone has been clear of such sightings for thirty minutes. Additional information on regulatory permits, exclusion zones, and contacts for blasting will be detailed in a blasting management plan, which will be developed prior to the start of construction. The exact radius of the exclusion zone (minimum of 500 m) will be determined through consultation with DFO. The implementation of these mitigation activities will minimize potential risk of mortality or injury to marine mammals.

Blasting is expected to cause an increased risk of mortality or injury to fish, larvae, or eggs within the immediate vicinity of the blast; however, the development of a blasting management plan, based on DFO's blasting guidelines, will limit the extent of this effect. Moreover, most species of commercial importance are expected to be rare or absent from the blast area. Dungeness crabs will be relocated prior to blasting. While some crabs may return to the construction area after relocation, this mitigation measure is considered a best practice and will reduce the overall number of crabs that are injured and/or killed.

13.5.4.3.2 Crushing or Burial

Modelling results predict that the majority of the MOF dredge pocket area will have sedimentation rates of less than 0.5 cm/year, with a small area (<100 m^2) receiving around 2 cm/year. As a result, the Project does not anticipate the need for regular or cyclical maintenance dredging in the MOF during operations (Appendix G.4 and G.19).

With the implementation of mitigation strategies as described above, the residual effect of physical injury and mortality to fish due dredging and disposal at sea during construction is expected to be generally limited in spatial extent to the immediate vicinity and areas in close proximity of these activities. Sedentary or slow-moving fish and invertebrates are least likely to be able to avoid injurious effects. While individuals near such activities might be lost, these species are expected to begin recolonizing the affected areas following completion of construction with no adverse effects on the viability of local populations.

Organisms in the deep, soft-sediment habitat present at Brown Passage, a previously used sediment disposal site are expected to be resilient and able to re-colonize the area following disposal. See Section 13.5.2.1 and Appendix O of the EIS for results of the three dimensional numerical modelling study conducted by ASL Environmental Services Inc. to conservatively estimate deposition of sediments from dredging and disposal activities at Brown Passage. Only immobile species are expected to experience burial, as most species will be able to migrate vertically through the sediment. Mitigation measures for vessel maneuvering are expected to reduce potential burial of organisms around the berth area (see Appendix G.16). Very little sediment deposition outside the berth area is predicted.

13.5.4.3.3 Increased TSS

Marine organisms, particularly eelgrass and sediment-dwelling invertebrates, are adapted to seasonal variations in TSS levels, as are juvenile salmon, which migrate to Flora Bank during late spring and summer. Species that use Flora Bank and the surrounding areas are not expected to experience chronic or acute (lethal) effects based on these low levels of TSS above background that will occur within the MOF dredge area. Chronic effects may occur in the active dredge area where WQGs are exceeded; however, the majority of mobile fish and invertebrates are expected to temporarily avoid the work area during dredging activities. Eelgrass on Flora Bank is exposed to varying TSS levels, and appears to be naturally adapted to higher TSS levels.

Residual effects caused by elevated TSS, associated with vessel maneuvering during berthing and departure will be reduced by applying mitigation measures (e.g., use of tugs with low amounts of propeller wash). As discussed in Section 13.5.2.3, TSS levels typically less than 5 mg/L and occasionally above 5 mg/L (up to 47 mg/L in one event over a 28-day model period, for one hour duration) are predicted in a small portion of Flora Bank. These levels are below those that cause lethal effects to salmon and other species and are therefore not expected to result in injury or mortality. In addition, salmon and other species are expected to avoid areas of high TSS concentrations.

TSS levels associated with construction dredging at the MOF are not expected to cause injury or mortality, with levels not expected to exceed the WQG of 5 mg/L for continuous activity, except immediately within the MOF dredge area (see Section 13.5.2). These are well below the acute toxicity levels of 1,000 mg/L for salmon identified by Wilber and Clarke (2001).

During disposal of dredged sediment from the MOF, TSS levels in the deepest waters of Brown Passage are predicted to be high (up to 1,100 mg/L); however, these levels will be localized and occur for only a few hours immediately after the disposal. Levels through the rest of the water column will range from 1 to 25 to 30 mg/L above background. The TSS levels predicted for bottom waters could result in lethal effects to some species of fish (e.g., salmon or herring but not, for example, halibut) if they last 24 hours or more (Wilber and Clarke 1998; Wilber and Clarke 2001); however, such high levels will last for less than 24 hours and the activity will occur in a designated disposal site, under permit, in an area selected for its low environmental sensitivity compared to shallower areas closer to shore.

Furthermore, the disposal at sea site is relatively far from shoreline habitats (i.e., over 3 km from the closest small island, south of Melville Island). The disposal site is also approximately 9 km from the closest documented potential biogenic sponge reef in Chatham Sound, as delineated during benthic habitat mapping conducted for the Prince Rupert Gas Transmission Project (2014a), and even further from the sponge reefs documented by the Westcoast Connector Gas Transmission Project through geophysical survey and subsequent inspection by remotely-operated vehicle [ROV] by Archipelago Marine Research Ltd. (2014). The edge of the 1 mm sediment deposition contour is greater than 3,700 m from the closest documented potential biogenic sponge reef.

13.5.4.3.4 Underwater Noise

Piles will be installed for the construction of the bridge between Lelu Island and the mainland (across Lelu Slough), the pioneer dock, the MOF, and the marine terminal (suspension bridge, trestle and berth). Use of low noise pile installation techniques (e.g., vibratory pile drivers) will be the primary method of pile installation in all areas due to the depths of soft sediment. Impact pile driving will likely only be used to seat the piles into bedrock. See Section 13.5.4.2, which discusses additional mitigation measures such as use of a bubble curtain and enforcement of a marine mammal safety zone.

Impact pile driving using a bubble curtain is not expected to exceed fish injury criteria (SPL_{peak} of 206 dB re: 1 µPa; SEL_{cum} of 187 dB re: 1 μPa^2s), except within the immediate vicinity of the pile. The radii ($R_{95\%}$ radius, see Section 13.5.1.2 and Appendix N of the EIS) at the marine terminal (deep scenario, and shallow scenario) and MOF are 0.011 km, 0.14 km, and less than 0.006 km, respectively (see Appendix N) (see JASCO Applied Sciences 2013, Appendix C). Fish close to the pile are expected to relocate in response to preparatory activities such as the installation of bubble curtains. Therefore, it is unlikely that fish will be injured or killed during pile driving.

Bubble curtains are a common sound-attenuation strategy (ICF Jones and Stokes and Illingworth and Rodkin Inc 2009), and designs are available with isolation casings that contain bubbles, making them effective in areas of high current (ICF Jones and Stokes and Illingworth and Rodkin Inc 2009), such as in Porpoise Channel.

With vibratory methods of pile installation (with a bubble curtain) used as a mitigation measure, there will be no effect of injury or mortality from pile driving on marine mammals or fish, based on NOAA and Southall et al. (2007) injury criteria (see Appendix N of the EIS). If an impact hammer with a bubble curtain is used, cetaceans within 1.0 km of the sound source may be exposed to sound levels capable of causing permanent auditory injury (see Table 13-14 and Table 13-15). In this case, a MMO will monitor this area to reduce the potential for such exposure, as described in Section 13.5.4.2.

Species that are expected to be found within the 1.0 km radius where injury criteria (Southall et. al 2007) are exceeded (using an impact hammer) for underwater noise are harbour porpoise, Dall's porpoise, Northern resident and Bigg's killer whales, and humpback whale (see Table 13-14). Loughlin's Northern sea lion and harbour seal are found within a larger radius of 5.0 km (see Table 13-14). Pacific white-sided dolphin may also be affected within a 1.0 km radius. Species such as fin and minke whale spend limited time in the LAA and are found closer to Triple Island, outside the area of potential injury (PTS). If these species were to occur within areas of ensonification, the implementation of the MMO program will assist in preventing PTS to these species. The potential extents of residual effects to marine mammal species most likely to occur in the LAA are presented in Table 13-14.

While Table 13-14 shows spatial and temporal overlap of marine mammal species with ensonified areas, suitable alternative habitat is available over large areas for all marine mammals affected by the Project. Density surface model outputs derived using marine mammal survey data from Best and Halpin (2011) were used to infer habitat availability. Mid to high density areas are listed in Table 13-14 and then used to determine if suitable habitat would be available to marine mammal species if habitat affected by the Project (e.g., underwater noise from pile installation) were to become unavailable. Areas showing low to mid density are not considered in the assessment, but may provide alternative suitable habitats and therefore the assessment is conservative.

The ranges over which marine mammals may experience PTS can be inferred from modelling results for impact pile driving. Although radii have not been calculated, the areas of ensonification exceeding TTS thresholds will be more extensive than those identified for PTS, and can be inferred from Appendix N of the EIS (Figure A-1 to Figure A-24). This is important for harbour porpoise which, relative to other marine mammals, are particularly sensitive to construction noise and often exhibit behavioural response to underwater noise (Kastelein et al. 2011). DFO's Management Plan for Pacific harbour porpoise lists acoustic disturbance as a threat of medium to high concern (DFO 2009b). TTS is a temporary condition and marine mammals are expected to recover shortly after exposure to underwater noise.

Mitigation measures are expected to reduce the effects of injury to marine mammals. The small size of harbour and Dall's porpoise can make MMO observations difficult in adverse weather; however, avoidance behaviour may further limit the potential for injury. Population viability is not expected to be affected given the relatively localized nature of this effect and the implementation of effective mitigation measures (see Table 13-14).

Following mitigation, some pinnipeds may still be exposed to sound levels capable of causing PTS at distances beyond those covered by the marine mammal observation program (i.e., for distances up to 5.0 km from the berths or 4.1 km from the jetty-trestle). However, like harbour porpoise, a study by (Kastelein et al. 2012a), demonstrated that seals may also avoid underwater sound sources at distances that exceed those expected to cause injury (PTS). The results of this study also showed that some seals were attracted to the underwater sound source and it is therefore uncertain whether harbour seals and other pinnipeds such as Loughlin's northern sea lion may vacate the area at the onset of such activities (therefore reducing their time of exposure, and likelihood of permanent auditory damage). While PTS would reduce an individual's fitness and could lead to indirect mortality (e.g., through higher susceptibility to predation), actual PTS occurrences are likely to be rare, and are not expected to have an effect on the viability of pinniped populations in the region (see population sizes in Table 13-14).

Table 13-14 Marine Mammal Injury Threshold Exceedances (PTS) and Residual Effects

Species	Maximum[1] Extent of Potential Injury[2]	Spatial and Temporal Overlap with Ensonified Areas	Status and Population Abundance Estimates, Queen Charlotte Basin[7]
Harbour porpoise and Dall's porpoise[3]	0.80 km	• Concentrations of harbour and Dall's porpoises found throughout ensonified areas (B.C. Cetacean Sightings Network 2013; Best and Halpin 2011) • Ensonified area occurs over the width of Porpoise Channel between Lelu and Ridley Island. • Present year-round (see Appendix M of the EIS).	Harbour porpoise (*Special Concern*, SARA) • 2,806 to 3,647 individuals • High density around Prince Rupert and throughout the southern portion of Chatham Sound (overlapping with the pile driving radius). • Other high-density areas exist south and west of the LAA and over a large area in Hecate Strait. Dall's porpoise (*Not Listed*, SARA) • 4,232 to 4,540 individuals • Density low to moderate around Prince Rupert, within LAA density is highest near Stephens Island. • Area of highest density is large area north of Haida Gwaii.
Northern resident and Bigg's killer whale[4]	0.81 km	• Killer whales have been observed within this radius (see B.C. Cetacean Sightings Network (2013). • Northern resident present May-July (see Appendix M of the EIS). • Bigg's present year-round (see Appendix M of the EIS).	• Both species *threatened*, SARA • 251-264 individuals (combined, both species) • Density in Chatham Sound approximately same as other areas in the Queen Charlotte Basin, with highest densities in Caamaño Sound.
Humpback whale[5]	0.96 km	• Humpback whales have previously been observed within this radius, but concentrations are around Triple Island (see B.C. Cetacean Sightings Network (2013). Present in highest densities May-October although observations of adults and juveniles have been made in the LAA during the winter months (i.e., December to May), particularly around the Kinahan Islands. Thus, humpback whales may be present year-round (see Appendix M of the EIS).	• Threatened, SARA • 995-1431 individuals • Areas of high density outside the LAA west of Triple Island with highest densities in southern Hecate Strait.

Species	Maximum[1] Extent of Potential Injury[2]	Spatial and Temporal Overlap with Ensonified Areas	Status and Population Abundance Estimates, Queen Charlotte Basin[7]
Loughlin's Northern sea lion[6]	5.0 km	• No major haulouts or rookeries overlap with ensonified area. • Present year-round, sightings in ensonified areas not as likely as for other species (see Appendix M of the EIS).	• Special Concern, SARA • 2692-4817 individuals • Density mapping does not show the presence of any Loughlin's northern sea lions in the LAA except near Triple Island (Best and Halpin 2011).
Harbour seal[6]	5.0 km	• Frequent observations made during field surveys in Porpoise Channel and near Flora Bank. • Haulout sites in and around the LAA likely support over 1,000 seals (DFO 2010a). • Present year-round (see Appendix M of the EIS).	• Not Listed, SARA • 2562-4181 individuals • Densities low in LAA relative to the Queen Charlotte Basin; highest densities in Caamaño Sound (hauled out).

NOTES:

[1] Maximum radii of all three locations modelled for pile driving: MOF and marine terminal (see Appendix N of the EIS).

[2] Injury determined according to Southall et al. (2007) PTS thresholds for cetaceans and pinnipeds (198 and 186 dB re 1 $\mu Pa^2 \cdot s$, respectively), using SEL_{cum} (see Table 13-12 and Appendix N of the of the EIS).

[3] Based on audiogram weighted results for high-frequency cetaceans (specialized odontocetes).

[4] Based on audiogram weighted results for mid-frequency cetaceans (some odontocetes, toothed whales).

[5] Based on audiogram weighted results for low-frequency cetaceans (mysticetes, baleen whales).

[6] Results are not audiogram weighted.

[7] Information derived from Best and Halpin (2011). Range is based on average observations of distance sampling estimates and abundance estimates for all surveys conducted in the Queen Charlotte Basin (shown in Figure 1, Best and Halpin [2011]). Best and Halpin (2011) stipulate the abundance estimates may underestimate true population size. Please also refer to Technical Memorandum: *Species Use of Marine Habitats in the Local Assessment Area* submitted in June 2014 for more information.

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Immobile species are not expected to experience population effects as a result of burial, crushing, or blasting, as species that will be affected are widespread in the LAA and will begin recolonizing affected habitats immediately following the completion of construction.

The magnitude of these effects are expected to be moderate for burial, crushing, blasting, and underwater noise, with changes outside the range of natural variability that are not expected to affect population viability for any species. Effects of burial and crushing will occur primarily within the PDA (and disposal at sea site) but effects of underwater noise will extend into the LAA. Effects are expected to be reversible at the population level for marine mammals and fish. Few, if any, marine mammals are expected to become injured and this is not expected to affect local populations. Sedentary or slow-moving fish (e.g., some flatfish species) and invertebrates (e.g., cockles and other clams) may be killed during construction as they are less likely to be able to avoid these activities. While individuals near such activities might be lost, these species are expected to begin recolonizing the affected areas following completion of construction with no adverse effects on the viability of local populations.

Increases of TSS from project activities causing injury or mortality are expected to be moderate in magnitude, local in geographic extent, occur over multiple regular events (construction) and over the long-term (operations) and medium-term (construction) and be reversible. Marine organisms in the area are exposed to naturally high concentrations of TSS during Skeena River freshet and are therefore considered to have moderate resilience.

13.5.4.4 Likelihood

The likelihood of injury or mortality to fish from project activities involving blasting, burial, or crushing is high. With the implementation of mitigation measures such as the marine mammal observation program, the likelihood of injury or mortality to marine mammals from blasting activities is low. The likelihood of injury or mortality to fish and marine mammals from underwater noise is low to moderate.

13.5.4.5 Determination of Significance of Residual Effects

The residual effects of injury and mortality to fish as a result of burial or crushing are not predicted to affect population viability of any species found in the LAA, nor are any fish species at risk or of management concern expected to be killed or injured. Marine fish species at risk (i.e., Northern abalone, bluntnose sixgill shark, and rougheye and yelloweye rockfish [SARA]) and of management concern (i.e., bocaccio, canary, darkblotched, quillback, and yellowmouth rockfish, eulachon, green sturgeon, North Pacific spiny dogfish [COSEWIC]) (see Table 13-7) are not likely to be affected by blasting, burial, or crushing, or effects of underwater noise as they are not expected to be found in locations where these effects might occur (see Section 13.5.2). Northern abalone are slow-moving and, if present, would likely have been observed during field surveys. Yelloweye and rougheye rockfish are usually found at depths of 170 m and 30 m or deeper, respectively, and are usually associated with hard substrates rather that soft-substrates (COSEWIC 2007, 2008) and are therefore unlikely to be affected by construction activities.

The use of mitigation measures to restrict the geographic extent of increased changes in TSS levels at the marine berth (during operations) and MOF dredge area (during construction), respectively, are important for managing adverse effects of TSS on fish (particularly juvenile salmonids) and invertebrates. As discussed in Section 13.5.2.5, residual effects on sediment and water quality will not result in an increased toxicological risk for marine organisms. As the predicted changes in TSS are not expected to result in lethal effects to fish they will therefore not affect the viability of fish or invertebrate populations.

Mitigation measures for potential injury or mortality of marine mammals include a pile installation management plan (entailing use of vibratory installation, bubble curtains, bubble containment casings, sound level monitoring and marine mammal observation programs) and a blasting management plan (entailing use of DFO's Blasting Guidelines and a marine mammal observation program). These mitigation measures will also be used to mitigate potential behavioural effects on marine mammals (see Section 13.5.5). Harbour porpoise (listed as *special concern* under SARA) could be harmed through propagation of underwater noise from pile installation; however, with mitigation the potential for this is reduced, and effects to population viability are considered unlikely.

For the most part, residual effects of direct mortality or physical injury to fish or marine mammals will be restricted to the construction phase. Effects during the operations phase (i.e., potential for burial or crushing from the increased TSS during vessel maneuvering) are expected to be negligible. As population viability is unlikely to be affected and the likelihood of mortality to species at risk or of management concern as a result of the Project is low, the residual effect of direct mortality or physical injury to fish or marine mammals is predicted to be not significant.

Effects of the Project have been assessed for each SARA and COSEWIC-listed species at risk, including marine fish and marine mammals. These species-specific assessments are presented in Appendix F.4.

13.5.4.6 Confidence and Risk

Confidence in the assessment of direct mortality or physical injury to fish from crushing or burial is high. This is due to the mitigations (e.g., relocation of commercially important Dungeness crabs), localized nature of this effect (i.e., limited to the immediate vicinity of construction or disposal at sea) and the correspondingly nil effect that this will have on population viability. Confidence in the assessment of direct mortality or physical injury to fish and marine mammals due to blasting is likewise rated as high, due to the implementation of effective mitigation measures (i.e., monitoring of changes in pressure levels and enforcement of a blasting safety radius).

Although the confidence in the assessment of injury or mortality to fish from blasting, crushing, and burial is high, the overall confidence level for injury or mortality to fish or marine mammals is moderate for the following reasons:

- Acoustic effects are poorly understood for most species
- Distribution and abundance of marine mammals in the LAA is not well defined. However, conservative assumptions about species presence were used to assess potential effects on marine mammals (e.g., all species were considered to be present year-round in the area affected by pile installation). Mitigation measures (e.g., use of low-noise pile installation techniques to reduce underwater noise) will be used to reduce these effects at all times of year, regardless of variation in species abundance. Furthermore, additional fisheries and habitat studies and marine mammal surveys will be conducted beginning in the winter of 2014, and results will be used to assess and refine mitigation measures (see Section 13.7)
- Several assumptions were made in acoustic modelling, and while scenarios were designed to be conservative and based on the worst-case scenarios to account for potential changes in project design, sound source levels

specific to the Project have not been field validated. Follow-up monitoring will determine the effectiveness of mitigations and additional measures will be applied if necessary

- Project design and operational details are subject to change.

Since the confidence in this prediction is not low, no additional risk analysis has been conducted.

13.5.5 Change in Behaviour

13.5.5.1 Potential Effects

Construction, operations, and decommissioning can create underwater noise resulting in behavioural effects to marine mammals and fish. Blasting and impact pile driving produce sudden, loud sounds that could trigger behavioural changes in both fish and marine mammals. Dredging, disposal at sea, and construction-related vessel movement produce continuous (non-pulse) underwater noise that could affect the behaviour of fish and marine mammals. LNG carriers will also produce underwater noise during operations (shipping and berthing), which is variable depending on speed and water depth, among other factors.

Behavioural effects caused by underwater noise are expected to be more prominent during the construction phase compared to operations, as in-water construction activities (e.g., pile installation) are known to produce louder underwater noise levels than operational activities (e.g., vessel movements). Adult fish and highly mobile invertebrates may also exhibit avoidance responses in areas with elevated TSS levels (Martens and Servizi 1993; Newcombe and Jensen 1996; Wilber and Clarke 2001); however, this temporary behavioural response may act to reduce the potential for injury or mortality (see Section 13.5.4) as TSS exposure durations are generally limited to minutes or hours (Newcombe and Jensen 1996; Wilber and Clarke 1998).

Underwater noise can cause stress (Rolland et al. 2012; Wright et al. 2007); (Wysocki et al. 2006); (Hastings and Popper 2005; Rolland et al. 2012; Southall et al. 2007) which may cause physiological responses such as lowered immune response and diminished reproductive effort (Southall et al. 2007), affect communication (Clark et al. 2009; Popper and Hawkins 2012; Richardson et al. 1995; Risch et al. 2012; Southall et al. 2007; Williams et al. 2013), and trigger avoidance behaviours that can disrupt migration (Southall et al. 2007; van Opzeeland and Slabbekoorn 2012) or foraging patterns (e.g. Slotte et al. 2004; Sundermeyer et al. 2012; Tougaard et al. 2012; Williams et al. 2006). However, the actual reactions of marine mammals and, especially fish, are difficult to predict and depend on a multitude of variables including the type, magnitude and duration of noise, the species and its distance from the sound source, and the activity state of the animal at the time (Popper and Hawkins 2012; Richardson et al. 1995).

Potential behavioural responses of fish to underwater noise include change in behavior, small temporary movements for the duration of the sound, large movements that displace fish from their normal locations, and large-scale changes in migration routes (Popper and Hastings 2009). Construction noise is expected to trigger behavioural changes in fish that are close to construction activities. Behavioural changes in fish from non-pulse noises have not been well-studied but are likely to be greater in hearing specialists (e.g., herring) than generalists (e.g., salmon). Fish hearing specialists rely on auditory signals for communication, foraging and schooling; they have greater hearing sensitivity and perceive sounds over wider bandwidths than generalists (Popper and Lu 2000).

The most common reaction for all fish species is expected to be a short-lived startle response by fish near the onset of pulse noises (e.g., in close proximity to a pile during impact driving); however, normal behaviour is likely to resume within seconds (Wardle et al. 2001).It is expected that juvenile fish (e.g., those that use the Flora Bank eelgrass bed as rearing habitat) will exhibit similar startle responses, but may be more sensitive at this life cycle stage.

Marine mammals most likely to experience effects of underwater noise include humpback whale, northern resident killer whale, Bigg's killer whale, Dall's porpoise, harbour porpoise, Pacific white-sided dolphin, and harbour seal. Loughlin's northern sea lion may also occur in the LAA and experience behavioural effects. Fin whales are usually absent from the LAA; however, they occasionally feed around Triple Island from July to August (see Appendix M of the EIS, Table 2) and could therefore be affected by underwater noise from shipping.

Behavioural effects to marine mammals from underwater noise can vary widely. Responses may include temporary displacement or avoidance of ensonified areas (of particular concern in areas that may provide important habitat for feeding or important life cycle stages), increased energy expenditure, reduced foraging efficiency, and increased stress potentially causing adverse physiological responses (Richardson et al. 1995; Rolland et al. 2012). Noise can also affect the ability of marine mammals to communicate and perceive sounds in their environment potentially affecting navigation, mate selection, predator avoidance, and prey detection (Payne and Webb 1971; Tyack and Clark 2000). Marine mammal species vary in their sensitivity to underwater noise and the bandwidth of sounds that they can hear (Richardson et al. 1995; Southall et al. 2007). The same sound could attract some species but deter others (Southall et al. 2007).

Underwater noise is listed as a concern in some of the recovery strategies and management plans for marine mammals that are listed under SARA and found in the LAA (e.g., DFO 2007, DFO 2008, DFO 2009b, DFO 2013e). Harbour porpoise are particularly sensitive to sound. DFO's 2009 management plan for the Pacific harbour porpoise identifies acoustic disturbance as a threat to harbour porpoises (*special concern*, SARA) of a medium to high concern. This is due to its potential for displacement, effects on feeding (and prey availability), reproductive success, and social behaviour (DFO 2009b). Observed behavioural responses include temporary habitat avoidance and exclusion from regions with chronic increases in noise levels (DFO 2009b).

Both northern resident and Bigg's killer whales are often seen in acoustically active groups; the former forages (often quite vocally) on fish and the latter forages silently on acoustically sensitive mammalian prey (i.e., pinnipeds and small cetaceans). Both populations likely rely on the ability to detect their prey acoustically. Harbour seals are the most frequently documented prey for Bigg's killer whale, followed by harbour porpoise, Dall's porpoise, and Loughlin's northern sea lion. Declines affecting the population viability of any of these species could negatively affect the Bigg's killer whale. Because both groups of killer whales communicate acoustically (Deecke et al. 2005; Ford and Ellis 1999), continuous underwater noise may result in masking (interfering with acoustic communication) and reduction of foraging efficiency (DFO 2007; Williams et al. 2006). Furthermore, research has demonstrated that Bigg's killer whales can be displaced from their habitats as a result of intense anthropogenic underwater noise (DFO 2013j).

Long-term implications of underwater noise are unknown for individual and populations of humpback whales (DFO 2013k).

13.5.5.1.1 Behavioural Thresholds for Marine Mammals

The interim behavioural thresholds for marine mammals (measured in SPL_{rms}) used by NOAA will be applied in this assessment. Although Southall et al. (2007) criteria are considered more comprehensive for assessing impulsive noise causing PTS (injury) in marine mammals, Southall et al. (2007) did not provide quantitative thresholds for behavioural disturbance. NOAA's behavioural thresholds, which are the same for both pinnipeds and cetaceans) are:

- 120 dB_{RMS} re: 1 µPa for continuous sounds (e.g., shipping and dredging)
- 160 dB_{RMS} re: 1 µPa for pulse sounds (e.g., impact pile driving) (Federal Register 2005).

NOAA thresholds are general, apply to all marine mammal species, and do not account for differences in marine mammal hearing abilities; however, specific behavioural disturbance thresholds have been developed for northern resident killer whales and these will be applied in this assessment. Killer whale disturbance thresholds were predicted by MacGillivray et al. (2012) based on behavioural responses to whale-watching vessels observed during field trials (Williams et al. 2002a; Williams et al. 2002b). Received sound levels of approximately 64 dB re: HT (hearing threshold for northern resident killer whale) were shown to cause overt avoidance responses and sound levels of approximately 57 dB re: HT were shown to cause subtle avoidance responses (MacGillivray et al. 2012).

For the assessment of potential behavioural effects on northern resident killer whale, the 57 dB re: HT threshold will be used as it is more conservative than the threshold for overt avoidance (64 dB re: HT). Species-specific behavioural effects thresholds have not been established for harbour porpoise; therefore, the killer whale threshold will be used, with audiogram-weighting for harbour porpoise applied. This is considered to be a conservative approach as it results in a larger predicted area of potential behavioural effects to harbour porpoise than would be predicted using the NOAA criteria. NOAA thresholds will be used for all other species. Acoustic modelling was used to assess behavioural effects on marine mammals from shipping, berthing, and pile installation.

13.5.5.1.2 Behavioural Thresholds for Fish

While the Fisheries Hydroacoustic Working Group has developed an interim criterion for the onset of physiological (injury) effects of pile driving on fish (FHWG 2008) (see Section 13.5.4.1), there are no comparable thresholds for effects of underwater noise on fish behaviour. Behavioural changes have been reported for some species (e.g., rockfish) at relatively low received levels for pulsed noise (i.e., 160 dB re: 1 µPa; McCauley et al. 2000) whereas other species (e.g., cod) have returned to normal behaviours within seconds, following much louder levels (i.e., pulses exceeding 200 dB re: 1 µPa; Wardle et al. 2001). In laboratory experiments, herring have shown startle responses (50% reaction threshold) at received levels of between approximately 160 and 180 dB re: 1 µPa (4 kHz pure tone); however, this was highly dependent on the frequency of the acoustic signal, as no reaction was observed even at the maximum received levels that could be produced for 15 of the 17 tested frequencies (Kastelein et al. 2008). Researchers warn against extrapolating results of anthropogenic sound across contexts or different species of fish (Popper and Hastings 2009). Thus, while it is recognized that fish species, and even individuals, may respond differently to underwater noise of different types and frequencies, the lack of scientific criteria identifying behavioural response levels limits the ability to conduct a quantitative assessment of change in behaviour, or to predict effects at the species level. This means that widely-applicable (i.e., across diverse species groups) behavioural thresholds for fish are not available. Therefore, the assessment of behavioural effects on fish is qualitative in nature and is based on available literature.

13.5.5.2 Mitigation

Several of the mitigation measures recommended in Section 13.5.4.2 for reducing injury will also reduce the potential for behavioural change to fish and marine mammals (e.g., MMO enforcement of an exclusion zone)(see the MMMPP; Appendix G.2 and G.3; and Appendix 1 of Appendix J.8). Use of low noise piling techniques (e.g., vibratory hammers) is the key mitigation measure to prevent injury, but is also expected to reduce the extent of behavioural effects. Low noise pile installation techniques will be the primary method of pile installation due to the depths of soft sediment in the area. Impact pile driving will likely only be used to seat the piles into bedrock. When impact hammers are used, additional mitigations, such as use of a bubble curtain and enforcement of a marine mammal safety zone will be implemented. A bubble curtain will also be used during low noise pile installation, to further reduce the extent over which underwater noise exceeds the behavioural threshold for marine mammals. In addition, if sound levels from blasting or pile installation exceed an SPLrms of 160 dB re 1 µPa at the edge of the marine mammal exclusion zone, these activities will cease and potential additional mitigation measures will be considered in consultation with DFO. Additional details on mitigation measures and underwater noise validation are provided in Section 13.5.4.2. PNW LNG has also begun a series of dedicated vessel-based line transect surveys to estimate relative abundance of marine mammal species in the PDA and LAA, prior to the start of construction, during construction, during operations, and during decommissioning. The results of the marine mammal surveys will be analyzed to assess periods of elevated usage/presence, and to confirm that appropriate mitigation measures are implemented to reduce the potential for change in behaviour. Additional details concerning these surveys are provided in Section 13.7.

Vessels will transit to and from the pilot station at reduced speeds to diminish the amount of underwater noise (and the likelihood of serious injury to large cetaceans from a vessel strike; see Accidents and Malfunctions, marine mammal vessel strikes, Section 22.8.1.3). The Project will also use tugs with less sediment scour-inducing propulsion systems (e.g., Voith Schneider), which is expected to reduce TSS levels (and any associated avoidance response by adult fish and highly mobile invertebrates), and may reduce underwater noise.

Mitigations include:

- LNG carriers, tugs, and barges will not exceed a speed of 16 knots within the LAA
- LNG carrier vessel speed will be reduced to 6 knots when approaching the Triple Island Pilot Boarding Station.

13.5.5.3 Characterization of Residual Effects

This section describes the potential behavioural responses of fish to increases in TSS and turbidity, sound profiles of key project activities (including modelling results based on threshold exceedances), and the characterization of potential residual effects of underwater noise on marine mammals and fish.

13.5.5.3.1 Fish Behavioural Responses to Increased TSS and Turbidity

During dredging and disposal at sea events, there is potential for adult salmon, halibut and other species to be present in the area, and to be exposed to elevated TSS levels (which will vary for each event and at each location). In areas with high TSS levels, their behaviour may be affected (e.g., they may swim around the area to avoid exposure). Avoidance is expected to be localized and short-term, occurring during and immediately following dredging and disposal events (e.g., lasting for only a few hours after disposal in the deepest locations of Brown Passage). In contrast to pelagic fish species (e.g., salmon, eulachon, and herring), halibut are likely to respond less to increased TSS because of their benthic nature. As groundfish, halibut occupy the nepheloid layers in the water column, the area above the seabed where the amount of suspended sediment tends to be high (Boetius et al. 2000; McCave 1986). They themselves re-suspend sediment when catching overhead prey, digging in the sediment, or rising out of the sediment to shift location. As such, they are likely to respond less to increased TSS compared to other fish species. Halibut can swim both horizontally and vertically, showing strong swimming ability, which would allow avoidance/escape from an area of increased of TSS or to prevent burial. Halibut are likely to avoid areas of high TSS to prevent burial, swimming to nearby areas that have lower levels of TSS. Avoidance responses are expected to be localized and short-term, with fish returning to the affected area as suspended sediments settle to the seafloor.

The approximate relationship between TSS and turbidity as well as the effects of dredging in the MOF area on fish and fish habitat are discussed further in the Technical Memorandum: *Effects of Dredging and Disposal at Sea* submitted June 24, 2014. The effect of change in turbidity on foraging ability of fish to find food is addressed here within the context of the assessment of TSS effects (i.e., elevated turbidity and TSS levels will both occur in the same locations during dredging). As noted in modelling of the TSS plumes, concentrations will be higher than water quality guidelines within the active work area (defined in Section 13.5.2) and, through use of mitigation measures such as silt curtains, will meet guidelines outside of the active work area. The elevated turbidity levels are expected to affect fish foraging to some extent, however, fish will be able to move away from turbid water. Furthermore, while adult fish and highly mobile invertebrates may exhibit avoidance responses in areas with elevated TSS and turbidity, this behavioural response may act to reduce the potential for injury or mortality (see Section 13.5.4) and with the implementation of mitigation measures for changes in sediment or water quality (Section 13.5.2.2), avoidance is expected to be localized and temporary.

This area already experiences extended periods of elevated TSS during the Skeena River spring freshet and throughout the year. The naturally high turbidity and TSS levels within these adjacent coastal waters mean that potential effects of suspended sediment plumes will likely be of little concern for marine mammals and no changes in behaviour are expected.

13.5.5.3.2 Sound Profiles of Project Activities

It is anticipated that sound produced during various phases of the Project will exceed behavioural thresholds for marine mammals. Table 13-15 summarizes areas of behavioural threshold exceedances for modelled project activities (see Appendix N of the EIS). Activities exceeding behavioural thresholds are impact and vibratory pile installation (with and without bubble curtains), berthing, and transit of tanker (assuming two accompanying tugs) in deep (approximately 20 m) and shallow (approximately 1 m) areas. A detailed assessment of the effects to fish and marine mammals (species-specific) is provided below, according to each project phase.

Table 13-15 Threshold Radii for NOAA1 Behavioural Response for Pulse and Non-pulse Sources and Northern Resident Killer Whale Thresholds[2] for Non-pulse Sources

Location	Activity	Pulse Sources (all species) 160 dB re 1 µPa SPLRMS	Non-pulse Sources (all species) 120 dB re 1 µPa SPLRMS	Harbour Porpoise 57 dB re HT	Killer Whale 57 dB re HT
Deep scenario	Impact pile driving (bubble curtain)	1.0 km	-	-	-
	Vibratory (bubble curtain)	-	3.2 km	2.4 km	4.5 km
	Berthing (2 tugs)	-	15 km	4.3 km	11 km
	Berthing (4 tugs)	-	18 km	5.6 km	15 km
Shallow scenario	Impact pile driving (bubble curtain)	0.94 km	-	-	-
	Vibratory (bubble curtain)	-	3.6 km	5.3 km	15 km
MOF	Impact pile driving (bubble curtain)	0.61 km	-	-	-
	Vibratory (without bubble curtain)		0.81 km	0.75 km	0.77 km
	Vibratory (bubble curtain)	-	0.70 km	0.70 km	0.71 km
Vessel Transit	Shallow –12 knots (2 tugs)	-	10 km	3.2 km	9.9 km
	Shallow – 9 knots (2 tugs)	-	3.4 km	1.1 km	2.3 km
	Deep –12 knots (2 tugs)	-	8.9 km	3.3 km	10 km
	Deep – 9 knots (2 tugs)	-	2.2 km	0.56 km	2.3 km

NOTES:
Source: Appendix N of the EIS.
[1] Federal Register (2005).
[2] Harbour porpoise thresholds based on northern resident killer whale thresholds developed by MacGillivray et al. (2012) and accounting for differences in harbour porpoise audiograms.

13.5.5.3.2.1 Construction

Although a vibratory hammer with bubble curtain will be used for pile installation whenever feasible (except at the MOF where a bubble curtain results in only a small reduction in underwater sound), during this activity all species may still exhibit behavioural responses within a radius ranging from 0.75 to 3.2 km from the sound source, based on NOAA broadband thresholds (non-species specific) (see Table 13-12). The predicted harbour porpoise and killer whale audiogram-weighted levels for the onset of behavioural response (57 dB re HT) (MacGillivray et al. 2012) are exceeded at all three modelled locations (MOF, deep, and shallow-water scenarios). Maximum radius exceedances during construction are predicted for vibratory pile installation with bubble curtain when it occurs at the shallow scenario (jetty-trestle); sound levels above the behavioural response threshold (relative to species-specific hearing thresholds) extend 5.3 km for harbour porpoise and 15 km for killer whale (see Table 13-15). Within these areas of ensonification, behaviour of marine mammals could be affected during pile installation activities; this is anticipated to occur for approximately three years.

In the rare case that impact pile drivers may be used, the NOAA behavioural threshold of 160 dB re 1 µPa will be exceeded, with or without a bubble curtain. Model results show the threshold is exceeded over smaller areas compared to exceedances for vibratory pile installation. However, it is important to note that the predicted extent of exceedances for pulse and non-pulse sounds are not comparable as they are calculated differently and based on different threshold values. Continuous impact pile driving (not possible to calculate) would exceed thresholds over areas greater than the vibratory hammer if metrics were comparable.

Sound levels produced during dredging tend to be strongest at low frequencies and are typically less than those produced by impact pile driving and blasting (Richardson et al. 1995; Thomsen et al. 2009). Underwater noise produced during dredging is characterised by a cacophonic mix of tones owing to the variety of dredging-associated sound sources (CEDA 2011). Other noises associated with dredging include those stemming from support vessels, including engine and mechanical sounds, propeller cavitation, and deposition of dredge material onto barges (CEDA 2011). Underwater noise from dredging was not modelled because sound source levels are not expected to exceed those produced by pile installation. Based on the project changes, it is highly unlikely that pile installation and dredging would occur concurrently at the MOF; however, construction activities at the MOF will overlap with the initial stages of construction for the marine terminal (i.e., tower foundations and anchor block), resulting in some overlap of underwater noise, and causing behavioural effects within both areas at the same time. Should pile installation and dredging indeed be determined to overlap temporally, modelling of the combined acoustic footprint will be undertaken in advance of these activities and appropriate and feasible mitigations will be determined through consultation with DFO as part of the permitting phase and in consideration of results of the model.

Shipping associated with disposal at sea will result in underwater noise that could affect the behaviour of marine mammals. Dredging and disposal of dredged material at sea from the MOF are expected to occur over six months, with one trip every 18 hours to the disposal site at Brown Passage during a portion of the six month period. Barge capacity is expected to be 3,000 m^3, and will require approximately 85 one-way trips of barges and assisting tugs to ship up to 200,000 m^3 of dredge material. It is unlikely that barge and assisting tug speeds will exceed those of LNG carriers used during operations.

Modelling results for LNG carriers can provide conservative estimates for the effects of construction-based vessel activities due to the anticipated slower vessel speeds and smaller sizes of vessels associated with transportation of construction materials. Effects of construction-based vessel movement are expected to be of equal or lesser magnitude to those of operational shipping.

13.5.5.3.2.2 Operations

Approximately 350 LNG carriers will arrive at the marine terminal each year (in Phase 2 of the Project) for at least 30 years. LNG carriers will follow the policies and procedures of the PRPA as well as Transport Canada's rules and regulations, as they travel though the LAA between the marine terminal and the Triple Island Pilot Boarding Station (accompanied by one escort tug during both inbound and outbound transits). At full build-out, one LNG carrier per day is expected to call on the marine terminal. Berthing will involve the LNG carrier and up to four tugs. Site decommissioning and clean-up will also require use of vessels.

While sound levels produced by project-related vessels are not predicted to exceed auditory injury levels, underwater noise from movement and berthing of LNG carriers is predicted to result in changes in behaviour to marine mammals. Underwater noise that exceeds behavioural thresholds could affect localized distributions and communication of marine mammals over the short-term (as potential exposure to the passing vessel will be transient in nature). During operations, LNG carriers will dock at the berths offshore from Lelu Island. During transit to the marine terminal, LNG carriers will travel at speeds of approximately 19 knots outside the LAA, decelerating on the approach to Triple Island to 4 knots for pilot embarkation. LNG carriers, tugs, and barges will not exceed a speed of 16 knots within the LAA. Figure 13-11 provides an overview of the predicted LNG carrier speeds along the 22 nautical mile primary southern shipping route within the LAA. LNG departures from the marine terminal will follow the same process as arrivals, only in reverse. The facility will function year round, meaning that shipping activity will be consistent throughout the year. Approximately one LNG carrier will berth at the marine terminal every two days initially, increasing to one carrier per day (i.e., 350 per year). Three potential shipping routes will be used (see Figure 13-1). The Project will also use Voith Schneider tugs, which may reduce underwater noise.

Acoustic modelling included two vessel speeds, 12 and 9 knots, at two representative depths (one at approximately 20 m and one at approximately 1 m) (Appendix N of the EIS). Results show that a reduction from 12 to 9 knots results in a reduction in the behavioural disturbance radius from 7.2 km (at 12 knots) to 1.7 km (at 9 knots), in the deep water scenario. Vessel speeds greater than 12 knots are expected to result in an increase in noise and a larger area of disturbance compared to the modelled speed of 12 knots. Speeds exceeding 12 knots are expected to occur within a portion of the LAA for short periods of time between Triple Island and the Kinahan Islands during the total transit time of approximately 1.5 hours (assuming an average speed of 12 knots). The reduction in vessel speed to 6 knots at the Triple Island Pilot Boarding Station will reduce effects of underwater noise, particularly for humpback whales that are present in this area (and likely feeding) from May through October.

Acoustic model inputs used a surrogate vessel, representing the closest ship class for which source level measurements were available (Appendix N of the EIS). At vessel speeds of 12 knots, NOAA behavioural disturbance thresholds for cetaceans and pinnipeds (120 dBRMS re: 1 µPa) are exceeded over a radius of 18 km during carrier berthing and over radii of 10 km and 8.9 km when transiting at 12 knots in shallow and deep waters, respectively.

Predicted behavioural thresholds for killer whales are exceeded over a distance of 15 km for subtle avoidance effects (57 dB re HT) during berthing operations. In transit, subtle avoidance was predicted at 9.9 km and 10 km from the source, in shallow and deep water, respectively (see Appendix N of the EIS). Behavioural exceedances for harbour porpoise are expected over shorter distances from the sound source than for killer whale (see Table 13-15).

Behavioural responses of marine mammals to shipping noise could be similar to those detailed for construction-related noises; potentially resulting in temporary avoidance of ensonified areas. Effects of shipping noise are expected to ensonify areas over the short term while transiting to the berth (approximately 1.5 hours at average speeds of 12 knots between Triple Island and the marine berth), potentially causing temporary displacement or habitat avoidance (Morton and Symonds 2002; Southall et al. 2007). Highly mobile species such as killer whales could encounter the transiting vessel more than once. Vessel berthing will result in an ensonified area exceeding behavioural thresholds within a radius of 15 km; however, this is expected to be a short-term effect occurring over a maximum of one to two hours per day during berthing, depending on weather conditions.

13.5.5.3.2.3 Decommissioning

Decommissioning activities that could alter fish and marine mammal behaviour are those that produce underwater noise above behavioural thresholds. These include dismantling of marine-based structures (if relevant) and associated vessel movement. Underwater noise produced by vessels involved in decommissioning activities is expected to be comparable to that of operational activities. Decommissioning will occur over a shorter time (i.e., limited to the period required to transport materials off the island), with vessels of smaller capacity, length, and transit frequency than the LNG carriers. The effects of behavioural change for fish and marine mammals during decommissioning are, therefore, likely to be of lower magnitude than those considered for shipping during the operations phase.

13.5.5.3.3 Effects on Fish

There is potential for fish to react to construction noises; however, if such reactions occur, they are likely to be spatially and temporally limited. Species of importance to CRA fisheries most likely to be affected by underwater noise from construction are migrating salmon and eulachon. The few studies on salmonid responses to underwater noise indicate extensive variability across species (Nedwell et al. 2006). Salmon may show local avoidance of particularly noisy zones (Feist et al. 1996), but this reaction is expected to be limited in spatial extent, short-lived, and unlikely to affect feeding ability or overall population well-being (Nedwell et al. 2006). These observations are likely attributed to the fact that salmon are hearing generalists and, therefore, are relatively insensitive to underwater noise levels. As a point of comparison, the Strait of Georgia, encompassing the Fraser River estuary (which boasts BC's largest salmon runs), has experienced rapid increases in coastal development and shipping traffic; yet the noise produced by associated activities has not been linked to changes in salmon migrating in and out of the Fraser River (Marmorek et al. 2011). Although lack of evidence does not constitute evidence of no effect, this observation suggests that salmon may be tolerant to changes in their acoustic environment relative to other potential stressors.

Most herring spawning occurs further away from the PDA, north of Digby Island and north of Porcher Island (see Appendix M of the EIS, Figure 7). Juvenile herring may be found in the LAA following spawning, potentially using Flora Bank and other eelgrass beds in the region for rearing. One deceased herring was observed in the eelgrass beds that were delineated during foreshore surveys near the jetty-trestle abutment. No herring spawning areas have been identified on Lelu Island or Flora Bank, but because juvenile and adult herring use nearshore habitats in this area, it is conservatively assumed they will be present, and mitigation measures are designed accordingly. For example, sensitive life history periods for herring are identified in Table 13-6, and these are addressed by restricting blasting to DFO's least-risk timing window (exact dates of which will be determined based on pre-construction field surveys and in consultation with DFO [See Section 13.7]). The mitigation measures (e.g., use of low noise piling techniques, paired with bubble curtains) will be implemented to reduce potential behavioural effects on all species of marine fish, including herring, as well as salmon and other species of commercial, recreational or Aboriginal (CRA) importance.

Rockfish, lingcod, and Pacific cod (Gadidae) could also be affected, but are generally found further offshore, away from the construction area. The most common reaction is expected to be a short-lived startle response by fish near the onset of pulse noises (e.g., in close proximity to a pile during impact driving); however, normal behaviour is likely to resume within seconds (sensu Wardle et al. 2001). Some species may also move away from particularly noisy areas (Thomsen et al. 2012), but such reactions are expected to be minimal beyond 500 m of sound sources.

13.5.5.3.4 Effects on Marine Mammals

During construction, and after mitigation, pile installation is expected to result in potential residual effects to marine mammals over distances of up to 15 km over a three-year schedule. Shipping and berthing during operations could also affect species' behaviours. Harbour porpoise are expected to experience residual effects to behaviour from underwater noise as they frequent the area year-round. Harbour porpoise are listed as *special concern* under SARA and are an important prey species for Bigg's killer whales. Effects on killer whales are also of concern, given their known occurrence in the area of behavioural threshold exceedance and their *SARA* status of *threatened*. Effects on Loughlin's northern sea lion are also discussed as they are a species of s*pecial concern* under SARA and could experience effects of underwater noise. Effects to harbour seal are expected to be similar to those incurred to Loughlin's northern seal lion.

Dall's porpoise are also common in the LAA; however, fewer studies have been conducted on their sensitivity to noise. Dall's porpoise are attracted to vessels and are often seen wake-riding and therefore are not expected to demonstrate behavioural effects from shipping. Effects of pile installation on this species are not well known and can be inferred from the assessment of harbour porpoise, as a conservative measure. Effects on Pacific white-sided dolphin can also be conservatively inferred from those to Harbour porpoise. Effects on other baleen whales that are observed less frequently in the LAA (fin whale, minke whale, grey whale) can be inferred from the effects to humpback whale, as a conservative measure.

13.5.5.3.4.1 Harbour Porpoise

Harbour porpoises are marine predators known to inhabit waters within the LAA and RAA Common prey species of harbour porpoise include Pacific herring, Pacific hake, smelt and cephalopods, particularly the opalescent squid (COSEWIC 2003).

It is conservatively assumed that harbour porpoises could avoid the LAA/RAA during project construction due to increased underwater noise. Previous studies of harbour porpoise responses (Brandt et al. 2011; Kastelein et al. 2011; Lucke et al. 2011) indicate that impact pile driving is likely to result in avoidance of areas of habitat for harbour porpoise within behavioural threshold exceedance zones. According to acoustic modelling results, areas of avoidance may occur within Porpoise Channel and a portion of Prince Rupert Harbour where several harbour porpoise observations have been made (see Appendix M of the EIS, Figure 7).

Acoustic modelling suggests that behavioural responses of harbour porpoise from LNG carrier berthing or vibratory pile installation using a bubble curtain will occur over distances of up to 5.6 km (see Table 13-15), based on the northern resident killer whale criteria determined by MacGillivray et al. (2012). Threshold-exceeding underwater sounds at the marine terminal and MOF will reach areas that are frequented by harbour porpoise, particularly at the MOF where pile installation may result in behavioural responses throughout Porpoise Channel regardless of whether an impact (with bubble curtain) or vibratory hammer is used (see Table 13-15). Under the worst case scenario, harbour porpoise may be displaced from the construction area for the entire 3-year construction period over a distance of 5.3 km. The actual reactions of marine mammals are difficult to predict and depend on many variables including the type, magnitude and duration of noise, the species and its distance from the sound source, and the activity state of the animal at the time (Richardson et al. 1995). Harbour porpoise have shown marked differences in degrees of response to similar disturbances (e.g., pile driving at different offshore wind farms; Teilmann and Carstensen (2012)).

The anticipated change in fish behaviour as a result of project construction is assumed to include temporary movements (i.e., startle responses) that are short-term in duration and localized to within 500 meters of the in-water construction activity. Because the prey species of harbour porpoise are anticipated to remain in the general area during construction and operations, avoidance of the RAA by harbour porpoises may result in less predation on common prey species, including Pacific herring.

Although abundance and population trends of harbour porpoise in the area are largely unknown, estimates by Best and Halpin (2011) indicate there are 2,806 to 3,647 individuals in the Queen Charlotte Basin (refer to Table 13-14), with high densities around Prince Rupert, the southern portion of Chatham Sound and a very large area of Hecate Strait. This suggests that, under the worst case scenario, if harbour porpoises are displaced for 3 years over a maximum distance of 5.3 km due to pile installation (see Table 13-14), they will have other suitable habitat available to them in the immediate vicinity. Therefore, potential changes in harbour porpoise behaviour attributed to project construction are not expected to affect the viability of the population.

13.5.5.3.4.2 Bigg's and Northern Resident Killer Whales

Bigg's and northern resident killer whales are also known residents of the LAA/RAA, though their home range is quite extensive. Bigg's killer whales prey on harbour porpoise and other marine mammals, while northern resident killer whales are fish eaters, focusing primarily on chinook salmon. Underwater noise from project-related activities may cause these predatory species to avoid portions of the LAA/RAA, particularly during construction. The killer whale behavioural response threshold will be exceeded over a maximum radius of 15 km (for the subtle response threshold of 57 dB re: HT) during vibratory pile installation at the jetty-trestle. Because harbour porpoise and other marine mammals in the LAA are important prey species for Bigg's killer whale; potential displacement of these species during pile installation could indirectly result in displacement of Bigg's killer whale. However, given the relatively small spatial scale of potential effects relative to the habitat area used by these species, effects on predator-prey relationships are expected to be negligible. While the Project may affect localized distributions of killer whales over the short-term, it is not expected to affect the population viability of either of these species.

The LAA has not been identified as critical habitat or a DFO Important Area for killer whales (DFO 2008). Recent scientific advice from DFO has indicated that waters within 3 nautical miles of Pacific coast are necessary habitat to meet the recovery objectives for Bigg's killer whale (DFO 2013j). Anthropogenic acoustic disturbance is considered an activity that could delay the recovery of this species but this is dependent upon the geographic extent, duration, and intensity of the activity (DFO 2013j). Although killer whales might exhibit behavioural response over large areas of the LAA as a result of project activities, this will occur mainly during pile installation over three years, which is a short-term effect relative to the operations phase of the Project, and the type of behavioural response is uncertain. It is not anticipated that this will have an effect on the viability of either killer whale population. The area predicted to be ensonified has similar population density to other areas in the Queen Charlotte Basin (refer to Table 13-14); therefore, it is expected that other habitats can be utilized during the construction period.

13.5.5.3.4.3 Humpback Whale

DFO classifies potential adverse effects on humpback whale in terms of risk. The risk of effects on habitat are deemed low to moderate, depending on the confinement of the habitat (i.e., fjords and narrow channels where sound dissipation is restricted would result in higher risk) (DFO 2013k). The LAA is open to Chatham Sound and acoustic disturbance is, therefore, a relatively lower risk than in other areas. Based on repeat sightings of individual humpback whales observed within 100 km of each other over multiple years (Ford et al. 2009) and limited interchange between feeding areas (Calambokidis et al. 2008), humpback whales may exhibit site fidelity and may be slow to re-colonize areas (DFO 2013k). The Triple Island area contains a high concentration of humpback whale sightings relative to the rest of the LAA and could be a feeding area (see Appendix M of the EIS, Figure 6). Modelling results indicate the humpback whales could experience behavioural responses over a radius of 8.9 km at the Triple Island area during shipping and over 18 km during berthing with 4 tugs (Table 13-15); however, behavioural response of humpback whale to underwater noise is not well understood. A study by Borggaard et al. (1999) indicates that humpback whales show some tolerance to frequent vessel traffic and are more affected by blasting and continuous dredging, with decreased return rates to feeding grounds as a long-term effect of blasting. Todd et al. (1996) suggest that low-frequency sounds did not result in obvious behavioural responses to humpback whales but that blasting may have led to increased entanglement of humpback whales in fishing gear. As indicated in Table 13-14, humpback whales are concentrated outside the LAA and, therefore, it is expected that population viability would remain unaffected by project activities.

13.5.5.3.4.4 Loughlin's Northern Sea Lion

Acoustic disturbance may affect Loughlin's northern sea lion (eastern Pacific sub-species of the Steller sea lion) habitat use (i.e., displacement from feeding areas), foraging success, and limit the availability of prey, potentially resulting in decreased reproductive rates (DFO 2010b). However, these effects are of primary concern near rookeries (i.e., breeding areas) and acoustic disturbance is considered a low concern for Loughlin's sea lion when in aquatic habitat, according to the *SARA* management plan for the species. The management plan classifies the severity of threat from disturbance at the population-level as "likely low", and this species is described as being able to habituate to chronic disturbances (DFO 2010a).

13.5.5.3.4.5 Summary

Project-related underwater noise constitutes multiple regular events during pile installation, dredging, and blasting in the construction phase and is continuous during shipping activities in the operations phase. Marine mammals and fish are expected to have moderate to high resilience to underwater noise from project-related shipping activities, given the relatively low source levels and the high volume of vessel traffic that currently exists within the LAA. Resilience to pile installation is expected to be low to moderate, given the relatively high source levels and the duration of this activity (approximately 3 years).

Based on implementation of the mitigation measures, it is expected that the residual effects of project-related underwater noise on fish and marine mammal behaviour during construction and operations will be moderate in magnitude, medium (construction) to long-term (operations) in duration, limited to the LAA, and reversible. Residual effects of project-related underwater noise on fish and marine mammal behaviour during decommissioning are predicted to be low in magnitude, short-term in duration occurring over multiple regular events, limited to the LAA, and reversible within a context of moderate ecological resilience. Based on density estimates from Best and Halpin (2011), it is concluded that potential behavioural effects will not affect the long-term viability of harbour porpoise, killer whale, or other marine mammal populations in the Queen Charlotte Basin.

13.5.5.4 Likelihood

The likelihood of a residual effect on marine mammal and fish behaviour is high. Although behaviour will likely be affected by underwater noise associated with project construction and operations (shipping), this is not expected to affect population viability.

13.5.5.5 Determination of Significance of Residual Effects

It is anticipated that underwater noise produced during shipping operations will exceed behavioural thresholds for marine mammals, including for SARA-listed species, such as humpback whales, northern resident killer whales and harbour porpoises. The residual project-related effects of this increase in underwater noise could affect localized distributions and communication of these species over the short-term (since potential exposure to a passing vessel will be transient in nature). Behavioural thresholds do not exist for marine fish; however, effects are expected to be limited to temporary startle responses.

Studies of harbour porpoise responses to industrial activities (Brandt et al. 2011; Kastelein et al. 2012b; Lucke et al. 2011) indicate that pile installation is likely to result in temporary avoidance of areas within behavioural threshold exceedance zones. Behavioural effects from underwater noise are expected to be more prominent during the construction phase compared to operations, as in-water construction activities (e.g., pile installation) are known to produce louder underwater noise levels than operational activities (e.g., vessel movements). Injury is likely to be prevented as a result of avoidance behaviour during construction activities (e.g., pile installation) and animals are expected to return to the area once construction activities cease. The viability of marine mammal and fish populations within in the LAA is not expected to be affected given the relatively localized nature of effects and the population sizes and generally broad-scale distributions of these species.

The significance threshold pertaining to toxicological risks (due to changes in sediment or water quality) is not relevant to the assessment of change in behaviour. The significance threshold pertaining to change in behaviour is defined as “Any residual effect with a high likelihood of affecting population viability of fish or marine mammals (these effects are likely to be of high magnitude and permanent)” (see Section 13.2.7). Based on the implementation of mitigation measures (such as low noise pile installation techniques), the extent of change in behaviour of fish and marine mammals due to project-related underwater noise is not predicted to affect the viability of local populations or result in a high likelihood of mortality to species at risk, and therefore residual effects will be not significant. The level of confidence associated with this significance assessment is moderate. Current understanding of how underwater noise affects marine organisms remains underdeveloped, particularly for marine fish. Nevertheless, the recommended mitigation strategies are conservative and, therefore, likely to reduce the potential residual effects.

Effects of the Project have been assessed for each SARA and COSEWIC-listed species at risk. These species-specific assessments are presented in Appendix F.4.

13.5.5.6 Confidence and Risk

A moderate level of confidence is given to the assessment of residual effects of the Project on behavioural effects. Confidence is not high primarily due to scientific uncertainty over sound levels capable of causing behavioural effects and how marine mammals respond to anthropogenic noise (see Section 13.5.5.6 for further details). This uncertainty is not unique to the Project; there are a limited number of studies that have investigated behavioural responses of marine mammals to underwater noise produced during in-water construction activities and in particular, to noise generated by large vessels such as LNG carriers. Due to this uncertainty, a number of mitigation measures will be applied to minimize potential behavioural disturbance to marine mammals. Since the confidence in this prediction is not low, no additional risk analysis has been conducted.

13.5.6 Summary of Residual Effects

With mitigation and habitat offsetting, the viability of local populations, or the marine species and community assemblages of the LAA are not expected to be compromised by project activities (Table 13-16). Mitigation measures will reduce project changes to sediment and water quality, reduce injury to fish and marine mammals, and reduce behavioural effects from underwater noise. With the implementation of habitat offsetting, the Project is expected to meet DFO's principle of no net-loss of productive capacity of habitat. Overall, residual effects are expected to be low to high in magnitude, short to long-term in duration, local in extent and reversible. Residual effects on marine resources (including fish habitat, direct mortality or physical injury to fish or marine mammals, and change in the behaviour of fish or marine mammals, and sediment and water quality) are expected to be not significant.

Table 13-16 Summary of Residual Effects on Marine Resources

Project Phase	Mitigation/Compensation Measures	Residual Effects Characterization: Context	Magnitude	Extent	Duration	Reversibility	Frequency	Likelihood	Significance	Confidence	Follow-up and Monitoring
Change in Sediment or Water Quality											
Construction	• A 30 m vegetation buffer will be retained around the perimeter of Lelu Island, except at access points • Sediment and erosion control measures will be used (e.g., sediment fences) for land-based construction, particularly at the shoreline, to reduce TSS inputs into water • Dredging will be conducted using methods and/or equipment that reduces sediment spill • TSS and turbidity will be monitored, the rate of the activity will be adjusted, or additional mitigation measures implemented as required • In areas of low to moderate currents (≤ 1 knot), silt curtains will be installed around dredging and blasting activities if monitoring indicates that inferred TSS levels are greater than predicted. Studies suggest that effectiveness of silt curtains is reduced when currents exceed about 1 knot • Dredging will occur at low tide, where possible • Dredged sediment will be disposed of at or near the center point of the Brown Passage disposal site, to minimize effects on water quality outside the site • Tugs with less powerful propulsion systems (Voith Schneider tugs) have been evaluated and will be used.	H	L–M	L	S	R	M	H	N	H	**Follow-up Program:** • Sediment Transport • Marine Country Foods **Monitoring:** • Compliance monitoring required for permits
Operations		H	L–M	L	L	R	C				
Decommissioning and Abandonment		N/A	N/A	N/A	N/A	N/A	N/A				
Residual Effects for All Phases		H	L–M	L	S-L	R	M/C				
Change in Fish Habitat											
Construction	• No offset habitats will be located on Flora Bank and Agnew Bank • Planned scour protection will be placed around tower platform below mud line through use of slightly larger substrate sized materials around the perimeter of tower platform based on 2D and 3D model outputs • Hard multi-facetted shoreline protection material (e.g., rip-rap boulders) will be used where needed (e.g., trestle abutment) to promote colonization by marine biota. • A Habitat Offsetting Plan will be developed and implemented to maintain productivity within the LAA. • Beneficial re-use of rock for fish offsets is being considered and will be determined in consultation with DFO	M	N	L	P	R	S	L	N	M	**Follow-up Program:** • Marine Fish and Fish Habitat • Habitat Offsetting Plan **Monitoring:** • Compliance monitoring required for permits
Operations		M	N	L	P	R	S				
Decommissioning and Abandonment		N/A	N/A	N/A	N/A	N/A	N/A				
Residual Effects for All Phases		M	M	L	P	R	S				

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Project Phase	Mitigation/Compensation Measures	Residual Effects Characterization						Likelihood	Significance	Confidence	Follow-up and Monitoring
		Context	Magnitude	Extent	Duration	Reversibility	Frequency				
Direct Mortality or Physical Injury to Fish or Marine Mammals											
Construction	• A Blasting Management Plan will be implemented • Fisheries and Oceans Canada's Blasting Guidelines will be implemented, including enforcing a safety radius of 500 m, and ensuring marine mammals are not present in the safety radius prior to blasting • Blasting will be conducted within DFO least-risk timing windows (approximately November 30 to February 15); exact dates to be refined based on additional studies and in consultation with DFO • Blasting design will consider measures to reduce overpressure • Dungeness crabs will be relocated from construction zones • In areas of low to moderate currents (≤ 1 knot), silt curtains will be installed around blasting activities if monitoring results indicate • inferred TSS levels will be higher than the WQG outside the active work area • Dredging operations will be conducted using methods and/or equipment that reduces sediment spill • At the disposal site, sediment will be disposed within the previously used disposal area at or near the center point of the disposal site • TSS and turbidity will be monitored, the rate of the activity will be adjusted, or additional mitigation measures implemented as required • A Marine Pile Installation Management Plan will be implemented • Low noise pile installation techniques (i.e., vibratory installation methods) will be used except during seating of some piles into bedrock • In instances when an impact pile driver is required (e.g., during pile seating), bubble curtains with bubble-containment casing will be used and the impact hammer will be constructed of sound absorbent material. To mitigate for behavioural effects, a bubble curtain will also be used during low noise pile installation • In instances when the efficacy of bubble curtains is diminished by high currents, isolation casings that contain bubbles will be used in lieu of bubble curtains • Bubble curtains will be used during pile installation (i.e., vibratory and impact) at the inner MOF. The exact style of bubble curtain and/or casing used will be determined on a case by case basis • If it is determined that pile installation and dredging need to occur simultaneously, potential underwater noise levels will be modelled to inform mitigation measures, and a monitoring program will be developed • A marine mammal observation program will be implemented during pile installation activities.	M	M	P–L	S	R	M	H	N	M	**Monitoring:** • Measure sound levels during pile installation
Operations		M	L	P	L	R	M				
Decommissioning and Abandonment		N/A	N/A	N/A	N/A	N/A	N/A				
Residual Effects for All Phases		M	M	L	L	R	C				

Project Phase	Mitigation/Compensation Measures	Residual Effects Characterization: Context	Magnitude	Extent	Duration	Reversibility	Frequency	Likelihood	Significance	Confidence	Follow-up and Monitoring
Change in Behaviour of Fish or Marine Mammals											
Construction	• Vessels will not exceed a speed of 16 knots within the LAA • LNG carrier vessel speed will be reduced to 6 knots when approaching the Triple Island Pilot Boarding Station.	L–M	M	L	M	R	M	H	N	M	None
Operations		M–H	M	L	L	R	M				
Decommissioning		M	L	L	S	R	M				
Residual Effects for All Phases		L-M	M	L	L	R	M/C				

KEY

Context:

Low resilience (L)—under baseline conditions, marine resources are rarely exposed to anthropogenic effects and are highly sensitive to them; such changes could trigger large and lasting ecological effects.

Moderate resilience (M)—under baseline conditions, marine resources are occasionally exposed to anthropogenic effects and are sensitive to them; such changes trigger small and short-term ecological effects.

High resilience (H)—under baseline conditions, marine resources often experience anthropogenic effects and are unaffected by them; such changes trigger no detectable ecological effects.

Magnitude:

Negligible (N)—no measurable change in fish and marine mammal populations, habitat quality or quantity, or contaminant levels.

Low (L)—a measurable change but within the range of natural variability (change in population levels or contaminant concentrations consistent with baseline levels). Will not affect population viability.

Moderate (M)—measurable change outside the range of natural variability but not posing a risk to population viability.

High (H)—measurable change that exceeds the limits of natural variability and may affect long-term population viability (includes exceedances of toxicological thresholds for sediment and water quality and thresholds for underwater sound levels, considering natural background levels).

Extent:

P—effect is restricted to the PDA.

L—effect is prevalent in the LAA.

Duration:

Short-term (S)—change limited to project construction and decommissioning phases.

Medium-term (M)—change continues for up to two years following construction or decommissioning before returning to baseline condition.

Long-term (L)—change continues for more than two years after construction project phase, or continues during operations project phase.

Permanent (P)—measurable parameter unlikely to return to baseline level.

Reversibility:

Reversible (R)—will recover to baseline conditions after project closure and reclamation.

Irreversible (I)—permanent.

Frequency:

Single event (S)—occurs once.

Multiple regular events (M)—occur often throughout the construction, operations, or decommissioning phase.

Continuous (C)—effect occurs continuously throughout the life of the Project.

Likelihood of Residual Effect:

Based on professional judgment.

L—low probability of occurrence.

M—medium probability of occurrence.

H—high probability of occurrence.

Significance:

S = significant.

N = not significant.

CONFIDENCE

Based on scientific information and statistical analysis, professional judgment and effectiveness of mitigation, and assumptions made.

L—low level of confidence.

M—moderate level of confidence.

H—high level of confidence.

13.6 CUMULATIVE EFFECTS

13.6.1 Context for Cumulative Effects

The RAA contains cold, nutrient-rich waters that create conditions for high primary productivity and support a diversity of habitats and species. The Skeena River provides freshwater input into the RAA, including Flora Bank where an eelgrass bed provides important rearing habitat to many fish species of ecological, economic, and cultural importance (e.g., salmon).

Many marine mammal species are present in the RAA throughout the year, with some species (e.g., northern resident killer whales and humpback whales) having seasonal peaks in abundance. The most common marine mammals found in the RAA year-round are harbour porpoise (*special concern*, SARA) and harbour seals. See Appendix M of the EIS and Section 13.3 for species commonly found in the area.

Past, present, and future activities within the RAA include development of shoreline infrastructure within the PRPA boundary and associated shipping activities along shipping lanes aligned east to west within the RAA. These activities have the potential to cause cumulative adverse effects on the marine environment.

Prince Rupert is considered the land, air, and water transportation hub of BC's north coast, with a population of 12,508 (544 in Port Edward) (Statistics Canada 2012). There are several industrial uses of Prince Rupert Harbour and numerous other economic, recreational, and cultural activities, including Aboriginal, commercial, and recreational fishing. The PRPA 2020 Land Use Management Plan identifies Lelu Island as a potential site for industrial development and recreational uses, and neighbouring Ridley Island as an industrial use site (Prince Rupert Port Authority 2011). There are two existing marine industrial terminals on the northwest side of Ridley Island: Ridley Terminals Inc. (primarily coal storage and shipping) and Prince Rupert Grain Limited, with rail and road access and jetties capable of handling vessels greater than 300 m in length.

Past, existing, and future industrial developments within the RAA that could interact cumulatively with the PNW LNG Project to affect marine resources are listed in Table 13-17. Figure 4-1of the EIS Addendum illustrates the locations of the projects (within the Port Edward area) considered in the cumulative effects assessment. Small-scale human uses of the marine environment, including fishing activity and marine transportation such as Aboriginal, commercial, and recreational fishing boats, eco-tourism operators, and recreational power and sailboats, are not listed in this table.

Table 13-17 Potential Cumulative Effects on Marine Resources

Other Projects and Activities with Potential for Cumulative Effects	Potential Cumulative Effects			
	Change in Sediment or Water Quality	Change in Fish Habitat	Direct Mortality or Physical Injury	Change in Behaviour
Atlin Terminal				✓
Canpotex Potash Export Terminal	✓		✓	✓
CN Rail Line				
Douglas Channel LNG				✓
Enbridge Northern Gateway Project				✓
Fairview Container Terminal Phase I	✓			✓
Fairview Container Terminal Phase II	✓		✓	✓
Kitimat LNG Terminal Project				✓
LNG Canada Project				✓
Mount McDonald Wind Power Project				
NaiKun Wind Energy Project				
Northland Cruise Terminal				✓
Odin Seafood				✓
Pinnacle Pellet Inc.				✓
Prince Rupert LNG Facility	✓		✓	✓
Prince Rupert Gas Transmission Project	✓		✓	✓
Prince Rupert Ferry Terminal				✓
Prince Rupert Industrial Park				
Prince Rupert Grain Limited	✓			✓
Ridley Island Log Sort				
Ridley Terminals Inc.	✓			✓
Rio Tinto Alcan Aluminium Smelter and Modernization Project				✓
WatCo (formerly Skeena Cellulose) Pulp Mill	✓			
Westcoast Connector Gas Transmission Project	✓		✓	✓

NOTES:
✓ = Those 'other projects and activities' whose effects are likely to interact cumulatively with the project residual effects.

13.6.2 Cumulative Effects Assessment

Cumulative effects on marine resources are assessed for each effect defined in Section 13.2.3, using a two-step process. In conducting the cumulative effects assessment, the residual effects arising from interactions that scored either a 1 or a 2 in Table 13-9 are considered. The first step consists of two questions:

- Is there a project residual effect?
- Does the project residual effect overlap spatially and temporally with those of other past, present or reasonably foreseeable future projects?

Where the answers to both of these two questions are affirmative, a check mark in Table 13-17 indicates that there is potential for the Project to contribute to cumulative effects on marine resources. Potential contribution of these project effects to cumulative effects is assessed through the second step, which consists of one question:

- Is there a reasonable expectation that the contribution (i.e., addition) of the project residual effects would cause a change in cumulative effects that could affect the viability or sustainability of the VC?

Negligible residual adverse effects to fish habitats are expected and therefore cumulative effects are not assessed for that effect. The remaining three effects have residual effects that are likely to overlap spatially and temporally with other projects, causing a change in cumulative effects. Each effect is therefore assessed for potential cumulative effects.

Existing projects in the RAA may have resulted in injury or mortality to fish or marine mammals through project works at the time of construction. Because these effects occurred several years ago, local fish and marine mammal populations and communities are expected to have recovered and cumulative effects of these existing projects and the Project are not discussed further. Similarly, existing projects are not expected to affect marine sediment and water quality as they are required to adhere to regulations set out in the *Environmental Management Act* and other regulatory legislation (e.g., *Canada Shipping Act* ballast water release provisions). These projects will, however, affect behaviour of marine mammals as a result of shipping. This is further discussed below.

The assessment of cumulative effects is designed to focus on how residual effects of the Project may or may not act in combination with other past, existing, or reasonably foreseeable projects and activities in the region. Combined effects (e.g., noise from all possible vessel traffic sources in combination with sediment dispersion modelling from all foreseeable projects) differ from cumulative effects of past, present and future projects. Combined effects are assessed by characterizing each effect individually and providing an overall conclusion of significance based on the collective effects (see Section 13.6.3.5).

The cumulative effects assessment for change in behaviour of fish or marine mammals (including from increased vessel traffic) is presented in Section 13.6.2.4. The assessment focuses on species of importance to CRA fisheries, species of conservation concern, and culturally important species. The conclusions of the assessment apply to all marine mammal and fish species (including humpback whales and herring, regardless of whether each individual species is explicitly discussed within this Section). The confidence in the predictions are low to moderate for cumulative effects because overlap of construction schedules (primarily for pile driving) for PNW LNG, Canpotex, and Prince Rupert LNG is not known and detailed engineering information for these projects was not available at the time of writing. Modelled predictions for PNW LNG are conservative and to confirm the assumptions and conclusions presented here, sound source levels will be validated during impact pile driving (with a bubble curtain), if vibratory pile driving is not feasible. Tyack (Tyack 2008) and Dähne (Dähne et al. 2013) noted that the links between short-term behavioural response and population-level effects are currently not clear. However, as discussed above for residual effects, population viability of the marine mammals found in the RAA is not expected to be affected by cumulative effects, given the relatively localized nature of these effects and the population sizes and generally broad-scale distributions of these species.

13.6.2.1 Change in Sediment or Water Quality

Past (non-operational) projects, such as the WatCo Pulp Mill, are not expected to have construction activities that overlap temporally with planned project construction activities. There is legacy sediment contamination (dioxins and furans) associated with effluent from this former pulp mill that overlaps spatially with the project RAA. Effects of these contaminants are already recognized in the baseline conditions, and disturbance associated with project construction has been assessed; therefore, no further cumulative interaction with the Project is anticipated.

Existing (operational) projects (Fairview Container Terminal Phase I, Prince Rupert Grain Limited, Ridley Terminals Inc., and the Westview Terminal at Pinnacle Pellet Inc.) could interact with the Project if they require maintenance dredging in the future. Such dredging events are expected to be infrequent, with localized and short-term increases in turbidity. Although it is possible for such dredging activities to occur during Project construction, there would be no spatial overlap of sediment plumes, given the distance from the Project. Prince Rupert Grain Ltd. and Ridley Terminals Inc. are 3 km away on Ridley Island and the Fairview Container Terminal (Phase I) and the Westview Terminal (Pinnacle Pellet Inc.) are further north on Kaien Island. For these reasons, any incremental effects on water and sediment quality associated with construction activities for the Project are not expected to contribute significantly to cumulative effects from existing projects.

Figure 13-12 gives an overview of potential cumulative water quality effects in terms of the maximum extent of temporal and spatial overlap of TSS plumes from dredging at the MOF, disposal from the Canpotex Project, and trenching and infilling during construction of the PRGT and WCGT pipelines. The maximum extent of TSS displayed for each project is very conservative given that it is an overlay of all modelling results over time, at all water depths. It should be noted that temporal overlap of these projects is unlikely given their current construction schedules.

The proposed pipeline projects (Prince Rupert Gas Transmission Project [PRGT] and Westcoast Connector Gas Transmission Project [WCGT]) include trenching and backfilling for pipeline installation in the shoreline approaches to Prince Rupert. Modelled sediment plumes associated with trenching and infilling were presented in the environmental assessments for both PRGT and WQGT based on currently understood construction methods. The maximum temporal and spatial extent of predicted TSS from these projects (overlays over time, at all water depths) have been summarized on Figure 13-12.

Effects of PRGT construction activities on TSS levels are not expected to overlap spatially or temporally with those of the Project. The TSS plumes modelled for excavation and backfilling of a trench along the proposed PRGT pipeline approach to Lelu Island will remain close to the pipeline corridor, which will extend from Lelu Island on the southeast end of Flora Bank (Figure 13-12; summarized from Stantec Consulting Ltd. (2014), Figure 2) 1.5 km or more away from the plumes predicted for dredging at the MOF. The trenching and backfilling methods used for pipeline installation will result in two to three day periods of localized effects at any given point as equipment moves along the route, not the continuous plume suggested in Figure 13-12. Construction is planned for November 2016 to May 2017, after completion of dredging and blasting for the MOF construction (October 2015 to March 2016).

There is potential for spatial overlap of construction activities for WCGT and the Project. The proposed WCGT Project will require excavation and subsequent backfilling for pipeline installation off the south end of Ridley Island over a five month period. The associated sediment plume has been modelled and identifies a fairly localized TSS plume with maximum TSS of 21 mg/L above background within the active work area (Figure 13-12; summarized from Golder Associates (2014), Appendix A , Figures 2-2 through 2-7 of the EIS). This plume would overlap with that predicted for MOF dredging, should dredging for both projects occur at the same time, and this could result in each project contributing 1 to <5 mg/L TSS above background to a sediment plume. The WCGT construction schedule presented in Golder Associates (2014) indicated pipeline installation between May and September 2015. However, there is uncertainty over the timing of WCGT construction, given that it is linked to decisions required for the connecting Prince Rupert LNG terminal (pipeline construction is not anticipated to proceed until an investment decision is made for the Prince Rupert LNG terminal, which has been delayed until 2016). At this time, any temporal overlap with MOF dredging is considered unlikely.

Proposed marine terminal developments in Prince Rupert include the Prince Rupert LNG Project, Canpotex Potash Export Terminal Project, and Fairview Phase II Expansion Project, any of which could involve sediment disturbance or dredging. These projects are unlikely to have construction effects on water quality that overlap in time or space:

For the proposed Prince Rupert LNG Project on the south end of Ridley Island (linked with the WCGT Pipeline Project), British Gas recently announced that a final investment decision has been delayed until 2016 (Jang 2014, October 29). Construction would not begin until 2017 or later, and would not overlap in space or time with construction of the MOF.

For the Canpotex Project, on Ridley Island about 2 km north of Lelu Island, the application to dispose of up to 411,000 m^3 of sediment at a new disposal site within the PRPA boundaries (the Coast Island Disposal Site, 'Site A'), not at Brown Passage, was obtained on October 14, 2014 (Stantec Consulting Ltd. 2011c). There could be temporal and only limited spatial overlap with MOF dredging: the permit is valid from September 7, 2015 to February 15, 2016. The sediment plume shown in Figure 13-12 indicates maximum TSS plume over the entire Canpotex disposal period; the plume at any given time would be much smaller, given that sediment will be piped from the dredge site to the disposal area, suspended from a support barge or pontoon and moved periodically to ensure sediment is distributed evenly over the disposal site. There will be little potential for spatial overlap of the plumes as the modelled Canpotex plume associated with disposal will largely extend north of Coast Island, away from the plume associated with dredging at the MOF (Figure 13-12; summarized from Stantec 2014b, Item 43).

For Fairview Phase II, dredging of 180,000 m^3 of sediment from a site on Kaien Island 9 km north of Lelu Island, with disposal at the Brown Passage site, is planned for Stage 2 of the expansion project (Stantec Consulting Ltd. 2011d). There would be no spatial overlap of plumes associated with dredging; however, the construction schedule for this multi-year project has not been defined and it is possible that the Brown Passage disposal site could be used for both the Project and the Fairview Project at the same time.

Should there be overlapping disposal activities at Brown Passage for any of these projects, regulatory authorities would likely establish timing windows for each proponent, to avoid an overlap in TSS plumes.

The need or timing for future maintenance dredging for any of the projects other than PNW LNG has not been established. Any future maintenance dredging is expected to be infrequent, with localized and short-term increases in turbidity, and disposal of dredged material in compliance with the Disposal at Sea Regulations. According to Environment Canada records, Brown Passage has not been used for disposal of material associated with maintenance dredging.

In summary, cumulative effects on sediment and water quality are not anticipated because the effects of dredging and disposal activities are not expected to overlap in both time and space, based on currently understood project construction schedules. In the event of a delay in any construction schedule that results in temporal overlap of projects that are shown to have the potential to overlap spatially with construction of the MOF (Figure 13-12), water quality monitoring will be used to inform the application of additional mitigations (i.e., slowed production rate) as necessary to ensure there are no exceedances of the predicted TSS levels outside the active work area. Residual project effects on sediment and water quality include TSS levels higher than the 5 mg/L WQG in the active work area during dredging and disposal; these are expected to be short-term. Sediments are eligible for open water disposal at a non-dispersive site because dioxin and furan concentrations are below the Environment Canada LAL and OMO. Spatial and temporal overlap for sediment disposal at the Brown Passage disposal site could occur if dredging occurs at the same time for the Fairview Terminal Phase II Expansion and the Project, although no construction schedule details are available for the Fairview Project. Mitigation of any cumulative effects associated with disposal of dredge material at Brown Passage could be achieved through scheduling of non-overlapping timing windows for each project.

The project contribution to cumulative effects of change in sediment or water quality is predicted to be not significant. As the effects do not pose toxicological risks to marine biota, will not affect population viability, and are unlikely to result in mortality of species at risk. Construction activities could overlap spatially and temporally with other projects (i.e., Canpotex); however, the Project is unlikely to contribute to these effects in a way that causes toxicological risks to aquatic life, affects the population viability and sustainability of any species of fish or marine mammal, or is likely to result in the mortality of species at risk. Therefore, the project contribution to the cumulative effect of changes in sediment and water quality is predicted to be not significant.

13.6.2.2 Change in Fish Habitat

Through appropriate mitigation and design and implementation of fish habitat offsetting measures, productivity within the LAA will be maintained, resulting in negligible adverse residual effects to fish habitat (see Section 13.5.3.3). A negligible residual effect is defined as no measurable change in fish and marine mammal populations and habitat quality or quantity. As only negligible residual effects are anticipated, there is no overlap spatially and temporally with other past, present, or reasonably foreseeable future projects. As such, an assessment of cumulative effects is not required for change in fish habitat.

13.6.2.3 Direct Mortality or Physical Injury to Fish or Marine Mammals

The Canpotex Potash Export Terminal, Fairview Container Terminal Phase II, Prince Rupert Gas Transmission Project, and Westcoast Connector have the potential to interact cumulatively with the Project for direct mortality or physical injury to fish or marine mammals (see Table 13-17). Construction of the proposed Prince Rupert LNG Project on the south end of Ridley Island (linked with the WCGT Pipeline Project) would not begin until 2017 or later, and therefore would not overlap in space or time with construction of the MOF.

Some invertebrates and/or sedentary or slow moving fish are likely to be killed by construction activities involving blasting, dredging, excavation, pile installation, and disposal at sea, with mortality confined to the immediate area of these activities. This is not expected to have an effect on the long-term viability of populations of these species. The affected species and community types are locally abundant in the RAA and are likely to recolonize and recover via the creation of productive offsetting habitat.

Ensonified areas from project construction activities (pile installation and blasting) are likely to overlap spatially and temporally with other construction activities for the Project (e.g., blasting at the MOF coupled with tower foundations for the marine terminal) or those of the Canpotex Project on Ridley Island.

It is most likely that a vibratory hammer will be used for pile installation for the Project; however, if an impact hammer is required (with use of a bubble curtain to reduce underwater noise) some marine mammals, primarily harbour seal, could be exposed to sound levels capable of causing permanent auditory damage. Injury to harbour porpoises and other species of marine mammal is possible but not likely given the mitigation measures.

Concurrent pile installation from multiple projects will result in a larger area of injury potential, especially if both projects (i.e., the Project and the Canpotex Project) have temporal overlap; however, the duration and degree of overlap is uncertain at this time. It is presumed that other projects requiring the installation of in-water piles will employ a vibratory hammer wherever possible. Given the abundance of soft sediment in the area, it is likely that a vibratory hammer can be used at most, if not all, locations for construction of the Project. Project mitigation measures, namely use of vibratory hammer and bubble curtains, are expected to substantially reduce the potential for injury to marine mammals and thus the potential for overlapping effects from other pile installation or blasting activities associated with other projects. It is presumed that other marine projects recently permitted will also be required to mitigate potentially injurious levels of noise from their projects. If using an impact hammer with a bubble curtain is the only viable option for one or more projects, the potential for injury to marine mammals will increase and a greater number of individuals could be affected, including harbour porpoise, which is listed under SARA as *Special Concern*.

In summary, the Project will result in residual effects to fish and marine mammals that are not significant as they do not pose toxicological risks to marine biota, will not affect population viability, and are unlikely to result in mortality of species at risk. Construction activities could overlap spatially and temporally with other projects (i.e., Canpotex); however, the Project is unlikely to contribute to these effects in a way that causes toxicological risks to aquatic life, affects the population viability and sustainability of any species of fish or marine mammal, or is likely to result in the mortality of species at risk. Therefore, the project contribution to the cumulative effect of direct mortality or physical injury to fish or marine mammals is predicted to be not significant.

13.6.2.4 Change in Behaviour of Fish or Marine Mammals

Of the 20 projects in the RAA, 17 could cumulatively add to the residual effects of the Project on change in behavior of fish or marine mammals (see Table 13-17). Given the likelihood of overlapping timelines between several projects, there will be overlap of underwater noise during construction and operations phases. This is expected to increase the spatial extent of behavioural effects; however, the spatial extent of underwater noise from reasonably foreseeable projects is not known. The zone of behavioural avoidance will vary depending on the species, the source level and frequency of activity for each project, and the degree of overlap with zones of ensonification from other projects. Noise from pile installation, whether vibratory or impact, is expected to last for approximately three years and will potentially overlap with marine construction noise from Canpotex, increasing the magnitude and extent of this effect.

Noise from shipping is likely to act cumulatively with existing and proposed projects during construction (i.e., material shipping, disposal at sea), operations (shipping LNG and other products), and decommissioning (i.e., shipping materials) as timelines for the reasonably foreseeable projects align closely with the Project. At full build-out of the Project, up to 350 LNG carriers will berth at the marine terminal per year.

The PRPA plans to increase annual shipping from 1,000 to 2,000 ships (4,000 movements) by 2025 (PRPA 2013). This includes all projects listed in Table 13-17 that have a shipping component. All shipping traffic into both the Prince Rupert Harbour and Kitimat will follow shipping lanes around Triple Island where overlapping of underwater noise could result in a larger area where behavioural effects (e.g., potential avoidance or masking) could occur. Not included in this number are tugs, ferries, water taxis, cruise ships, fishing vessels, recreational vessels, and other vessels that also contribute to underwater noise in the RAA. Development of the Project is expected to increase large vessel traffic by 35% at full build out based on current PRPA numbers of 1,000 vessel transits per year. The Project is expected to represent 17.5% of the total annual large vessel traffic in the area once total traffic has increased to 2,000 vessels per year.

Shipping is expected to result in only a temporary increase in underwater noise at a given location, resulting in potential behavioural effects for less than half an hour with the passing of each individual vessel. However, cumulatively, an increase in traffic levels will increase the duration over which the RAA is ensonified, potentially causing longer term avoidance of high traffic areas by marine mammals. Masking could also occur as a result of cumulative increases in traffic, potentially affecting the ability of marine mammals to find prey or communicate. A recent study by Williams et al. (2013) demonstrated that current underwater noise levels at Triple Island have resulted in a loss of communication space for killer whales, potentially reducing the distance over which they are able to communicate.

Cumulative effects of vessel berthing would occur from spatial and temporal overlap from the Project, Prince Rupert LNG, and Canpotex, potentially resulting in larger ensonified areas than what is predicted for PNW LNG alone. Since berthing-related vessel movement is temporary, occurring over no more than a few hours per vessel, temporal overlap is expected to be minimal as PRPA will likely stagger arrivals and departures of large vessels operating within the general area. However, the number of hours of underwater noise per day is likely to increase as a result of increased numbers of vessels berthing in the RAA.

Marine mammals are most likely to experience residual behavioural effects from underwater noise during pile installation, but also from shipping and berthing to a lesser extent. Effects include potential for localized avoidance of these areas for the duration of the construction phase for the Project (i.e., 3 years) and temporary displacement during shipping and berthing (approximately two hours). Effects are expected to overlap spatially and temporally with other projects, which could act cumulatively to affect behavior over larger areas and for longer durations, particularly during construction. The Project is expected to contribute to cumulative effects causing changes in behaviour to fish and marine mammals, particularly harbour porpoise during the construction phase. However, these effects are not likely to result in mortality to species at risk and are not expected to affect population viability of any marine species, given the large geographic ranges of those species likely to be affected. For example, the range of harbour porpoise spans most of southern Chatham Sound as well as a large area in Hecate Strait (Best and Halpin 2011). Therefore, the project contribution to the cumulative effect of change in behaviour of fish or marine mammals is predicted to be not significant.

13.6.2.5 Summary of Cumulative Effects

Cumulative effects to sediment quality are not anticipated due to lack of both temporal and spatial overlap of dredging and disposal activities; however, cumulative effects to water quality are likely to occur if there is any spatial and temporal overlap of dredging and disposal of marine sediment for other reasonably foreseeable projects. The only project this has been identified for is the Fairview Phase II Expansion, if disposal of sediment at the Brown Passage site occurs at the same time as the Project ; however, no scheduling information is available for the Fairview Phase II Expansion). Mitigating these cumulative effects by appropriate scheduling of dredging and disposal at sea make this effect not significant.

Cumulative effects on direct mortality or physical injury are expected to be moderate in magnitude, due to potential increases in injury to marine mammals caused by overlap in pile installation schedules with other reasonably foreseeable projects. This is not expected to have an effect on population viability and is therefore predicted to be not significant. In addition, underwater noise from pile installation might deter marine mammals from the area before injury occurs.

Pile installation, shipping, and berthing will act cumulatively with other projects, increasing the spatial extent over which marine mammal behaviour could be affected. Marine mammals, namely harbour seals, harbour porpoise, and killer whales, could experience behavioural effects over larger areas and for longer periods of time as a result of concurrent construction and operations activities. These effects are not expected to affect population viability due to the large area of available habitat (see Section 13.5.4.3) and are therefore predicted to be not significant.

Confidence in the conclusions for cumulative effects of direct mortality or physical injury to fish and marine mammals has been considered at numerous scales. Confidence in the cumulative assessment of injury or mortality from crushing or burial and from blasting is moderate, for similar reasons to residual effects. While this effect will act cumulatively with construction effects of other projects, it is assumed that other projects will implement similarly effective mitigation measures, the spatial scale and number of organisms affected will remain limited, and no effects on population viability are expected. Prediction confidence has been rated as low to moderate for cumulative effects of noise with respect to the population-level response of marine mammals (including the SARA-listed harbor porpoise) to underwater noise and uncertainty regarding details of construction and operational noise to be generated by other projects with spatial and temporal overlap with the Project.

Prediction confidence in the assessment of cumulative effects on sediment and water quality is high as sediments in the MOF are well-characterized and conservative modelling has been performed to determine the extent of sediment dispersion.

13.6.2.6 Combined Cumulative Effects

As previously discussed, the assessment of cumulative effects is designed to focus on how residual effects of the Project may or may not act in combination with other past, existing, or reasonably foreseeable projects and activities in the region. Assessment of combined effects (e.g., underwater noise from all sources in combination with TSS and potential vessel strikes from all foreseeable projects) differs from an assessment of cumulative effects. Combined effects are assessed by characterizing each effect individually and providing an overall conclusion of significance based on the collective effects.

The cumulative effects considered above for marine resources were: change in sediment or water quality; direct mortality or physical injury; and change in behaviour. The following subsection considers the overall potential effect on marine resources of these three effects acting together in combination, along with the effects of accidental vessel collisions with marine mammals. Fish habitat offsetting measures will ensure no net loss in productivity, resulting in no adverse residual effects to fish habitat (Section 13.6.2.2); therefore, an assessment of potential for combined cumulative effects is not required for fish habitat.

Dredging at the MOF, disposal at sea, and vessel maneuvering at the berths will all introduce underwater noise (discussed further below) and result in resuspension of marine sediment, leading to increases in TSS levels and potential for dispersal of contaminants from sediment. However, given that the levels of dioxins and furans within the dredge area for the Project do not pose a concern for bioaccumulation or toxicological effects on marine biota, any such project-related change in sediment or water quality is not expected to contribute to cumulative sediment quality effects in an additive fashion with the other effects considered here (i.e., direct mortality, injury, or behavioural change due to underwater noise, or injury or potential mortality from vessel collisions). As such, cumulative effects on sediment and water quality (Section 13.6.2.1) are not considered further in this combined cumulative effects assessment.

Some invertebrates and/or sedentary or slow moving fish are likely to be killed by construction activities involving blasting, dredging, excavation, pile installation, and disposal at sea, with mortality confined to the immediate area of these activities. Individuals affected in this manner will be removed from the population and thus consideration of other effects (e.g., as a result of underwater noise) in combination with mortality from burial or crushing is not warranted. Even with the cumulative losses from other past, existing, or reasonably foreseeable projects, this is not expected to have an effect on the long-term viability of populations of invertebrates or sessile, slow-moving fish species. The affected species and community types are locally abundant in the RAA and are likely to recolonize and recover via the creation of productive offsetting habitat. As such, cumulative effects on direct mortality or physical injury of fish (Section 13.6.2.3) are not considered further in the combined cumulative effects assessment.

Project-related marine construction and shipping operations, in combination with the effects of other projects and activities in the RAA (including small-scale human uses of the marine environment) will increase the frequency of exposure to and, possibly, the intensity of underwater noise. The potential for direct mortality, auditory injury (i.e., PTS), TTS, or behavioural change in marine resources as a result of underwater noise, are all different (i.e., more or less severe) endpoints on the same scale. While only high sound pressure underwater construction activities, such as blasting and pile driving, have any potential (if unmitigated) of causing physical injury, all project-related activities that introduce underwater noise have some potential to cause behavioural change to some degree. It is therefore intrinsically assumed in the residual effects assessment that any project activity capable of potentially causing direct mortality or physical injury due to underwater noise will also result in behavioural change. The two effects (physical injury or change in behaviour) are separated out in the assessment for ease of discussion, and because the regulatory guidelines considered are broken down into these two categories. As there are no thresholds for assessing the effects of underwater noise on fish behaviour, the following example, provided for illustrative purposes, focusses on marine mammals.

The NOAA behavioural disturbance threshold for pinnipeds and cetaceans is160 dB_{RMS} re: 1 µPa for pulse sounds (e.g., impact pile driving) (Federal Register 2005). NOAA's interim sound threshold guidance on injury criteria (i.e., potential for causing PTS) is 190 dB_{RMS} re: 1 µPa for pinnipeds and 180 dB_{RMS} re: 1 µPa for cetaceans (NOAA 2013). In considering the acoustic modelling conducted for the Project (Appendix N of the EIS), any activity predicted to produce sound pressure levels of 190 dB_{RMS} re: 1 µPa is therefore automatically considered in terms of its potential to cause *both* auditory injury and behavioural change, by virtue of the fact that both thresholds are exceeded. The mechanism for causing injury or behavioural change is the same (i.e., introduction of a sound in exceedance of the considered thresholds) and the varying potential biological responses to that source level (i.e., from behavioural modification to physiological injury) are only considered separately for ease of interpretation – they are already inherently a combination of potential effects that result from the same impact. As such, the conclusions presented in the residual effects and cumulative effects assessments already consider the combination of these two effects because the stressor is the same (i.e., underwater noise) and the range of potential outcomes to this stressor has already been explored (Sections 13.6.2.3 and 13.6.2.4).

Although project construction activities could overlap spatially and temporally with other projects (e.g., the Canpotex Project), and concurrent pile driving (in particular) from multiple projects would result in a larger area of injury potential, it is assumed that other projects would also require similar mitigation measures (e.g., the installation of in-water piles employing a vibratory hammer wherever possible, use of marine mammal observers etc.; see the MMMPP; Appendix G.2 and G.3; and Appendix 1 of Appendix J.8 for further details on project mitigation measures for marine mammals). If using an impact hammer with a bubble curtain is the only viable option for one or more projects, the potential for injury to marine mammals will increase and a greater number of individuals could be affected, including harbour porpoise, which is listed under SARA as Special Concern.

Harm to marine mammals under this scenario could act additively with the potential for injury or mortality from other sources, such as accidental collisions with marine vessels. However, while the primary species of concern during construction is harbour porpoise (as a result of their known presence in the PDA and heightened sensitivity to construction noise), the primary species' of concern for vessel strikes are the larger species of baleen whales, due to their higher relative likelihood of being struck by a vessel (see Section 22.8.1.3 for the assessment of

Accidents and Malfunctions). Toothed whales, such as harbour porpoise, are more agile and smaller and are rarely struck by vessels. Of the marine mammals species found in the marine LAA, humpback whale populations are likely most vulnerable to effects from vessel strikes because of their status as Threatened under SARA and their likelihood of occurrence in the LAA (see Appendix M of the EIS, Marine Resources Technical Data Report). Fin whales are also vulnerable, although they are less commonly found in the LAA. Project mitigation measures (shared information between BC pilots of recent marine mammal sightings, and alteration of course upon sighting of a marine mammal in a vessel's path) are anticipated to greatly reduce the likelihood of serious injury to marine mammals, particularly large cetaceans, associated with vessel collisions.

Noise from shipping is likely to act cumulatively with existing and proposed projects during construction (i.e., material shipping, disposal at sea), operations (shipping LNG and other products), and decommissioning (i.e., shipping materials) as currently anticipated timelines for the reasonably foreseeable projects align closely with the Project. The spatial extent of behavioural effects would increase due to the effects of other projects but the zone of behavioural avoidance would vary depending on the species (and individual), the source level and the frequency of activity for each project, and the degree of overlap with zones of ensonification from other projects. In some cases, behavioural avoidance may actually reduce exposure to more severe outcomes, such as auditory injury. Behavioural responses (such as avoidance) to underwater noise from shipping may also act to reduce the likelihood of vessel strikes.

Overall, the project contribution to the combined cumulative effect on marine resources is predicted to be not significant. The Project is unlikely to contribute to these effects in a way that poses toxicological risks to marine biota, affects the population viability and sustainability of any species, or results in the mortality of species at risk.

13.7 FOLLOW-UP AND MONITORING

Monitoring programs will occur before, during, and after construction of the Project, with details to be further determined collaboratively with Aboriginal groups, communities, stakeholders, and government departments including DFO and Environment Canada. Follow-up and monitoring programs include:

- Monitoring as part of the Fish Habitat Offsetting Plan
- Monitoring of Flora Bank eelgrass bed extent and density
- Follow-up measurements of underwater noise during pile installation to confirm effectiveness of mitigation
- Turbidity monitoring during dredging and disposal of marine sediment
- Monitoring of long-distance effects of TSS dispersion from the Brown Passage disposal site (e.g., effects on seaweed and shellfish harvesting areas)
- Confirmatory monitoring of sediment quality at the dredge site after completion of dredging is often a condition of a Disposal at Sea permit (depending on baseline conditions). Environment Canada conducts monitoring at the disposal site periodically (last done at Brown Passage in 2014)
- Monitoring of TSS and sediment deposition rate during and after the construction of marine terminal structures to confirm that the values of TSS and rates and extent of deposition are within the ranges predicted
- Monitoring of TSS and changes in bathymetry (i.e., sediment elevation) around the berth areas, along with characterization of propeller wash derived scour and associated TSS and sediment movement during LNG carrier maneuvering and berthing.
- Marine mammal, fisheries, and fish habitat studies.

Turbidity will be monitored during dredging and blasting activities at the MOF and disposal activities at the Brown Passage site. Turbidity, rather than TSS, will be measured in real time in the field. Results will be compared to the WQG (5 and 25 mg/L) and compared to sediment dispersion modelling predictions. A TSS-turbidity calibration curve is currently under development using sediment samples with particle size distributions representative of those in the MOF. As sediment samples collected from the MOF were no longer available in archive, three archived samples from those collected from the former LNG carrier berth area were selected that are representative of the range of particle size fractions analyzed in sediments from the MOF. Samples with sand content ranging between 40% and 65%, silt content ranging between 30% and 45%, and clay content ranging between 5% and 12% were selected for this experiment. Dilutions of each sample in the 5 to 1,000 mg/L TSS range conservatively reflect the range of TSS levels predicted to occur at the MOF (maximum 41.6 mg/L TSS) and Brown Passage (1,100 mg/L TSS). Three correlation curves will result (one for each of the three sediment profiles), of which the most conservative (highest associated turbidity) will be used during real-time water quality monitoring during dredging, blasting, and ocean disposal. Turbidity will be monitored every two hours during daylight at select sites within 500 m of the active dredge area (the immediate area surrounding operating construction equipment) and at the disposal site (at the edge and up to 3 km away), focusing on areas down current from the dredging, and in a nearby reference area (to establish background concentrations). If turbidity and inferred TSS levels are higher than predicted outside the active work area at any monitored depth or location, the rate of activity will be slowed or other mitigation measures (e.g., silt curtains) used. In the first week of turbidity monitoring at the MOF, 25 water samples will be collected and analyzed for both turbidity and TSS to verify the relationship identified in the calibration curve. Turbidity monitoring during disposal at the Brown Passage site will be done at the edge of the disposal site and up to 3 km down current of the site following a disposal event, with samples collected within the reasonably accessible portion of the water column (e.g., surface 100 m). If turbidity levels are higher than the inferred TSS levels, the rate of disposal will be slowed.

In November 2014, PNW LNG began a marine mammal field program to estimate relative abundance of marine mammal species in the LAA. These vessel-based line transect surveys will be conducted once per month for one year prior to construction, will each take approximately 4 days to complete (plus potential weather delays), and will be designed, conducted, and analyzed using generally accepted and statistically rigorous survey protocols and analytical techniques based on distance sampling methods (Buckland et al. 2001). The data collected during the surveys will be used to estimate densities of marine mammal species' sighted, given appropriate numbers of sightings. Where possible, density estimates will also be used to produce density surface maps. Results, which will be made publicly available, will be used to further scientific understanding of the densities, seasonal use, and distribution of all marine mammal species present in the study area. An additional finer-scale survey of the PDA will be conducted once per month in coordination with fish and fish habitat surveys. The primary purpose of the program is to use the results of the surveys to assess and refine mitigation measures, prior to construction activities, to better address the specific needs of local marine mammal populations (see the MMMPP; Appendix G.2 and G.3; and Appendix 1 of Appendix J.8). For example, further understanding of the time periods for peak densities of marine mammals in the LAA will allow PNW LNG, in consultation with DFO, to identify refined timing windows for marine construction activities, and thus mitigate potential effects. Additional surveys will be conducted during operations (and potentially decommissioning, if deemed necessary at the time.

Underwater sound levels will be measured/monitored in situ during the first seven days of underwater blasting and impact pile driving to acquire baseline data on sound pressure levels produced during each activity, and to field-validate the effectiveness of bubble curtains and the size of the safety radius (currently set at 500 m and 1.0 km respectively). Monitoring will be conducted at the sound source and at the edge of the marine mammal safety radius (i.e., exclusion zone). PNW LNG is also investigating options for hydrophone deployment to collect information on vocalizing marine mammal species in the PDA, results of which will be used to supplement the vessel-based visual observation program.

Fisheries and habitat studies, to be conducted between November 2014 and June 2015 will focus on the project area around Lelu Island, Flora, Agnew and Horsey Banks. These studies will use a range of methods (e.g., habitat reconnaissance surveys, hydroacoustic surveys, trawls, seining, intertidal and subtidal trapping, and collection of oceanographic water property data and physical habitat information) to quantify the relative abundance, distribution and habitat use of CRA species and forage fish that have been identified as important by DFO including: Pacific salmon, crab, shrimp, herring, eulachon, and flatfish (flounder, sole), and forage fish species (surf smelt, sandlance). Based on the results, the fisheries assessment program can be amalgamated into the construction monitoring and compliance follow-up program for the Project and continued for a multi-year program as required. Please refer to the MMMPP (Appendix G.2 and G.3; and Appendix 1 of Appendix J.8) and the Habitat Offsetting Plan (Appendix G.10) for further information on mitigation measures, and follow-up and monitoring programs associated with marine resources.

Final assessment methodologies will be developed in consultation with DFO and post-construction monitoring will be informed by the results of pre-construction monitoring.

13.8 CONCLUSION

Project residual effects on marine resources are predicted to be not significant. Changes in sediment or water quality will be short-term and are not expected to affect fish health or marine resources as a whole. Changes to fish habitat and sediment and water quality will be localized, and mitigation measures are considered effective and well established. Increases in potential for direct mortality and physical injury to fish and marine mammals are expected to occur during construction. Marine mammals, and to a lesser extent fish, are expected to experience changes in behaviour during project construction, operations, and decommissioning. Harbour porpoise are the marine mammals most likely to change their behaviour (e.g., avoid areas during construction), primarily during the construction period. Because of the short term duration of most effects, the viability of local populations will not be affected. Mitigation measures will reduce the potential for mortality and injury and residual effects are not expected to affect population viability of any species.

Cumulative effects on marine resources are predicted to be not significant. Cumulative effects to water and sediment quality are not anticipated due to lack of both temporal and spatial overlap of dredging and disposal activities and appropriate scheduling of dredging and disposal at sea associated with other reasonably foreseeable projects. Through appropriate mitigation and design and implementation of fish habitat offsetting measures, productivity within the LAA will be maintained, resulting in negligible adverse residual effects to fish habitat and no cumulative effects. Cumulative effects of direct mortality or physical injury are expected to be moderate in magnitude, due to potential increases in injury to marine mammals caused by overlap in pile installation schedules with other reasonably foreseeable projects. Pile installation, shipping, and berthing will act cumulatively with other projects, increasing the spatial extent over which marine mammal behaviour could be affected. Marine mammals, namely harbour seals, harbour porpoise, and killer whales, could experience behavioural effects over larger areas and for longer periods of time as a result of concurrent construction and operations activities. Mitigation measures will reduce the potential for mortality and injury and residual effects are not expected to affect population viability of any species.

The overall project effect on marine resources is determined to be not significant.

The prediction confidence in this assessment is deemed to be moderate.

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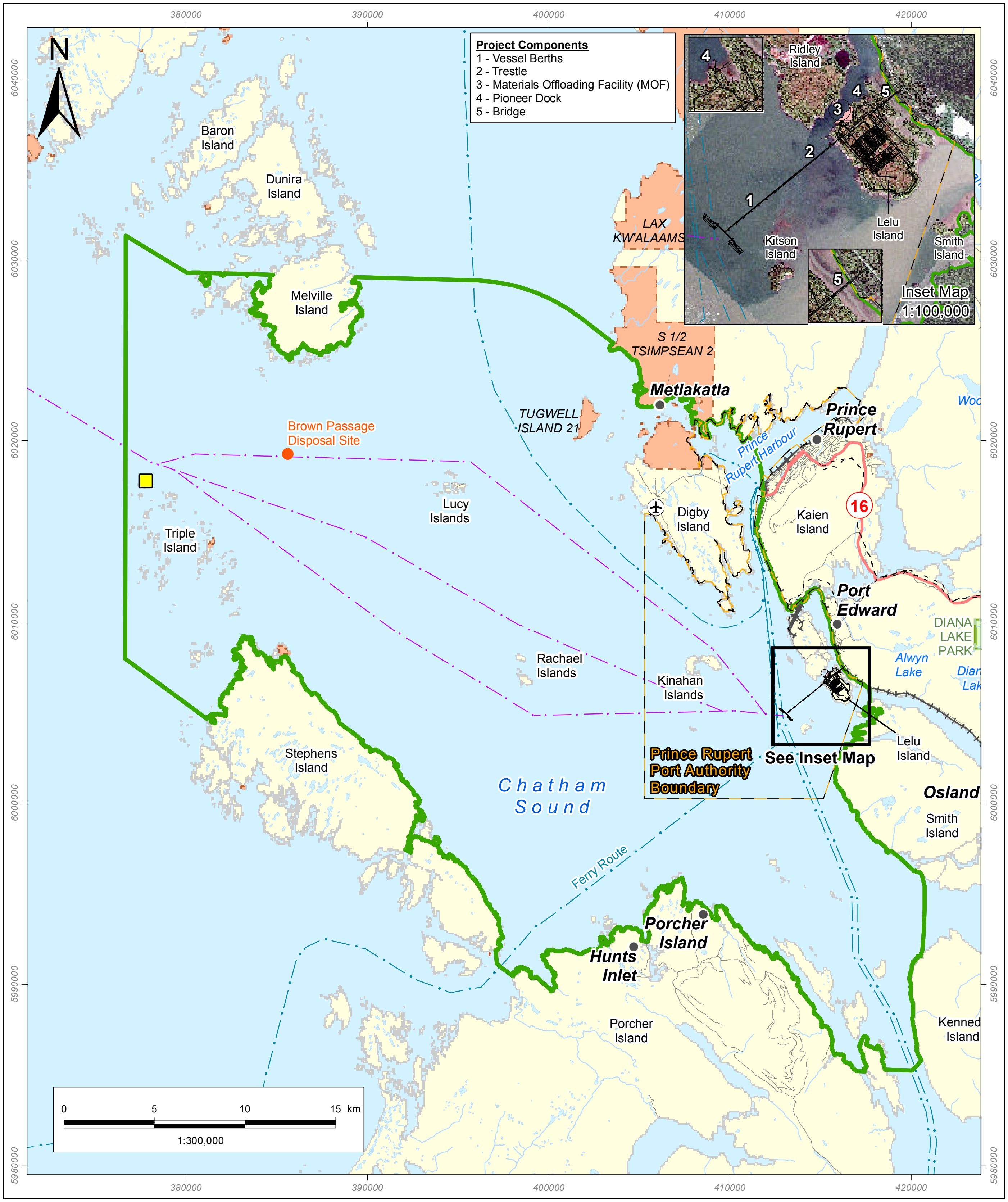
Marine Resources
December 12, 2014

13.10 FIGURES

See the following pages.



Disposal at Sea Site	Airport	Secondary Road
Potential Shipping Route	City or Town	Watercourse
Project Component	Pilotage Station	Indian Reserve
Marine Resources Local and Regional Assessment Area	Electrical Power Transmission Line	Prince Rupert Port Authority Boundary
Proposed Dredge Area	Ferry Route	Protected Area
	Highway	Waterbody
	Railway	

Pacific NorthWest LNG

Marine Resources Local Assessment Area and Regional Assessment Area

EIS ADDENDUM

Sources: Government of British Columbia; Prince Rupert Port Authority; Government of Canada, Natural Resources Canada, Centre for Topographic Information; Progress Energy Canada Ltd.

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.

DATE: 21-NOV-14
FIGURE ID: 123110537-388
DRAWN BY: K. POLL

PROJECTION: UTM - ZONE 9
DATUM: NAD 83
CHECKED BY: A. GROMACK

PREPARED BY: Stantec

PREPARED FOR: Pacific NorthWest LNG

FIGURE NO: **13-1**

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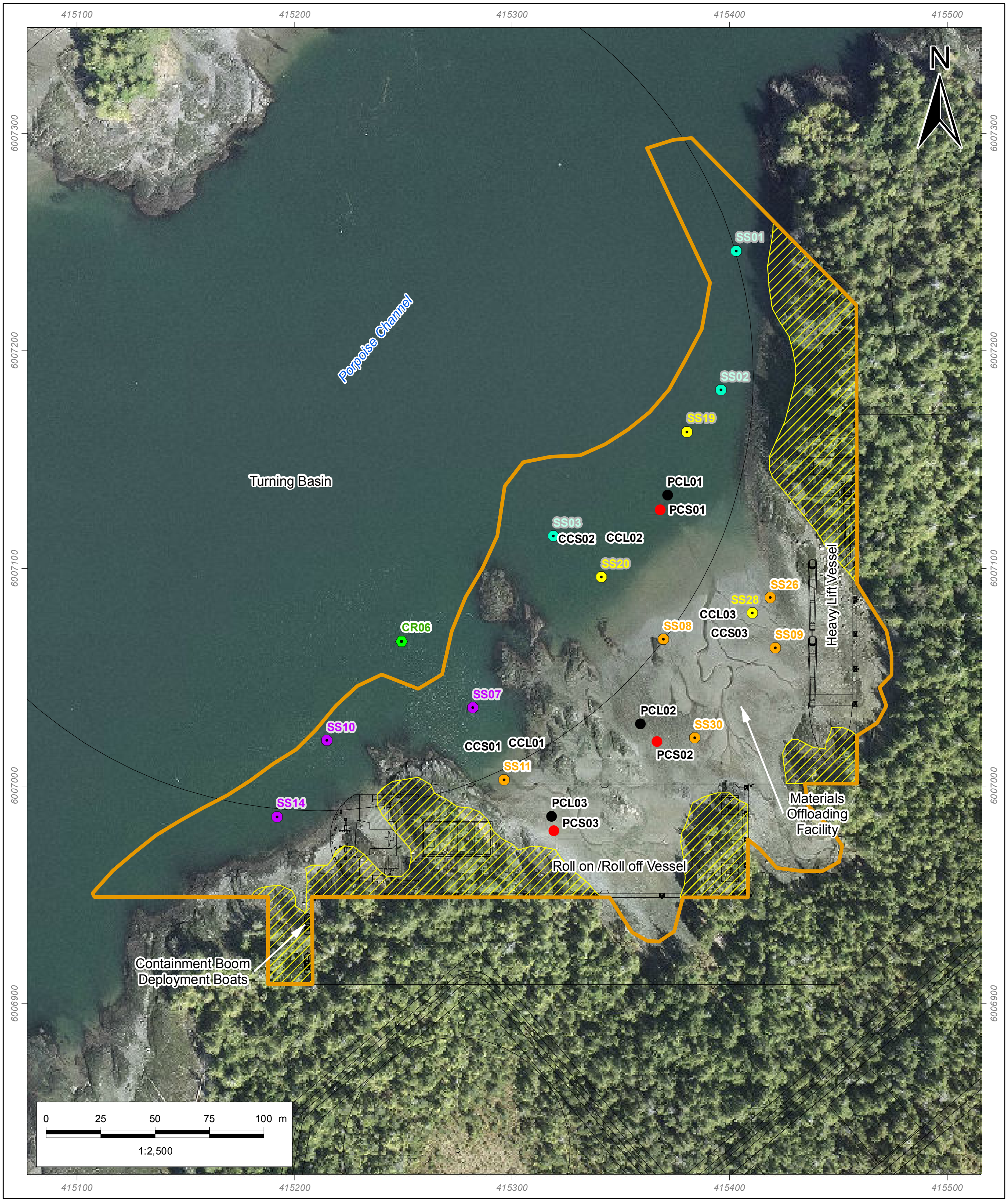


Primary Core (Analysis)

- Large interval (0.50 m) core sample
- Small interval (0.20 m) core sample
- Composite core sample (0-0.5 m and 0.5-1.0 m) with dioxin/furans
- Composite surface sample 1 (0-0.075 m) with dioxin/furans
- Composite surface sample 2 (0-0.075 m) with dioxin/furans
- Surface sample (0-0.075 m) with dioxin/furans
- Crab Sample
- Bathymetry - 1m interval
- Low water line – LWL (0 m, chart datum)
- Project Component
- Dredge Boundary
- Material for Land Disposal Approximate Boundary

Pacific NorthWest LNG

Sediment Sampling Locations for Dioxins and Furans

EIS ADDENDUM

Sources: Government of British Columbia; Government of Canada, Natural Resources Canada, Centre for Topographic Information; Progress Energy Canada Ltd., McElhanney Consulting Services Ltd. 2012. Ridley and Lelu Island Prince Rupert Hydrographic Survey Summary Report. Prepared for Kellogg Brown & Root LLC. Imagery date: 2009.

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.

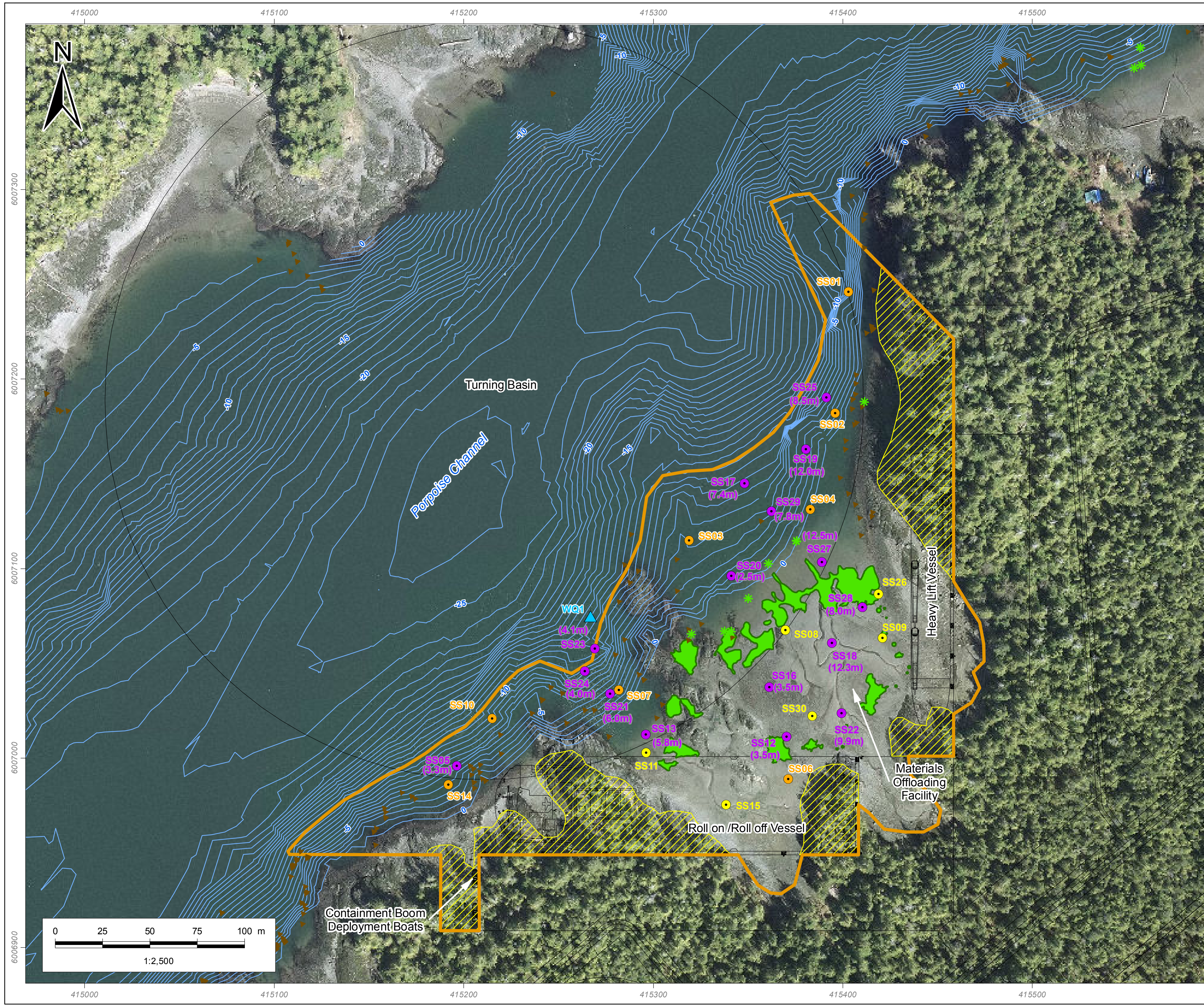
DATE: 09-DEC-14	PROJECTION: UTM - ZONE 9
FIGURE ID: 123110537-445	DATUM: NAD 83
DRAWN BY: K. POLL	CHECKED BY: B. LYNCH

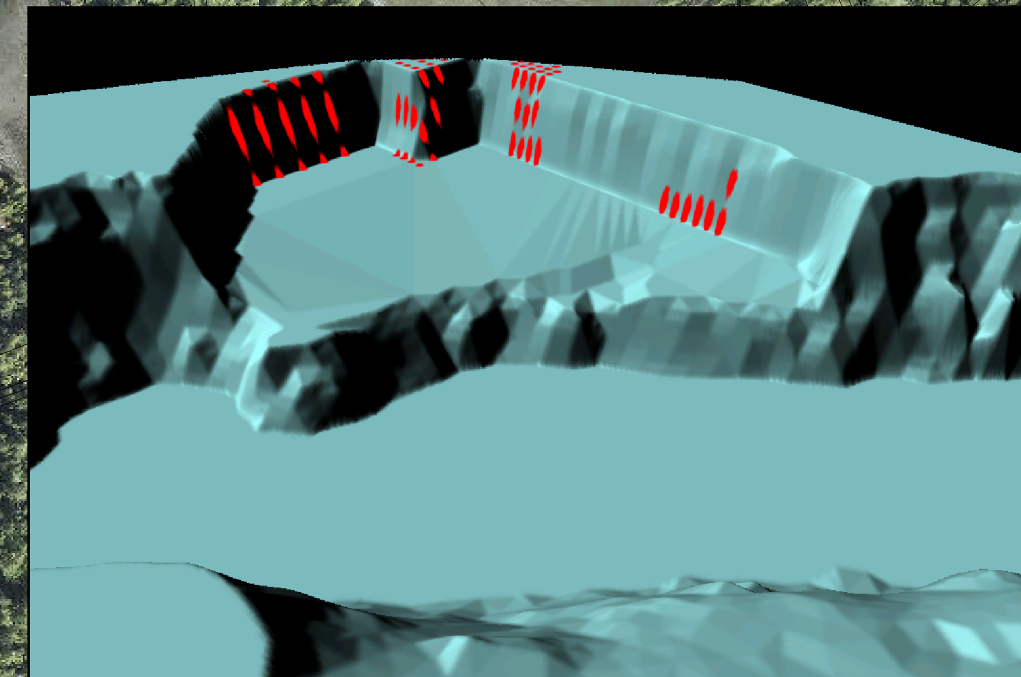
PREPARED BY: Stantec

PREPARED FOR: Pacific NorthWest LNG

FIGURE NO: **13-2**

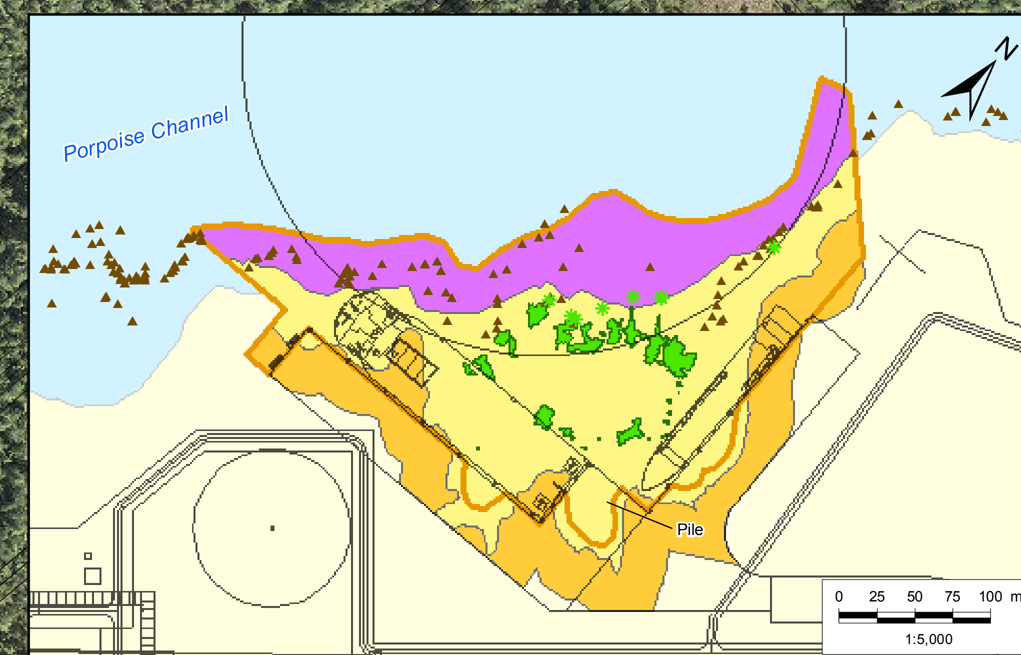
12/9/2014 - 1:25:50 PM V:\active\123110537\gis\figures\EA_Addendum\fig_123110537_ea_add_13_02_dioxin_furans_sample_locations.mxd





3-D view of MOF site dredged to 12.5 m depth. View looking southeast.

JASCO Applied Sciences (A. McCrodan). 2013. *Modelling of Underwater Noise for Pacific Northwest LNG Marine Construction and Shipping Scenarios Marine Construction and Shipping Scenarios.* Prepared for Stantec Consulting Ltd.



- Brown Algae
- Eelgrass
- Core Sample Location
- Grab Sample Location
- Intertidal Grab Sample Location
- Water Quality Sample Location
- Eelgrass Bed
- Intertidal Alteration
- Pile - Intertidal Loss
- Riparian Loss
- Subtidal Temporary Disruption
- Dredge Boundary
- Material for Land Disposal Approximate Boundary
- Bathymetry - 1m interval
- Low water line – LWL (0 m, chart datum*)
- Project Component

* as determined by Canadian Hydrographic Service charts

Reference for bathymetry:
McElhanney Consulting Services Ltd. 2012. Ridley and Lelu Island Prince Rupert Hydrographic Survey Summary Report. Prepared for Kellogg Brown & Root LLC.

Pacific NorthWest LNG

Habitat Affected in Dredge Area (MOF)

EIS ADDENDUM

Sources: Government of British Columbia; Government of Canada, Natural Resources Canada, Centre for Topographic Information; Canadian Hydrological Service (CHS), 1995. Imagery date: 2009.

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.

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FIGURE ID: 123110537-389	DATUM: NAD 83	CHECKED BY: A. GROMACK

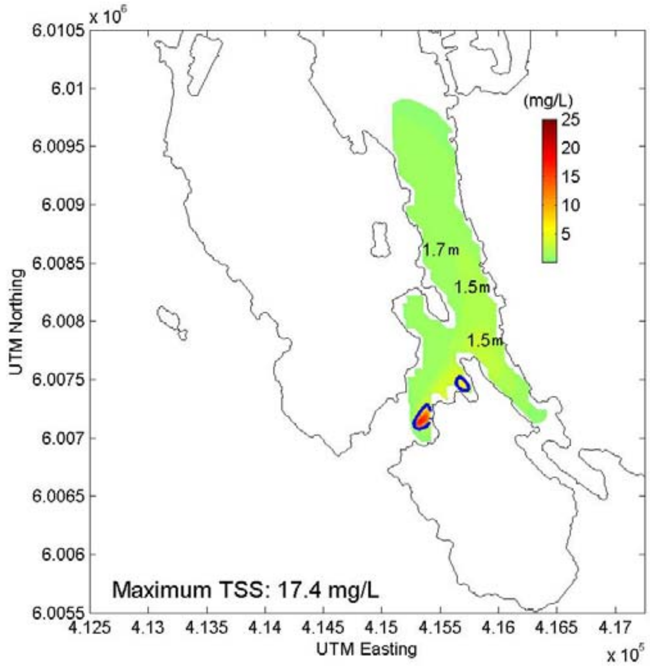
PREPARED BY: Stantec

PREPARED FOR: Pacific NorthWest LNG

FIGURE NO: **13-3**

12/9/2014 - 1:27:19 PM V:\active\123110537\gis\figures\EA_Addendum\fig_123110537_ea_add_13_07_marine_habitat_alteration_destruction_ea.mxd

Marine Resources
December 12, 2014



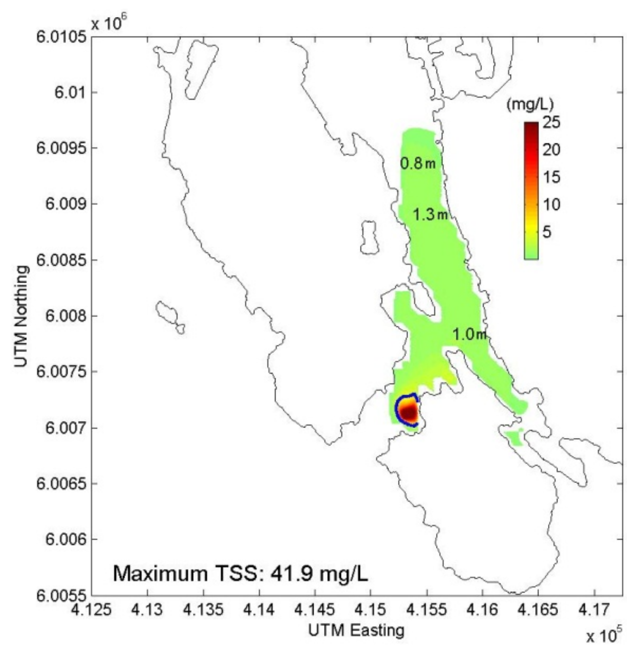


Figure 13-4 Model-Derived TSS (mg/L above background, maximum value in the water column) at Flood Flow from Dredging

Notes: Top panel, 3 p.m., January 12, 2015. Bottom panel (flood slack), 6 p.m., January 12, 2015. Numbers mark depths (above seabed) of maximum values in vertical column. Blue contours present the areas of TSS greater than 5 mg/L. (**Source:** See Appendix O of the EIS).

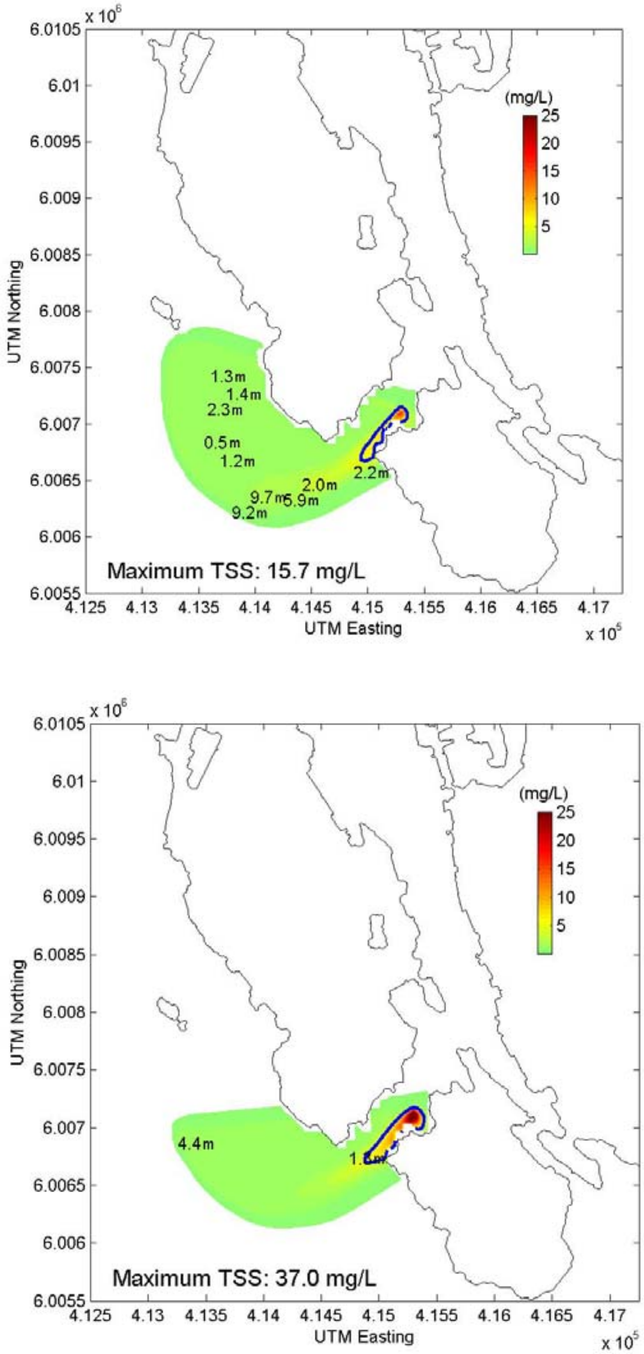


Figure 13-5 Model-Derived TSS (mg/L above background, maximum value in the water column) at Ebb Flow from Dredging

Notes: Ebb flow (top panel), 9 p.m., January 12, 2015. Ebb slack (bottom panel), midnight, January 13, 2015. Numbers mark depths (above seabed) of maximum values in vertical column. Blue contours present the areas of TSS greater than 5 mg/L.
Source: See Appendix O of the EIS.

Marine Resources
December 12, 2014

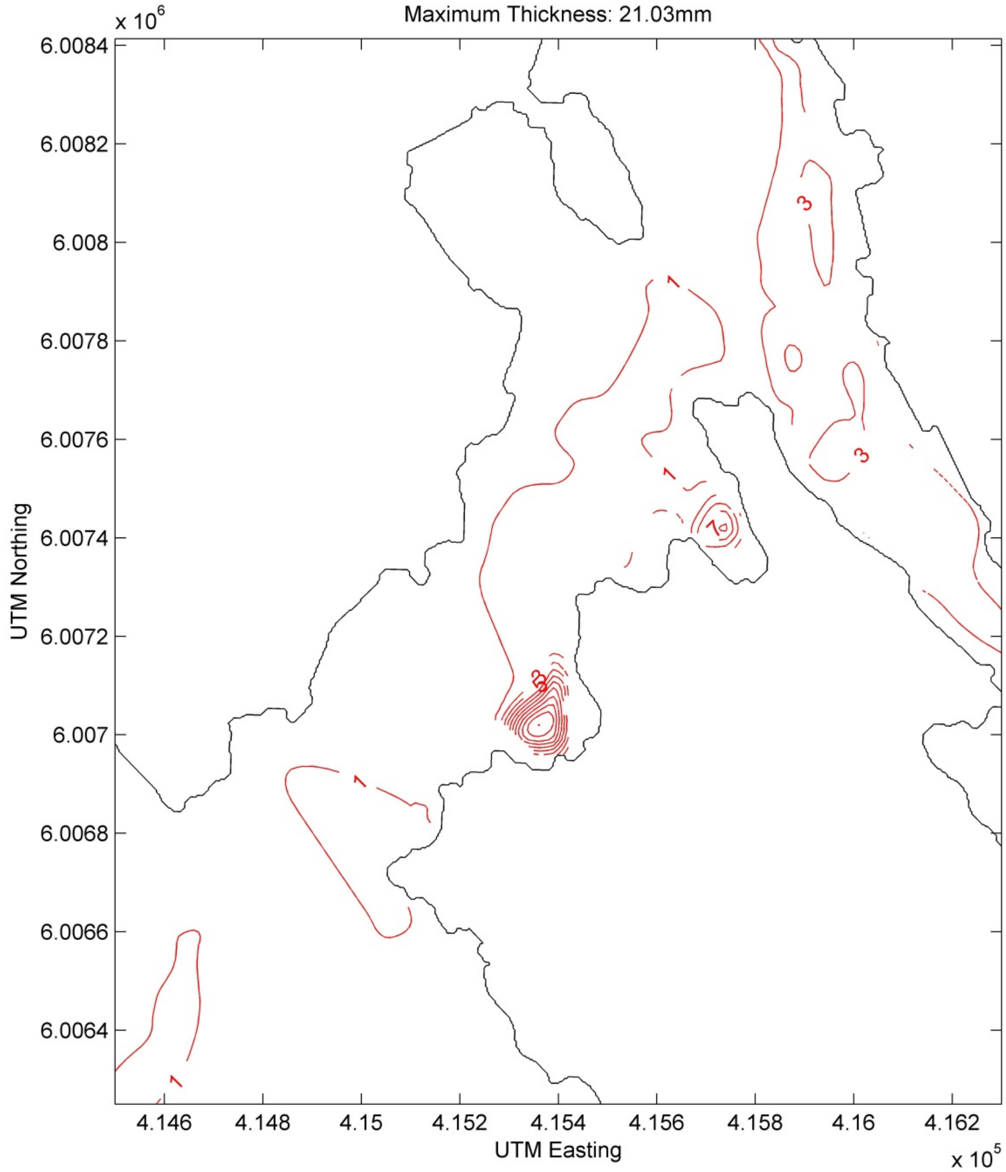


Figure 13-6 Estimated Deposition (mm) after Dredging Completed (interval between each contour is 2 mm

Note this figure has been rescaled to account for the decreased volume of sediment (200,000 m^3, compared with 615, 000 m^3 originally modelled, and replaces Figure 11 in Appendix O of the original EIS).

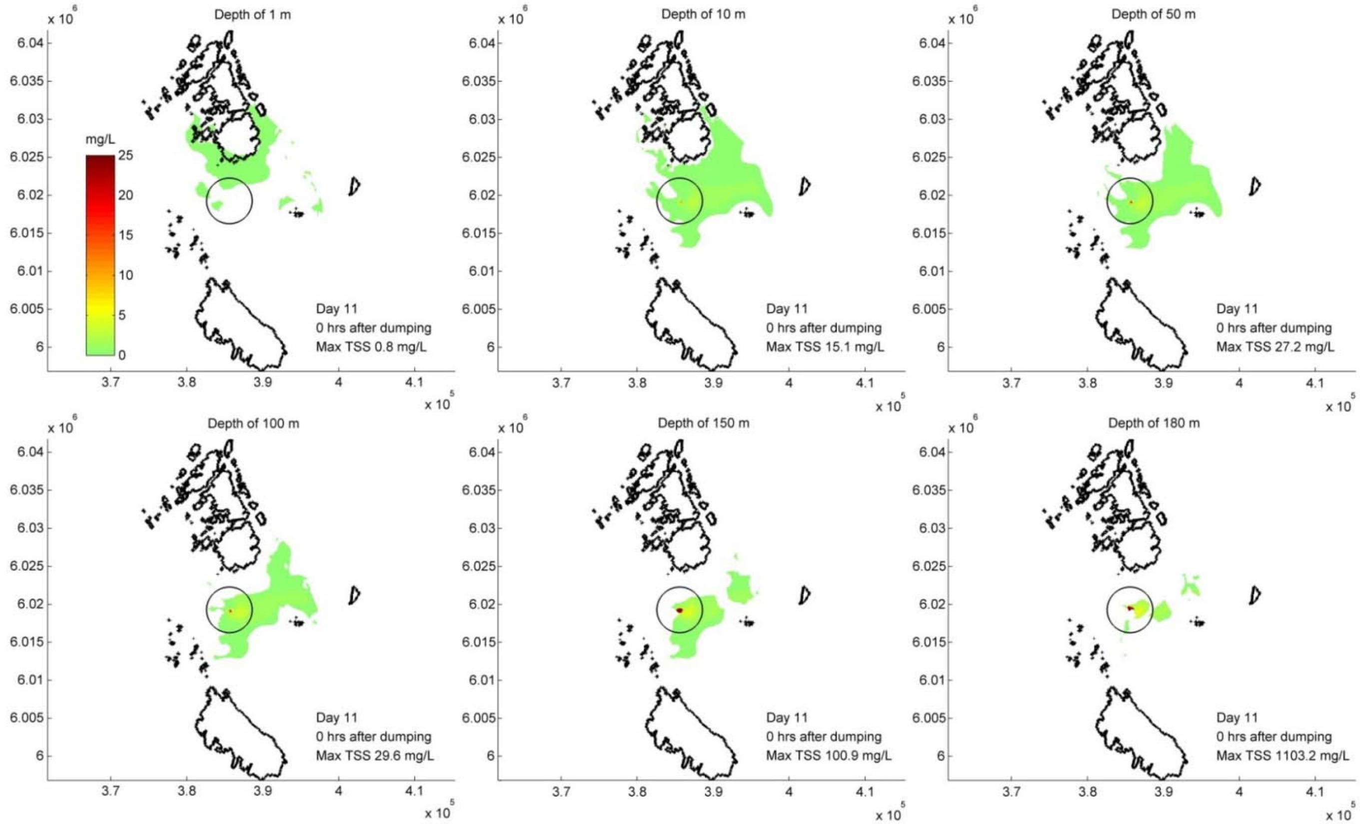
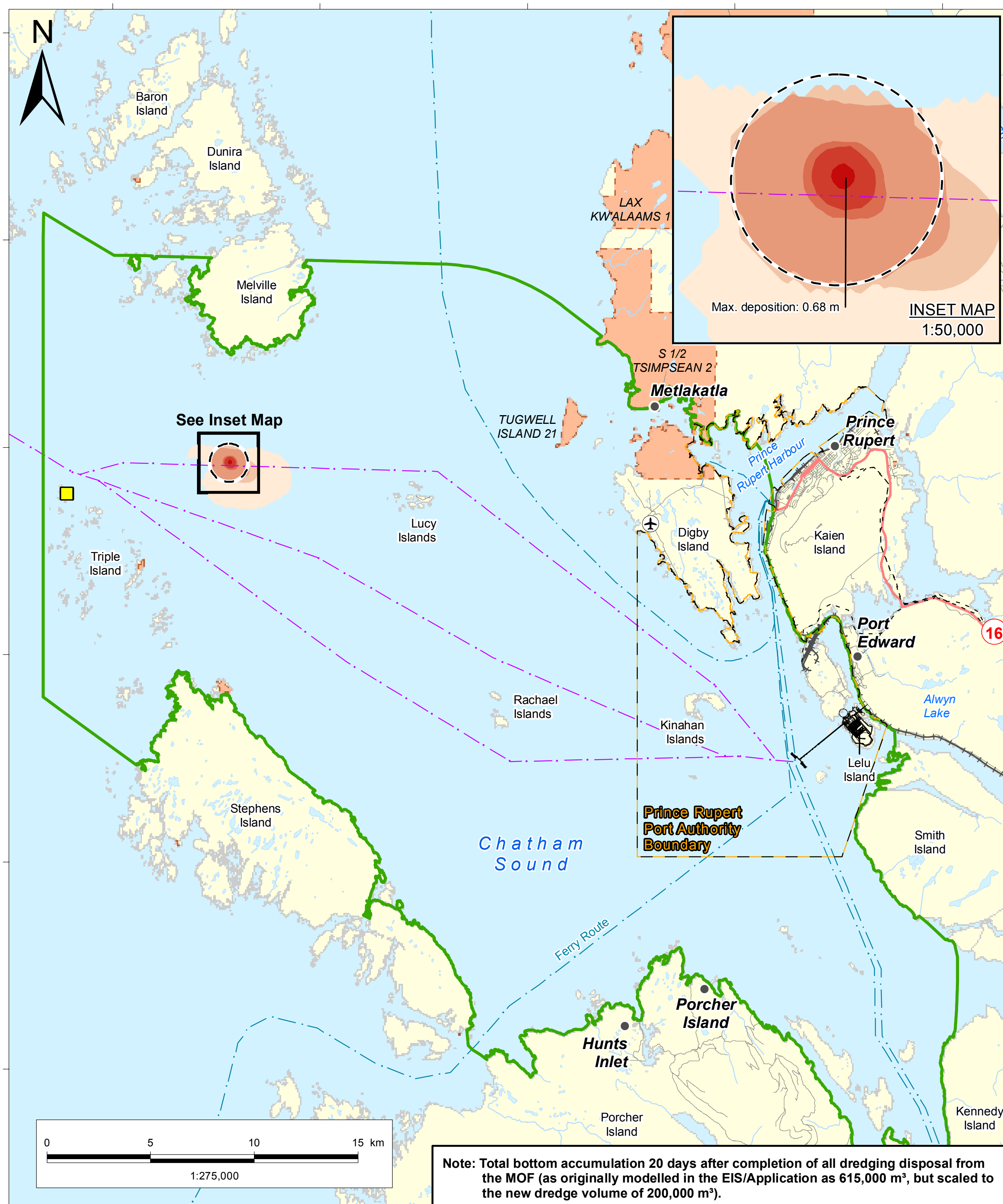


Figure 13-7 TSS Plume in the Water Column from Disposal at Sea (Brown Passage)

Notes: Modelled for a disposal trip, 0 hours after disposal. The black circle marks the designated disposal area (1.85 km in diameter).

Source: See Appendix O of the EIS.



Note: Total bottom accumulation 20 days after completion of all dredging disposal from the MOF (as originally modelled in the EIS/Application as 615,000 m³, but scaled to the new dredge volume of 200,000 m³).

Legend

- Brown Passage Designated Disposal Site
- Local and Regional Assessment Area

Total Sediment Deposition after Completion of Disposal from the MOF (mm)

- 1
- 5
- 10
- 50
- 100
- 500
- Potential Shipping Route
- Project Component
- Airport
- City or Town
- Pilotage Station
- Electrical Power Transmission Line
- Ferry Route
- Highway
- Railway
- Secondary Road
- Watercourse
- Indian Reserve
- Prince Rupert Port Authority Boundary
- Waterbody

Pacific NorthWest LNG
Total Bottom Accumulation at Brown Passage 20 Days after Completion of all Dredging Disposals

EIS ADDENDUM

Sources: Government of British Columbia; Prince Rupert Port Authority; Government of Canada, Natural Resources Canada, Centre for Topographic Information; Progress Energy Canada Ltd.

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.

DATE: 09-DEC-14
FIGURE ID: 123110537-417
DRAWN BY: K. POLL

PROJECTION: UTM - ZONE 9
DATUM: NAD 83
CHECKED BY: A. GROMACK

PREPARED BY: Stantec

PREPARED FOR: Pacific NorthWest LNG

FIGURE NO: **13-8**

12/9/2014 - 1:27:34 PM V:\active\123110537\gis\figures\EA_Addendum\fig_123110537_ea_add_13_08_total_bottom_accumulation_brown_passage_20_days_after_completion_of_all_dredging_disposal.mxd

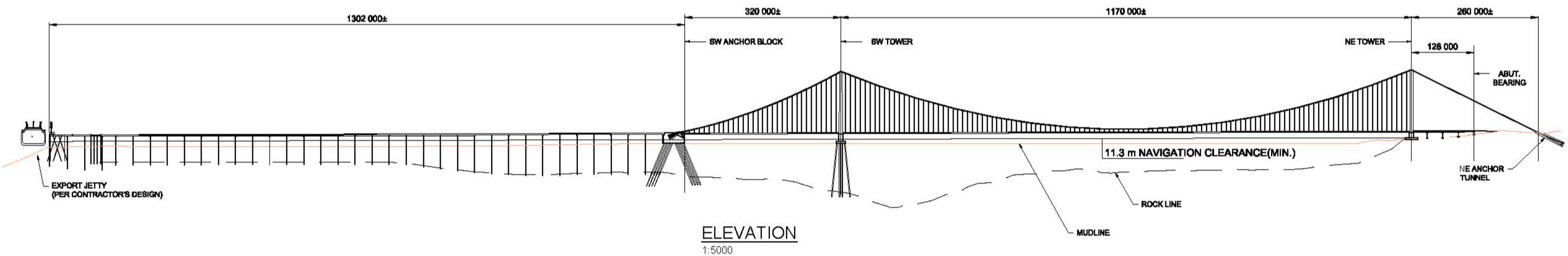
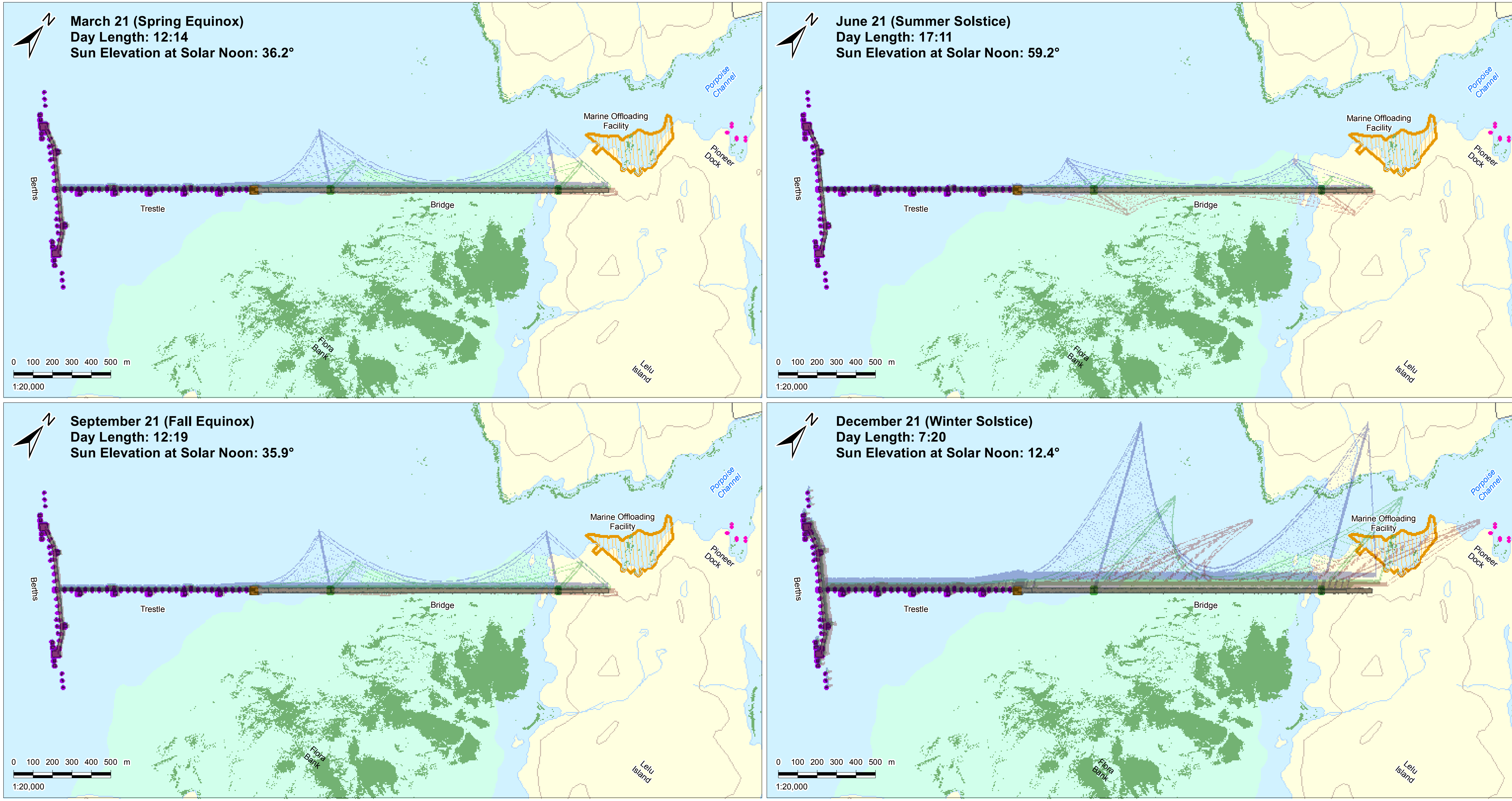


Figure 13-9: Marine Terminal (suspension bridge, trestle and berth)



Contour (m)
Secondary Road
Watercourse
Waterbody
Flora Bank
Pioneer Dock Piles
Bridge Supports in Water
Jetty/Trestle
SW Anchor Block
Core Eelgrass Area
MOF Dredge Boundary

Shadow (time of day):
Evening
Midday
Morning

Pacific NorthWest LNG

PNW LNG Marine Terminal Footprint: Plan View Shadows

EIS ADDENDUM

Sources: Government of British Columbia; Government of Canada, Natural Resources Canada, Centre for Topographic Information; Progress Energy Canada Ltd; WorldView-2 Imagery. Imagery date: 2011.

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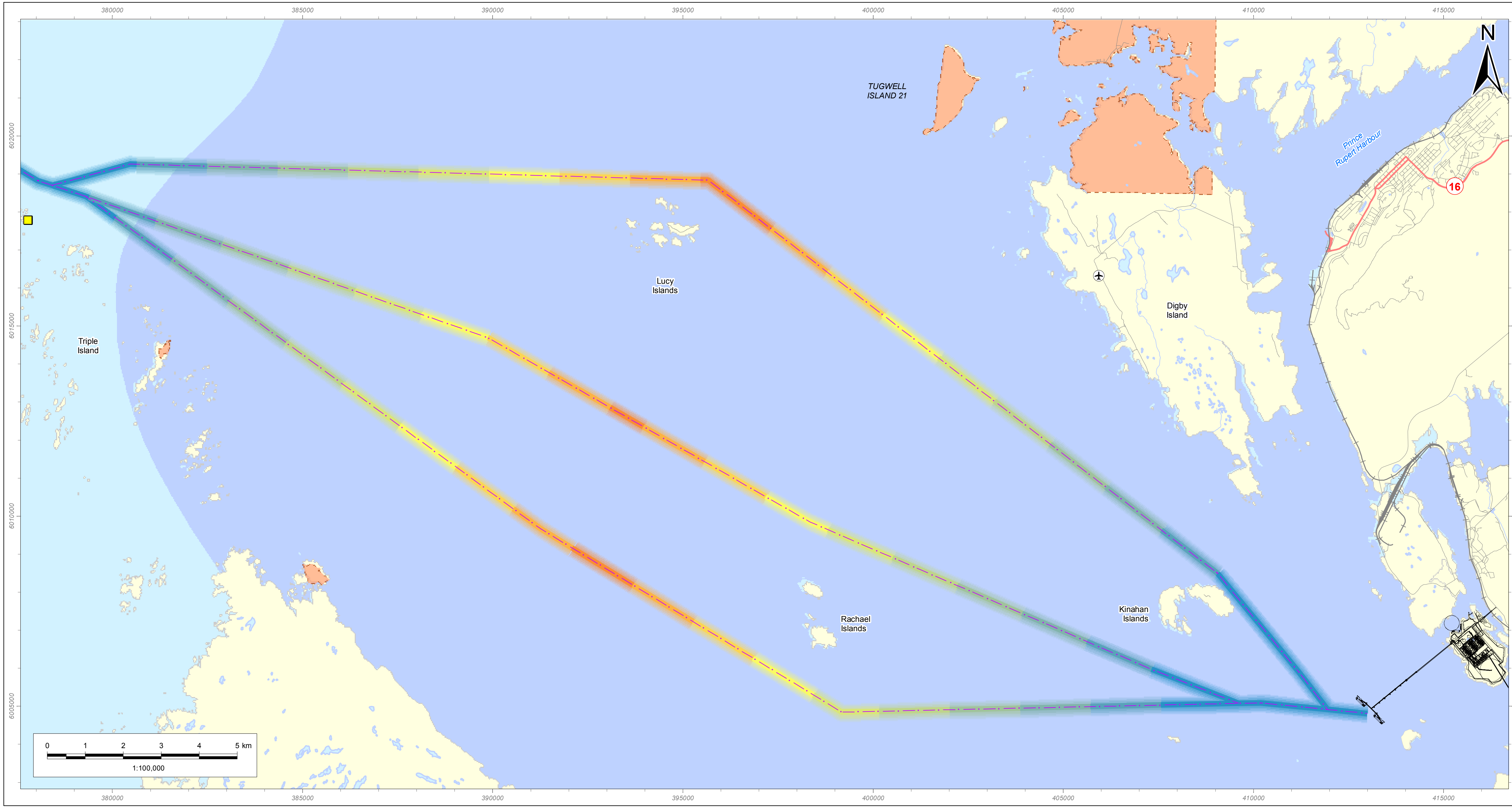
DATE: 09-DEC-14	PROJECTION: UTM - ZONE 9	DRAWN BY: R. COATTA
FIGURE ID: 123110537-856	DATUM: NAD 83	CHECKED BY: C. DOUGHTY

PREPARED BY: Stantec

PREPARED FOR: Pacific NorthWest LNG

FIGURE NO: 13-10

12/9/2014 - 1:30:31 PM V:\active\123110537\gis\figures\EA_Addendum\fig_123110537_ea_add_13_10_marine_terminal_footprint_plan_view_shadows.mxd



Project Component
Project Shipping Route
Pilotage Station
Airport
City or Town
Highway
Secondary Road
Railway
Electrical Power Transmission Line
Watercourse
Water Body
Skeena Estuary
Indian Reserve
Protected Area

Speed (kt)	
4	10
5	11
6	12
7	13
8	14
9	15
	16

Pacific NorthWest LNG

Estimated LNG Carrier Speeds

EIS ADDENDUM

Sources: Government of British Columbia; Government of Canada, Natural Resources Canada, Centre for Topographic Information; Progress Energy Canada Ltd.

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.

DATE: 09-DEC-14
FIGURE ID: 123110537-846
PROJECTION: UTM - ZONE 9
DATUM: NAD 83
DRAWN BY: T. CARDINAL
CHECKED BY: G. MATHEWS

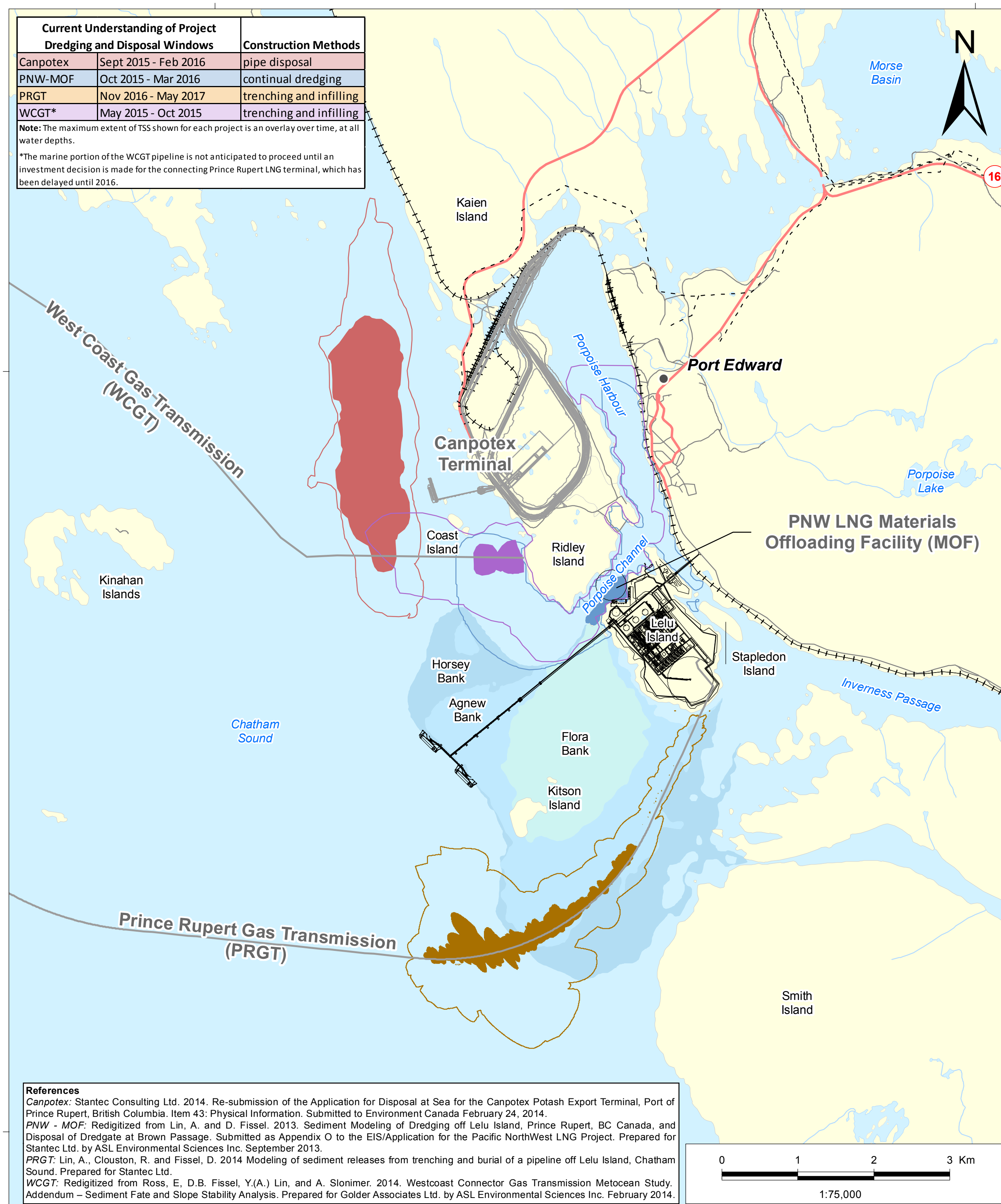
PREPARED BY: Stantec
PREPARED FOR: Pacific NorthWest LNG
FIGURE NO: **13-11**

12/9/2014 - 1:32:34 PM V:\active\123110537\gis\figures\EA_Addendum\fig_123110537_ea_add_13_11_estimated_lng_carrier_speeds.mxd

Current Understanding of Project Dredging and Disposal Windows		Construction Methods
Canpotex	Sept 2015 - Feb 2016	pipe disposal
PNW-MOF	Oct 2015 - Mar 2016	continual dredging
PRGT	Nov 2016 - May 2017	trenching and infilling
WCGT*	May 2015 - Oct 2015	trenching and infilling

Note: The maximum extent of TSS shown for each project is an overlay over time, at all water depths.

*The marine portion of the WCGT pipeline is not anticipated to proceed until an investment decision is made for the connecting Prince Rupert LNG terminal, which has been delayed until 2016.



References

Canpotex: Stantec Consulting Ltd. 2014. Re-submission of the Application for Disposal at Sea for the Canpotex Potash Export Terminal, Port of Prince Rupert, British Columbia. Item 43: Physical Information. Submitted to Environment Canada February 24, 2014.

PNW - MOF: Redigitized from Lin, A. and D. Fissel. 2013. Sediment Modeling of Dredging off Lelu Island, Prince Rupert, BC Canada, and Disposal of Dredgate at Brown Passage. Submitted as Appendix O to the EIS/Application for the Pacific NorthWest LNG Project. Prepared for Stantec Ltd. by ASL Environmental Sciences Inc. September 2013.

PRGT: Lin, A., Clouston, R. and Fissel, D. 2014 Modeling of sediment releases from trenching and burial of a pipeline off Lelu Island, Chatham Sound. Prepared for Stantec Ltd.

WCGT: Redigitized from Ross, E, D.B. Fissel, Y.(A.) Lin, and A. Slonimer. 2014. Westcoast Connector Gas Transmission Metocean Study. Addendum – Sediment Fate and Slope Stability Analysis. Prepared for Golder Associates Ltd. by ASL Environmental Sciences Inc. February 2014.

Legend

- City or Town
- Electrical Power Transmission Line
- Highway
- Railway
- Secondary Road
- Watercourse
- Waterbody
- Other Project Infrastructure
- Project Component

Total Suspended Solids (mg/L)

- Canpotex, <5
- Canpotex, >5
- PNW - MOF, <5
- PNW - MOF, >5
- PRGT, <5
- PRGT, >5
- WCGT, <5
- WCGT, >5

Pacific NorthWest LNG

Overview of Potential Cumulative Water Quality Effects

(Maximum Temporal and Spatial Extent of Predicted Total Suspended Solids)

EIS ADDENDUM

Sources: Government of British Columbia; Government of Canada, Natural Resources Canada, Centre for Topographic Information. Refer to Appendix 8 for full citations. See Section 6.1 "Spatial Data References" for additional reference information.
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.

DATE: 09-DEC-14
FIGURE ID: 123110537-473
DRAWN BY: L. TRUDELL

PROJECTION: UTM - ZONE 9
DATUM: NAD 83
CHECKED BY: M. BREWIS

PREPARED BY: Stantec

PREPARED FOR: Pacific NorthWest LNG

FIGURE NO:

13-12

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Marine Resources
December 12, 2014

Figure 13-12 Overview of Potential Cumulative (Maximum Temporal and Spatial Extent of Predicted Total Suspended Solids)