22 ACCIDENTS OR MALFUNCTIONS

This section evaluates the potential effects of any project-related accident (unexpected occurrence or unintended action) or malfunction (failure of a piece of equipment, a device, or a system to function normally), which may be associated with an adverse environmental or human health effect.

A focus of the current regulatory regime for the oil and gas sector in British Columbia (BC) is to prevent the occurrence of accidents and malfunctions associated with industrial activities. The Project will be built in accordance with the BC *Oil and Gas Activities Act* and associated Pipeline and Liquefied Natural Gas Facility Regulation (2010), which dictates that an LNG facility is built according to the design requirements and operational parameters of the Canadian Standards Association (CSA). CSA standard Z276-11: Liquefied Natural Gas (LNG) – Production, Storage, and Handling (2011) standardizes the design, location, construction, operation, and maintenance of domestic LNG facilities, resulting in safer operations and proactive response planning with regards to accidents and malfunctions.

In addition to the above regulatory provisions, current legislation applicable to potential accidents and malfunctions that could be associated with the Project includes:

- Fuel or hazardous materials spills:
  - Spill Reporting Regulation under the BC Environmental Management Act
  - Federal Transportation of Dangerous Goods Act and associated regulations
  - Canadian Environmental Protection Act (CEPA)
  - Pollution prevention provisions of the Federal Fisheries Act (Section 36)
  - Canada Shipping Act
  - Migratory Birds Convention Act.
- Explosion or fire:
  - BC Wildfire Act and Wildfire Regulation.

PNW LNG will implement various PETRONAS internal technical standards (PTSs), which address management and response procedures for preventing and mitigating accidents and malfunctions with the potential to result in adverse effects. These PTSs include:

- **Emergency Drill and Exercise Planning** – provides guiding principles and minimum requirements in planning emergency drills and exercises for emergency management, preparedness, and mitigation.
- **Environmental Incident Prevention and Control Implementation Guide** – provides guidance to implement both proactive and reactive controls with respect to environmental incidents.

- **Environmental, Social and Health Impact Assessment** – provides guidance for the conduct of environmental, social, and health impact assessment studies so as to reduce negative effects and enhance positive effects from projects with respect to environment, social, and community health. This explicitly provides for the inclusion of potential incidents, accidents, and emergency situations (such as spills, fire, and explosion) that may occur during the construction or operations phases.
- **Group Contingency Planning Standard** – provides the philosophy of operations for responding to any emergency at every level of PETRONAS' operations.

The main objective of this section is to determine potential effects that may result from identified project-related accidents and malfunctions. It also identifies operational procedures and management measures to be implemented, including:

- Procedures that will reduce or eliminate potential for accidents and malfunctions to occur
- Initial response measures following an accident or malfunction
- Processes to remediate and restore the environment to a pre-incident state, including follow-up and monitoring programs.

Such procedures follow PNW LNG and PETRONAS corporate guiding principle of managing emergencies, which is to protect and save people, environment, long-term operability of assets, and reputation, in that order.

22.1 Approach

22.1.1 Identification of Potential Accidents and Malfunctions Scenarios

Potential effects from the following accident and malfunctions are considered in this assessment:

4. Emergency flaring and LNG facility shutdown
5. Explosion or fire
6. Fuel or hazardous material spill (at the storage or loading facilities from mobile equipment and storage vessels)
7. LNG spill (at the storage or loading facilities)
8. Marine vessel allision (vessel striking another fixed vessel or object), grounding, or collision (two moving vessels), including:
   e) Marine vessel allision with the LNG terminal or grounding
   f) Marine vessel collision with another vessel
   g) Marine vessel collision with a marine mammal.

Project-based scenarios relating to each of these potential accidents or malfunctions have been developed using professional judgment from previous experience with similar projects and results of the quantitative risk assessment completed for the Project (Det Norske Veritas 2013a, 2013b). A hypothetical, credible worst-case scenario for each type of accident or malfunction forms the basis for assessing the potential environmental effects from that incident and intentionally introduces conservatism into the assessment.

Accidents and malfunctions resulting from intentional acts of terrorism are beyond the scope of this assessment.

22.1.2 Assessment Method

This assessment of potential effects from accidents and malfunctions includes:

- A brief description of a credible worst-case scenario for each accident and malfunction that could occur in any phase of the Project, from construction to decommissioning, for which an environmental effect of concern has been identified. This includes a description of the likelihood and circumstances under which such potential accidents and malfunctions could occur.
- A description of project design measures that will be implemented to manage or mitigate risk from each potential accident or malfunction.
- The identification of potential interactions between each accident and malfunction scenario identified above and the valued components (VCs) for the Project, with only those interactions for which an environmental effect of concern was identified (check mark in Table 22-1) carried forward to the next step of the assessment.
- A description of the environmental effects and associated significance that may result from accidents and malfunctions should mitigation measures and contingency plans not be fully effective, including a consideration of environmental effects as they are identified in Section 5 of the *Canadian Environmental Assessment Act*, 2012 (CEAA 2012).

The spatial and temporal boundaries, significance criteria, and thresholds applied in the assessment of accidents and malfunctions are the same as those defined in the assessment of routine project effects for each individual VC (Sections 6 through 21).

22.1.3 Identification of Potential Interactions with Valued Components

Potential interactions between each accident and malfunction scenario and VC are indicated in Table 22-1. A check mark indicates that an interaction occurs, the magnitude of which is discussed in subsequent sections by scenario.

Table 22-1: Potential Interactions of Project Accidents and Malfunctions Scenarios with Valued Components

Accidents and Malfunctions Scenario	Air Quality	Greenhouse Gas Management	Acoustic Environment	Ambient Light	Vegetation and Wetland Resources	Terrestrial Wildlife and Marine Birds	Freshwater Aquatic Resources	Marine Resources	Economic Environment	Navigation and Marine Resource Use	Infrastructure and Services	Visual Quality	Community Health and Well-Being	Human and Ecological Health	Archaeological and Heritage Resources	Current Use of Land and Resources for Traditional Purposes
▪ Emergency flaring and LNG facility shutdown	✓	✓	✓	✓		✓						✓		✓		
▪ Explosion or fire	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
▪ Fuel or hazardous material spill at the storage or loading facilities (from mobile equipment or storage vessels) to the marine or terrestrial environment	✓				✓	✓	✓	✓	✓	✓				✓	✓	✓
▪ LNG release at the storage or loading facilities to the marine or terrestrial environment	✓	✓				✓		✓	✓	✓				✓		✓
▪ (a) Marine vessel allision with the LNG terminal or grounding causing a ship-sourced LNG or hazardous materials release to the marine environment	✓	✓				✓		✓	✓	✓				✓		✓
(b) Marine vessel collision with another vessel causing a ship-sourced LNG or hazardous materials release to the marine environment	✓	✓				✓		✓	✓	✓				✓		✓
(c) Marine vessel collision with a marine mammal								✓								

22.2 Baseline Conditions

For a description of baseline conditions applicable to each VC discussed in this section, see Sections 6 to 21.

22.3 Emergency Response Planning

Response to emergencies associated with the Project will be based on PETRONAS' and PNW LNG's three-tiered approach, which clearly identifies roles and responsibilities among the emergency response team (ERT), emergency management team, and local authorities.

Tier 1

Tier 1 is an emergency where the facility operations are not seriously threatened, nor is there a danger to life. The risk of damage to the environment or property is also minimal. A Tier 1 emergency can be managed by the onsite emergency teams, including the onsite clinic and fire station.

Tier 2

Tier 2 is an emergency where the facility operations are seriously threatened and the emergency poses a danger to life. The risk of damage to environment or property under this scenario is also extensive. This type of emergency may require the support of outside resources (i.e., the assistance of local firefighters and emergency management personnel in Port Edward and Prince Rupert).

Tier 3

Tier 3 is an emergency where there is potential for severe damage to multiple facilities and assets, the environment, and neighbouring sites and surrounding communities. The incident is clearly beyond the capacity of the project resources to control and consequently requires action from government agencies or other external parties.

Tier 2 and 3 emergencies will be managed through the incident command system using unified command with local governments, provincial and federal agencies, and Aboriginal groups where appropriate. PETRONAS and PNW LNG will develop and maintain emergency response plans (ERPs) in accordance with applicable legislation for each of its facilities and operations that encompass these three tiers of emergencies.

The Project will manage substances that are listed in Schedule 1 of the Environmental Emergencies Regulations under *CEPA* (namely a mixture of methane, ethane, butane, propylene, propane, ethylene, and nitrogen, which comprise LNG), which exceed the threshold storage quantity of 4.5 tonnes (t) listed in the regulations (onsite storage capacity at the terminal site is 248,000 t [based on storage volume of 540,000 m^3, and LNG density of approximately 0.46 kg/L]). Preparation and implementation of an environmental emergency plan is therefore required under federal law. The BC Oil and Gas Commission (BC OGC) (2004) also requires oil and gas operators to have a current ERP to "ensure a quick, effective and appropriate response to emergencies in order to protect the public, company, and contract personnel from fatalities and irreversible health effects and the environment from damage." Taking into consideration the physical and chemical properties of LNG, the processing activities that will be undertaken at the facility, the location of the facility and the surrounding area, and the potential consequences from an environmental emergency, PNW LNG will develop an ERP specific to this Project (henceforth referred to as the ERP) that includes the following components (as regulated under the Environmental Emergencies Regulations):

- Identification of any environmental emergency that can reasonably be expected to occur as a result of project activities and associated harm that would likely be caused to the environment or constitute a danger to human life or health
- A description of the measures used to prevent, prepare for, respond to, and recover from any such environmental emergency
- Adoption of the provincial/federal incident command structure, including a description of the roles and responsibilities of those individuals who would implement the ERP
- A description of the training requirements for those individuals identified as being involved in emergency response duties
- An inventory (including storage locations) of the emergency response equipment included as part of the environmental emergency plan
- Notification, communication, and activation procedures (internal and external), including a description of the measures to be taken to notify members of the public who may be adversely affected by an environmental emergency.

PNW LNG will also include the following in the ERP developed for the Project, as mentioned in the PTS documents referenced in the introduction to this section and the recommendations developed during the hazard identification process conducted for the Project:

- A description of the type and frequency of emergency response drills and exercises to be conducted by emergency responders
- A list of resources and relevant personnel that may be called upon as needed during an emergency (e.g., subject matter experts, third-party response contractors)
- Linkages to other related internal (e.g., mutual aid) and external (e.g., government emergency response) plans
- A standalone pre-incident plan, which is a pre-emptive document containing succinct information on response strategies, associated resources, and potential escalation hazards for credible, project-specific incident scenarios. The pre-incident plan is intended to be used by emergency responders to rapidly establish control and successfully deal with an incident.
- Guidance specific to simultaneous operations and construction activities (e.g., during Phase 2 construction), resulting in an increased risk of an environmental emergency.

The Project will adopt the following principles (in order of priority) in managing emergency situations:

- Protect and save people
- Protect and save the environment
- Protect and save the long-term operability of assets and reputation.

PNW LNG is also willing to establish a joint ERT with other facilities handling hazardous materials in the vicinity of the Project. It is envisioned that this team would be comprised of ERTs internal to each facility and would conduct large-scale drills and exercises together at pre-determined intervals, in addition to the drills and exercises they conduct independently. The joint ERT would be ready to provide the necessary human and physical resources required in the unlikely event of an accident or malfunction that exceeded the response capacity of the Project.

22.4 Scenario 1: Emergency Flaring and LNG Facility Shutdown

22.4.1 Description of the Possible Scenario

Flare stacks are primarily included as a safety measure at LNG facilities to prevent the accumulation of gases that could pose a hazard to humans or the environment. Emergency flaring involves routing the gas stream to one or more flare stacks. This can occur when a fire, loss of containment, or gas leak has been detected; when a pressure safety valve lifts; or when an emergency shutdown button is triggered. Since the gas intake line valves are closed in an emergency situation, emergency flaring is a short-term event and would generally last for less than one hour.

The credible worst-case scenario involves shutdown of all three production trains at the LNG facility and flaring of feed gas for one hour from the warm flare. The likelihood of this scenario occurring is very low. Final engineering design will not exceed this scenario, and most flare cases would have a lesser effect.

22.4.2 Project Design Measures to Reduce Risk

Engineering controls will be incorporated into the project design for efficient operations that reduce the risk of emergency flaring and LNG facility shutdown. These controls will be developed based on the outcome of risk assessment studies conducted during the detailed design phase to mitigate hazardous risks onsite and will include measures for protection from operational malfunctions (e.g., overpressures, temperature exceedances, and abnormalities in tank levels), human operator error, and risks associated with routine maintenance activities. Furthermore, the project design will include protection barriers (e.g., high and low temperature alarms, level and pressure controls, and trip limits) to safely shut down equipment so that operations occur within the allowed and safe operational ranges. Detectors for combustible gas, fire, smoke, and heat, and manual call points will be installed throughout the facility to trigger an alarm in the case of emergencies and to allow for an immediate and safe shutdown of the facility if a predetermined threshold limit has been reached.

The flare system for the Project will comply with modern design developments in view of no-smoke requirements and applicable noise criteria, and will have a minimum destruction efficiency of 99.53%. The system will include two flare stacks for reliable and safe disposal of hydrocarbon streams in upset operating conditions and emergencies. The main flare stack is a derrick-supported, multi-riser elevated stack consisting of warm, cold, and spare flares. A derrick-supported flaring system has been deemed preferable to a ground flare system for safety of project personnel. The warm flare handles warm and wet hydrocarbon releases from the front end of the LNG trains. The cold flare handles cold and dry releases from the liquefaction and refrigeration areas. The spare flare is designed as a cold flare to be used as a temporary replacement for either the cold or warm flares during maintenance. A low-pressure flare will be used to combust cold vapour released from the LNG storage areas. Both the main flare stack and the low-pressure flare will have pilot lights ignited continuously to address emergency situations. The facility design will incorporate extensive trip and shutdown systems to accomplish the relief required in a total LNG facility shutdown scenario.

Administrative controls will also be implemented as mitigation for emergency flaring and LNG facility shutdown. These controls include safe work procedures, applicable work permits, and the ERP. As per industry standards and requirements, work sites and equipment will undergo regular maintenance and inspection, personnel qualifications will be maintained, and associated documentation will be reviewed and updated on a regular basis. Supervisors will conduct risk assessments for activities deemed necessary to identify potential hazards and take appropriate conservative measures.

Should emergency flaring and LNG facility shutdown occur, a post-incident investigation would be conducted to identify the cause and identify corrective and preventive actions to prevent recurrence.

22.4.3 Emergency Response Approach

In the case of an emergency flaring or LNG facility shutdown, the extensive trip shutdown systems will be designed to safely initiate shutdown of the whole facility. There would be no requirement for further emergency response actions to be initiated, unless the cause of such emergency flaring results from an LNG spill, fire, or explosion. For these scenarios, refer to their respective emergency response approach descriptions.

22.4.4 Clean-Up and Restoration Methods

No clean-up or restoration works would be required in an emergency flaring and LNG facility shutdown scenario, because the flare system is designed to safely divert all combustible gases to the designated flare stacks. If the emergency flaring and LNG facility shutdown is caused by a spill, fire, or explosion, clean-up and restoration activities would be initiated as described for these scenarios.

22.4.5 Potential Environmental Effects

22.4.5.1 Air Quality

Emergency flaring of feed gas results in the release of air contaminants in the form of carbon monoxide (CO) with negligible amounts of unburned hydrocarbons, particulates, nitrogen oxides (NO_x), sulfur dioxide (SO_2), and hydrogen sulphide (H_2S).

Potential effects of emergency flaring and LNG facility shutdown on air quality are assessed based on the results of the upset modelling scenario presented in the Air Quality TDR (Appendix C). The scenario considers the shutdown of all three processing trains over the course of one hour. The total combined gas that would be sent by the response system to the warm flare would have a mass flow rate of 700 kg/s. Composition of this gas would consist of about 96% methane and 2.3% ethane. The initial SO_2 emission rate for this scenario is 14.8 kg/h. The predicted maximum 1-hour SO_2 concentration is 2.00 $\mu g/m^3$ extending to 200 m from the project boundary. During the upset condition, it is assumed that 99.53% of H_2S is oxidized to SO_2. The resulting H_2S emission rate for this scenario is 0.08 kg/h. The predicted maximum 1-hour H_2S concentration is 0.011 $\mu g/m^3$ extending to 200 m from the project boundary.

The total combined gas that would be sent to the cold flare would have a mass flow rate of 59 kg/s, composed of about 100% propane. Emergency combustion of propane at the cold flare would generate only carbon dioxide (CO_2). Carbon dioxide equivalent (CO_2e) emissions generated during emergency flaring are summarized in Section 22.4.5.2.

The volume of SO_2 and other hazardous emissions that would be released during the credible worst-case emergency flaring and LNG facility shutdown scenario would be well below the ambient air quality objectives for 1-hour (450 µg/m^3) and 24-hour periods (160 µg/m^3) (BC MOE 2013).

22.4.5.2 Greenhouse Gas Management

Natural gas is predominantly comprised of methane, which is a greenhouse gas (GHG). Through emergency flaring, feed gas combustion would result in CO_2e emissions to the atmosphere. Priority GHG management requires that fugitive methane emissions be minimized and methane be combusted efficiently during operations and malfunctions, as methane is a more potent GHG than CO_2.

The total amount of CO_2e emissions generated during an emergency flaring and LNG facility shutdown scenario is 858 kg/s by the warm flare and 2,160 kg/s by the cold flare, with a total CO_{2e} emission rate of 3,020 kg/s (or 10.9 t during a 1-hour event). The recurrence interval for this scenario is assumed to be less than 10 times per year for all three trains during normal operations.

22.4.5.3 Acoustic Environment

Flares generate both heat and noise; the magnitude of each is proportional to the type and amount of gas in the flare stack. Given that the gas intake valves would be closed during an emergency flaring and LNG facility shutdown scenario, flaring is anticipated to be short term and would typically last for less than one hour. There is potential for flare noise to be heard outside the facility; however, flaring would be short term in duration. The BC OGC noise guideline does not provide a quantitative noise limit on emergency events.

22.4.5.4 Ambient Light

Increases to ambient light created by an emergency flaring and LNG facility shutdown scenario are anticipated to be short term (less than one hour in duration) and likely unnoticeable during daylight hours. The main flare has been relocated to the south of Lelu Island (furthest from human settlements) to mitigate potential human disturbance associated with increases in ambient light from emergency flaring that may occur during nighttime.

22.4.5.5 Terrestrial Wildlife and Marine Birds

Birds are attracted to artificial illumination and can suffer mortality through direct collision with sources of artificial light, such as light emitted during emergency flaring. Birds may also deplete energy reserves by circling lit structures, eventually grounding themselves from exhaustion or injury and becoming vulnerable to predation (BirdLife International 2012; Longcore et al. 2013). Because suspended moisture refracts more light (Longcore et al. 2013), attraction to and mortality from illuminated structures is amplified during precipitation or fog when birds are more likely to adjust flight patterns (e.g., reduce flight altitude, fly along coastlines). This effect might be greatest during seasonal migration or among juveniles and species that optimize foraging efficiency in illuminated waters (Rich and Longcore 2006).

The recent mortality of 7,500 birds at the Canaport facility in New Brunswick provides an example of the potential effects artificial lighting may have on birds. Researchers, cited in an interview by the Canadian Broadcasting Corporation (2013), indicated that design of the flare tower, in combination with seasonal timing of migration and foggy conditions, likely caused birds to adjust flight paths and become oriented towards the light at the flare tower.

Emergency flaring and LNG facility shutdown is expected to be uncommon and irregular. Mitigation, including retention of a 30 m vegetation buffer around Lelu Island, would further limit light dispersal. As such, emergency flaring is expected to have a negligible effect on regional bird populations.

22.4.5.6 Visual Quality

Similar to effects on the acoustic environment, effects on visual quality from the flare stack during emergency flaring are anticipated to be short term and localized.

22.4.5.7 Human and Ecological Health

Emergency flaring may result in short-term release of additional CO_2 and SO_2, with negligible concentrations of particulate matter and NO_x also released. Concentrations of these contaminants are not expected to exceed applicable air quality criteria. Release of H_2S during emergency flaring is not expected to affect human and ecological health, as it is assumed that nearly all H_2S would be oxidized to SO_2. Because emissions associated with emergency flaring are relatively low and limited in duration, the potential risk to human and ecological health from inhalation of air contaminants associated with the emergency flaring and LNG shutdown scenario is expected to be negligible.

22.5 Scenario 2: Explosion or Fire

22.5.1 Description of the Possible Scenario

Major accidents at LNG facilities are very rare. LNG is not stored under pressure, LNG is not explosive, and LNG vapour is not explosive in an unconfined environment. Only two large explosions at LNG facilities are known to have occurred in the past 60 years. An explosion and fire in Ohio occurred in 1944 because of leaks from an LNG tank constructed from inappropriate material, and in 2004, an explosion occurred in Algeria because of a steam boiler problem (boilers are not part of the project design). However, flammable materials associated with the Project, including natural gas, multi-component refrigerant gas (ethane, propane, and butane), acetylene, and liquid fuels (e.g., hydrocarbon condensate, diesel, petrol, and gasoline), do present a potential risk. Of these materials, natural gas will be present in the greatest quantities at the facility. As such, a credible worst-case fire scenario is any LNG explosion or fire that results in human deaths outside the facility. The probability of this scenario occurring is quantified by the location-specific individual risk (LSIR), which is the risk of fatality experienced by a single individual located in a specific location for 24 hours per day, 7 days per week, 52 weeks per year. The LSIR for populated areas near the facility (e.g., Port Edward) is less than one-in-ten million (or recurrence of less than one death per ten million years). Some areas on the southern tip of Ridley Island have LSIR of between one-in-one million and one-in-ten million (recurrence of one death between one and ten million years).

While natural gas is not flammable in its liquid state, it is flammable in a narrow range of concentrations from the lower flammable limit (LFL) of 5% vapour in air (by volume) to the upper flammable limit (UFL) of 15% vapour in air (by volume). Natural gas is lighter than air, and dispersion from the source of an LNG spill would result in mixing and dilution of the natural gas vapour cloud to below the LFL. In the unlikely event that a natural gas vapour cloud at concentrations within the flammability range was ignited by, for example, a discharge of static electricity, rapid combustion would result. Once the vapour cloud burned back to its source, the magnitude of the fire would depend on the rate of LNG release, which would continue to fuel the fire until the source was eliminated or the fire extinguished.

Explosions of LNG are very unlikely to occur, except in poorly ventilated, confined conditions, when natural gas vapours are present within the range of flammability and are exposed to an ignition source. Confinement in an enclosed structure can allow for the accumulation of flammable vapours. Once ignited, the pressure produced by rapid combustion of the vapours exerts an outward force on the containing structure, which could result in a deflagration-type explosion. A deflagration event, which propagates through heat transfer, is differentiated from a detonation-type explosion, which is supersonic, propagates through shock, and has much higher damage potential. If LNG were to quickly absorb heat from a water body, rapid phase transition (RPT) could occur. The heat transfer causes the LNG to instantly convert from the liquid to gaseous phase while releasing a significant amount of energy. This process can result in a physical explosion without any combustion. The hazard potential of a RPT can be severe, but it is generally localized.

The magnitude of effects associated with an explosion or natural gas-fuelled fire depends on factors such as the volume of LNG available for combustion and the duration of availability, atmospheric conditions dictating the movement and dispersion of the vapour cloud (particularly wind speed and direction, temperature, humidity, and precipitation), proximity of the incident to personnel and sensitive resources, and the effectiveness of emergency response activities. Primary concerns would be effects on air quality as a result of combustion and direct exposure of onsite personnel to the explosion or fire. While it is unlikely that a fire would extend beyond the boundaries of the LNG facility, there is a remote possibility that a wildfire could ignite on Lelu Island, which could have broader effects on vegetation and wildlife. It is not expected that a wildfire would be sustained for a great length of time by the amount of vegetation on Lelu Island, nor would it develop to sufficient size to migrate to the mainland given the amount of precipitation that falls in the region (which would act to suppress the fire). In addition, the surrounding channels would act as natural firebreaks.

Fires and explosions could also be associated with an LNG carrier. Normally such fires or explosions would not lead to loss of containment. However, should an explosion occur that leads to an LNG tank failure, it could result in an LNG release from one cargo tank, and in the worst case, all cargo tanks (Det Norske Veritas 2013a). In this scenario, the LNG would be ignited close to the vessel so dispersion of a flammable gas vapour cloud would not be anticipated.

22.5.2 Project Design Measures to Reduce Risk

Prevention is the primary mitigation measure for natural gas explosion and fire, followed by fire control and suppression. A systematic approach will be established for identifying potential risks and preventing and managing fire and explosion hazards. In general, the safe containment and handling of the LNG product is the central design principle of the entire facility.

Engineering controls that will be implemented to manage a fire or explosion include both preventive and protective measures, as described below.

Fire prevention measures to be incorporated during detailed design include:

- Confinement or diversion at potential spill sources using curbs, dikes, and trenches
- Systems to prevent or limit releases (e.g., fire-safe valves, remote operable valves, minimum flanges, small bore connections, and minimal use of sight glasses for visual observation of liquid levels in pipes/vessels to minimize potential failure points)
- A drainage system layout that limits the travel distance of potential spills
- Use of welded joints in valve and piping arrangements
- Design of the processing facilities and overall facility layout to promote natural ventilation and dispersion of potential vapour clouds, and which is at a safe distance from uncontrollable ignition sources outside the facility boundaries
- Natural ventilation of multi-story facility structures by using grated floors rather than closed concrete decks, thus avoiding accumulations of released vapour into a relative confined space
- Ignition source control by intelligent application of area classification guidelines and by using adequate inter-equipment distances
- Process control and instrument protective systems, providing early warning when normal process parameters are approaching their limits or are exceeded
- Emergency shutdown systems, providing means to bring the facility or facility sections to a safe or steady state
- Emergency depressurizing systems, providing means to dispose of the inventory of the facility or facility sections in a safe manner.

Fire protection measures that will be incorporated during detailed design include:

- Arrangement and layout of equipment and materials that pose a fire hazard to reduce the probability of fire escalation in the event of fire
- Use of fire-resistant construction in selecting load-bearing structures, such as pipe rack and vessel skirts
- Protection of electric cables, instrument conduits, and hydraulic tubing critical to a controlled emergency isolation, shutdown, or depressurization or use of required fire protection systems against a fire-induced failure
- Design of control valves and depressurizing valves, along with their actuators and actuating systems, to remain operable in a fire emergency
- Location of firefighting equipment (which includes fixed water monitors, dry risers, fire extinguishers, fire hose boxes, fire hydrants, fire water pumps, fire trucks, and foam systems) at pre-determined, strategic locations in the process areas
- Onsite storage of water in a volume sufficient for six hours of continuous firefighting, plus a secondary system to pump seawater if required

- Exposure protection by means of water deluge systems for equipment handling butane and lighter products beyond a certain volume, or products close to their auto-ignition temperature
- Use of a detection system that includes fire, gas, heat, and smoke detectors to immediately detect any release of hydrocarbon at the earliest stage of development
- Location of the main control room outside the hazard area to facilitate rapid plant shutdown in an emergency.

CSA standard Z276-11 provides provisions for flammable mixture dispersion distances and radiant heat distances to protect the public beyond the boundaries of the facility from fires related to LNG releases. The standard specifies minimum distances from LNG tank impoundment areas to the nearest facility property line to allow for sufficient vapour cloud dispersion, such that an average concentration of methane in air of 50% of the LFL does not extend beyond the property line (as calculated through the use of a vapour dispersion model validated by experimental test data). CSA Z276-11 also specifies exclusion distances meant to prevent radiant heat flux (heat transfer) from a fire from exceeding specified thresholds at property lines and adjacent occupancies. Both vapour dispersion modelling and radiant heat modelling must take into account physical factors specific to the facility location that may affect the dispersion of LNG vapours and radiant heat from a fire (e.g., ambient temperature, relative humidity, and wind speed), in addition to accounting for mitigation design features, such as impoundment dikes and water curtains unique to the facility's containment configuration.

In addition to potential fires and explosions at the terminal facility, fire and explosion could also potentially occur on an LNG carrier. Small fires and explosions in the engine room, on deck, or in the accommodation areas would be controlled by suitable fire detection systems and automatic fire fighting, in addition to manual firefighting response by trained vessel staff. The modern LNG carriers to be used for this Project use gas vapour from the LNG boil-off as fuel for the machinery, resulting in no operational venting of gas from the boil-off, which thereby reduces the risk of fire or explosion.

22.5.3 Emergency Response Approach

The Project's ERP would be initiated in any emergency. The general response to an emergency situation, including a fire or explosion, would include the following actions and be scaled to suit the severity of the incident:

- Initiation of Tier 1 response for the emergency
- Assessment of the situation with regard to personal and public safety, and evacuate personnel from the hazard area
- Notification of immediate supervisor to provide an assessment of incident location, area potentially affected, and other hazards
- Administration of first aid as necessary
- Determination of the need for escalation to Tier 2 or Tier 3 response measures
- Notification of appropriate regulatory agencies, affected stakeholders, Aboriginal groups, and local governments
- Assessment of the need to shut down the facility to reduce risk to personnel and equipment

- Implementation of control procedures with available personnel and equipment to reduce effects, if risk is deemed low
- Establishment of an incident command post with required communication between internal and external parties
- Establishment and maintenance of a secure incident scene
- Completion of incident reports (internal and external for regulatory authorities, as required).

Depending on the severity of the fire or explosion incident, public authorities would only take control of response operations for reasons of public safety, national interest, or if it is determined that the project emergency management team is unable to effectively manage the situation.

22.5.4 Clean-Up and Restoration Methods

Once the fire or explosion is completely extinguished, investigation and inspection crews would begin to determine the cause. Necessary information, materials, witness accounts, and computer logs would be obtained through this process. Associated equipment involved in the fire or explosion would be inspected, retested, and replaced if damaged. Equipment that meets the standards associated with the project approvals and design standards would be re-stamped and issued as compliant. Project components would then be retested as a group, and project start-up procedures would be introduced to begin operations. Waste materials from the accident would be recycled or disposed of at a licensed facility. Contaminated soil or materials (on or offsite) would be disposed of at an approved waste facility. Once all excavation work associated with the incident is complete, the necessary sampling and reporting procedures would be conducted, and damaged terrestrial areas would be remediated to the appropriate land remediation standard.

22.5.5 Potential Environmental Effects

22.5.5.1 Air Quality

A fire or explosion restricted to the combustion of natural gas in a worst-case scenario would result in the emission of air contaminants equivalent to the emergency flaring scenario presented in Section 22.4.5 but over a shorter duration. This scenario is predicted to have only an incrementally larger effect on air quality than the emergency flaring scenario. As with worst-case emergency flaring, a fire or explosion would result in the release of approximately 14.8 kg/h of SO_2. The additional potential combustion of a chemical such as a motor fuel or hydraulic oil would be only incrementally more serious because of the relatively small quantities of such materials at the project site. Combustion of various hydrocarbon-based operational chemicals would generate primarily CO_2, CO, and water vapour. Smoke and other particulate matter would impair air quality for the duration of the fire.

22.5.5.2 Greenhouse Gas Management

A fire or explosion restricted to the combustion of natural gas in a worst-case scenario would result in the emission of GHGs similar in quantity to the emergency flaring scenario presented in Section 22.4.5 but over a shorter duration. As with worst-case emergency flaring, a fire or explosion would result in the emission of approximately 3,020 kg/s of CO_{2e} (or 10.9 t of CO_{2e} released during a 1-hour period).

22.5.5.3 Acoustic Environment

An explosion would create an acoustic disturbance that is temporary and short term in duration.

22.5.5.4 Ambient Light

Increases to ambient light near the Project in the unlikely event of a fire or explosion are anticipated to be short term in duration.

22.5.5.5 Vegetation and Wetland Resources

It is not anticipated that vegetation and wetland resources would be affected by a contained fire or explosion at the liquefaction facility. However, in the unlikely event of a fire escaping the facility boundaries and igniting a wildfire, there is a possibility of loss of vegetation in the riparian buffer through burning. This effect is likely reversible through subsequent regrowth.

22.5.5.6 Terrestrial Wildlife and Marine Birds

Terrestrial wildlife (e.g., small mammals, amphibians, and birds) and marine birds that are present within the boundaries of the facility at the time of a fire or explosion incident could be injured or killed during the fire or explosion. Potential for mortality would be greatest for species with limited dispersal abilities (e.g., small mammals, amphibians, and nesting songbirds), although it is unlikely that there would be a population-level effect. Species that are highly mobile, such as large mammals and adult terrestrial or marine birds, would likely disperse from the area.

22.5.5.7 Marine Resources

Effects on marine resources are assessed in the context of a vessel-based explosion resulting from RPT during an LNG spill. While the hazards associated with RPT would be localized to the spill area, there is the potential for acoustic effects on marine organisms, particularly marine mammals, as a result of the blast. Such effects are unlikely given that the timing would have to coincide with the presence of a marine mammal in the immediate vicinity of the explosion. Fish are more likely to be present should RPT take place, and shockwaves could result in high fish mortalities, but it is unlikely that this would result in population-level effects on fish species.

22.5.5.8 Economic Environment

Any reduction in access to marine resources (Section 22.5.5.9) from an explosion or fire could in turn have negative effects on incomes associated with marine use activities, causing an adverse effect on the economic environment.

22.5.5.9 Navigation and Marine Resource Use

Should an explosion or fire occur, regulator concerns in the case of fish mortality may lead to fishery closures, which would reduce access to marine resources.

22.5.5.10 Infrastructure and Services

A fire at the liquefaction facility would likely be contained within the facility boundaries and responded to internally by PNW LNG personnel. In the unlikely event of a large-scale fire or explosion that escalated to a Tier 2 or Tier 3 emergency and required external emergency response resources, there could be increased strain on local infrastructure and services (e.g., firefighting and medical services). The likelihood is extremely small.

22.5.5.11 Visual Quality

A large fire or explosion would have a short-term, reversible effect on the visual quality of the surrounding area. The flames and smoke associated with a fire would likely temporarily impede visibility in and around Lelu Island.

22.5.5.12 Community Health and Well-Being

A large fire or explosion that resulted in injury or death of onsite personnel could have an effect on the health and well-being of the communities that personnel originated from. Such accidents or malfunctions would be highly unlikely, but community counselling and trauma support services would be provided to mitigate effects in the event of injury or death of personnel.

22.5.5.13 Human and Ecological Health

The human and ecological health effects related to inhalation of criteria air contaminants following combustion of methane from a fire or explosion are expected to be no greater than those associated with a worst-case emergency flaring situation (Section 22.4.5). Because of the likely short duration and relatively low levels of SO_2 released, adverse effects on human health from inhalation of air contaminants would be not significant. Sensitive human receptors would not experience adverse effects from short-term changes to air quality from an explosion or fire. Population-level effects in ecological receptors are also not anticipated.

The possibility of injury (e.g., burns) or direct mortality is another threat to human and ecological receptors posed by an explosion or fire. Individual risk can be quantified in terms of a location-specific individual risk (LSIR), which is the risk of fatality experienced by a single individual located in a specific location for 24 hours per day, 7 days per week, 52 weeks per year (this value does not include a presence factor to account for the actual amount of time a person would be expected to spend in a given area). The maximum offsite LSIR has been calculated to be less than 1.0×10^{-7} (one in ten million) fatalities per year, which falls well below the United Kingdom Health and Safety Executive (which develops industry standard risk criteria) tolerability criteria of 1.0×10^{-4} (one in ten thousand) fatalities per year for members of the public, and below PETRONAS' tolerability criteria of 1.0×10^{-6} (one in one million) fatalities per year for members of the public (Det Norske Veritas 2013b). Thus, effects to offsite human populations from a fire or explosion are expected to be not significant. Furthermore, the neighbouring communities of Port Edward and Prince Rupert fall outside the maximum flammable hazard zone (Figure 22-1) calculated for various scenarios resulting from the release of LNG during loading operations, which are discussed further in Section 22.7.

Risks to onsite workers from a fire or explosion fall outside the scope of this assessment and will be addressed during the occupational health and safety permitting phase of the Project.

22.5.5.14 Archaeological and Heritage Resources

Archaeological and heritage resources would not be affected by a contained fire or explosion at the liquefaction facility. However, in the unlikely event of a fire escaping the facility boundaries and igniting a wildfire, there is a possibility of loss of vegetation through burning. Such a fire or explosion could result in irreversible damage to culturally modified trees (CMTs) that are present in the riparian buffer that is to be preserved.

22.5.5.15 Current Use of Land and Resources for Traditional Purposes

Following construction, access to Lelu Island for hunting, fishing, marine harvesting, and gathering of trees and plants will be restricted. Incremental effects on the current use of land and resources on Lelu Island for traditional purposes beyond those anticipated from construction and routine operations are not anticipated from a fire or explosion scenario. However, a fire at the facility that escalates into a forest fire on the mainland could potentially affect Aboriginal groups' use of land for traditional purposes, including harvesting activities and cultural practices.

Furthermore, any explosion or fire that leads to a reduction in access to marine resources (Section 22.5.5.9) could lead to a reduction in use of marine resources for traditional purposes. Fire or explosion causing destruction of plants and trees and wildlife mortality would result in a diminished capacity to harvest certain preferred species. Such a scenario is considered to be highly unlikely given the natural barriers to wildfire spreading that exist at the project site (e.g., precipitation and marine channels), or localized in nature in the case of RPT.

22.6 Scenario 3: Fuel or Hazardous Materials Spills

22.6.1 Description of the Possible Scenario

Motor fuel (i.e., gasoline or diesel) and fluids (e.g., oil, hydraulic fluid) for vehicles and machinery are expected to be used in large quantities throughout the life of the Project. Various other hazardous or toxic liquid wastes (as specified under the BC *Environmental Management Act* (2003) Hazardous Waste Regulation, and Schedule 1 of CEPA (1999) have the potential to be generated during project activities, including:

- Solvent- or hydrocarbon-contaminated wastewater (including hydrostatic test water) and surface runoff
- Mercury removed from the feed gas during the natural gas liquefaction process (trace amounts)
- Waste catalysts and adsorbents
- Waste lubricating oils
- Spent solvents
- Untreated sewage (to be piped to the neighbouring municipal system for treatment).

Although the components of LNG are considered hazardous materials, a spill of LNG is considered in a separate scenario (see Section 22.7) given the larger volumes to be handled by the Project and the unique properties of LNG that govern its fate and behaviour when released in the environment.

While all hazardous wastes used for and generated by the Project would be handled and stored according to applicable regulations, a spill could occur, potentially releasing one or more of these substances to the environment. A credible, worst-case scenario of a hazardous material spill associated with the Project would be the moderately unlikely spill of 12,000 L of diesel fuel to a watercourse on Lelu Island, with subsequent migration to the surrounding marine environment. Such a release could originate from a rupture of a fuel storage tank onsite or a vehicular collision involving a fuel transport truck. Given there will be only trace amounts of mercury generated annually over the project's lifetime, quantities of mercury are not sufficient to warrant further consideration of a spill scenario for this hazardous material.

The magnitude of environmental effects associated with a large-scale fuel spill depends on the chemical composition of the spilled product, the volume that is released, the exact location where the release occurs (e.g., proximity to a sensitive environment), the timing of the spill (e.g., whether meteorological conditions will contribute to evaporation of spilled hydrocarbons) and the success of response operations. Spilled fuel could potentially affect vegetation, soil or sediment, water, and wildlife.

22.6.2 Project Design Measures to Reduce Risk

PNW LNG, in conjunction with all contractors and subcontractors, will take measures to reduce the risk of a spill of fuel or other hazardous materials associated with the Project:

22.6.2.1 Design Controls

- Fuel and hazardous waste storage tanks will be designed and operated as per the specifications of the BC *Environmental Management Act* (2003), the BC Fire Code (2006), the National Fire Code of Canada (2010), the recommendations included in the *Field Guide to Fuel Handling, Transportation and Storage* (BC MOE 2002), and the *Environmental Code of Practice for Aboveground and Underground Storage Tank Systems Containing Petroleum and Allied Petroleum Products* (Canadian Council of Ministers of the Environment 2003). For example, secondary containment systems will be designed such that they have a volumetric capacity of 110% of the tank capacity for an aboveground storage tank system that consists of a single tank (CCME 2003).
- Drainage systems will be in place for continuous oil contaminated water collection, accidently contaminated water collection, and collection of process effluent.
- An amine drainage system for the acid gas recovery unit will be used.
- Storage of hazardous materials will be prohibited less than 100 m from waterbodies and other sensitive habitats.
- Designated refueling and heavy equipment maintenance areas will be situated more than 100 m from waterbodies and sensitive habitats.
- Spill containment kits (with contents such as absorbent pads and socks, specialized personal protective equipment [PPE], and disposal bags or bins) will be located at strategic locations throughout the project site and will be regularly maintained and replenished following an incident.

22.6.2.2 Management Controls

- All construction and operations management programs and plans (e.g., the construction environmental protection plan developed for the Project) will incorporate requirements for the safe handling and storage of hazardous materials and spill contingency measures, and will be properly enforced. Such procedures will be in compliance with the Workplace Hazardous Materials Information System (WHMIS), as established under the *Hazardous Products Act* and associated Controlled Products Regulations.

- All drivers will be trained in safe driving procedures and will be required to adhere to strict driving safety precautions (e.g., defensive driving training, speed limit adherence). The transport and handling of any hazardous materials associated with the Project will be in compliance with the *Transportation of Dangerous Goods Act.*
- All machinery and heavy equipment will be regularly maintained according to manufacturer and mechanic recommendations.
- All operations employees, contractors, and subcontractors of PNW LNG will be trained and equipped to provide initial response for spills of fuel or other hazardous materials.
- All employees, contractors, and subcontractors of PNW LNG will be trained in the appropriate communication and notification protocols for a spill of fuel or other hazardous materials.

22.6.3 Emergency Response Approach

In the event of a hazardous materials spill, actions would be initiated to protect human safety as a priority. Once the area is deemed to be safe, measures would be taken to control the source of the spilled material and contain the spill to prevent further migration. Appropriate actions and best management practices, to be outlined in greater detail in the ERP for the Project, would follow the general steps described previously in Section 22.5.3 and would be scaled for the severity of the incident. Emergency response actions specific to a spill of fuel or hazardous materials would include:

- Closing of valves and securing of the hazardous material in its containment vessel to eliminate the source of the release (this may involve temporarily patching a tank or transferring to another tank if the original is severely compromised)
- Containment of spilled material to prohibit migration from the release site
- Assessment of spill response and cleanup options
- Implementation of spill response and clean-up measures (e.g., deployment of absorbent pads or excavation of affected soil), including disposal at approved hazardous waste facilities.

Depending on the severity of the incident, PNW LNG may engage the services of a third-party spill response contractor to support the spill response, as necessary.

22.6.4 Clean-Up and Restoration Methods

The response to a hazardous materials spill would vary greatly depending on a number of factors, such as the physical chemical characteristics of the material spilled, the nature of the affected environment, and the quantity of the spilled substance. Clean-up and restoration efforts, such as removal of hydrocarbon-affected soil or sediment, could reverse the effects of a spill on the environment. All clean-up and restoration efforts would be ranked using the net environmental benefit analysis approach, whereby the benefits of various alternatives (e.g., natural attenuation, in situ bioremediation, or removal and off-site disposal of affected materials) are compared to the environmental damages that may result from such activities. This approach allows choosing of the response option that provides the most benefit to the environment affected by the release.

Clean-up methods could range from the application of absorbent pads on a small volume spill of diesel fuel on a concrete surface, to the excavation and removal of affected soil resulting from a large-scale fuel release into the surrounding environment. Spills migrating to the marine environment could be contained with absorbent booms. All clean-up and restoration activities would be approved by the appropriate regulatory agencies.

22.6.5 Potential Environmental Effects

22.6.5.1 Air Quality

A fuel or hazardous material spill would have a low to negligible effect on air quality. This type of an incident is most likely to occur in the project development area and would be managed to acceptable levels through site-specific emergency response procedures. Containment for hazardous materials storage will be designed in accordance with the BC Fire Code and the material safety data sheet guidelines.

22.6.5.2 Vegetation and Wetland Resources

Vegetation directly affected by the spill of a hazardous material could be harmed or destroyed. Effects on vegetation would be localized to the area of the spill and would be largely or entirely reversible through regrowth or restoration activities, such as replanting affected species. Furthermore, a spill is most likely to occur in the project development area (where the hazardous materials are stored); this area will have very little vegetation.

22.6.5.3 Terrestrial Wildlife and Marine Birds

A fuel or hazardous materials spill could result in the release of oil, fuels, or lubricants into the terrestrial environment. The magnitude of effects on terrestrial wildlife and marine birds would be influenced by the type and volume of materials released, and the season and habitat in which the accident occurs.

Terrestrial wildlife and marine birds could suffer effects from acute exposure to hazardous materials through direct contact, ingestion of contaminated sediment or prey, inhalation, or absorption (Leighton 1993). These effects would be greatest in habitats that support large concentrations of wildlife or during seasons when wildlife abundance and richness is higher (e.g., migration or breeding). However, a spill would be most likely to occur at the onsite storage tanks of hazardous materials and would be contained within the boundaries of an industrially developed facility designed to exclude wildlife. If required, additional fencing or other exclusion or hazing devices would be used to divert wildlife from the release site until any threats posed by the spill were eliminated. These techniques could alter foraging, breeding, and localized migration habits of terrestrial wildlife species; however, such effects would be localized and temporary.

22.6.5.4 Freshwater Aquatic Resources

Only two watercourses on Lelu Island are classified as fish streams, potentially providing habitat for fish. These streams will be infilled during construction; thus, it is not anticipated that freshwater aquatic resources would be exposed to hazardous materials or fuel in the event of an accidental spill.

22.6.5.5 Marine Resources

Marine life in the estuarine area adjacent to Lelu Island would only be affected if a spill in the terrestrial or aquatic environments on Lelu Island migrated to the marine environment. A spill of sufficient magnitude required to reach the marine environment, especially of a volatile substance such as fuel or diesel, is considered to be extremely unlikely. Confinement or diversion at potential spill sources within the facility would be achieved through curbs, dikes, and trenches, and stormwater separators will be used to prevent the offsite migration of hydrocarbons. In the unlikely event that a fuel spill was not retained within the facility by these containment measures, or in the event of a release of fuel or oily bilge water directly from a vessel, effects on the organisms living on the water surface and in the water column from liquid hydrocarbon product would likely be localized to a small area of the marine environment but could be as serious as mortality. The project ERP would include identification of habitats that may be particularly sensitive to a release of hydrocarbons, such as the eelgrass bed on Flora Bank or along the shore of Lelu Island near the trestle pilings, and would therefore be a priority for protection.

22.6.5.6 Economic Environment

Any reduction is access to marine resources (Section 22.6.5.7) from a fuel or hazardous material spill could in turn have adverse effects on incomes associated with marine use activities, causing an adverse effect on the economic environment.

22.6.5.7 Navigation and Marine Resource Use

Should a fuel or hazardous material spill occur, spill response efforts would likely restrict access to the area. Regulator concerns about the viability of a fishery because of the spill may lead to fishery closures, which would reduce access to marine resources.

22.6.5.8 Human and Ecological Health

Spills of fuels, hazardous materials, and wastewaters containing residual hydrocarbons and solvents in the terrestrial environment could lead to potential health risks for ecological receptors and humans in the area. Potential exposure could occur through direct dermal contact with chemicals, inhalation of vapours, or ingestion, although dermal contact would be the most likely exposure route.

The accidental release of untreated sewage could also pose a potential health risk of bacterial infection or illness in people and potential chemical exposure to ecological receptors near a spill.

The potential for adverse health risks to humans or to ecological receptors will be mitigated through appropriate spill response management to limit the potential for biological exposures. Steps would be taken to isolate any spill zones from the public, which would in turn eliminate the possibility of any serious effects on human health related to a hazardous materials spill. Similarly, wildlife would be excluded from the spill area using techniques previously discussed (e.g., fencing, hazing devices).

22.6.5.9 Archaeological and Heritage Resources

Vegetation, including CMTs, directly affected by the spill of a hazardous material could be harmed or destroyed. Effects on vegetation would be localized to the area of the spill, which is most likely to occur in the project development area (where the hazardous materials are stored); this area will have very little vegetation and no CMTs.

22.6.5.10 Current Use of Lands and Resources for Traditional Purposes

A hazardous materials spill within the confines of the liquefaction facility would not affect the use of land and resources by Aboriginal groups for traditional purposes, such as harvesting or hunting. In the unlikely event of a hazardous materials spill that extended beyond the boundaries of the facility, use of land and resources for traditional purposes (e.g., gathering of trees and shrubs for food, materials, and medicinal purposes) could be temporarily disrupted in localized areas during spill response and reclamation activities. However, a spill into the marine environment that leads to a reduction in access to marine resources (Section 22.6.5.7) could lead to a reduction in use of marine resources for traditional purposes.

22.7 Scenario 4: LNG Spills

22.7.1 Description of the Possible Scenario

LNG spills associated with the terminal storage or loading facilities could originate from leaks within the upland storage facility, along the loading line, or at the loading arm that connects to the berthed vessels receiving the LNG. These releases could affect the terrestrial or marine environments.

The storage facility on Lelu Island will be designed to accommodate up to three 180,000 m^3 full containment LNG storage tanks (two to be constructed in Phase 1, with provision for a third in Phase 2). A possible accident or malfunction scenario would involve the release of LNG to the terrestrial environment from these onsite storage tanks or from a location in the liquefaction train. According the CSA Z276-11, LNG facilities must be designed with containment facilities (such as dikes, berms, or impounding walls) that have sufficient capacity to contain a variety of design spills (potential spills whose size is based on the design of the facility, especially storage volumes and flow rates). The designs of LNG tanks and LNG carriers make it extremely unlikely that a spill would occur from a tank or a carrier.

While still very unlikely (recurrence of 7.6 times in 10,000,000 years), the credible worst-case scenario considered for an LNG spill is a full rupture (diameter of 500 mm) of the loading line at the marine terminal. In the event of a pipe rupture or equipment malfunction during LNG loading, a release at the full flow rate (15,000 m^3/h) through the pipeline could be possible until shutdown could be completed. One of the two emergency shutdown valves could be used to complete shutdown, which would normally take approximately 30 seconds. However, it is possible that some aspects of the emergency shutdown system could be disabled by a malfunction. Thus, the worst-case credible loading line rupture accident scenario would be associated with a four-minute shutdown time (and therefore release duration) because of the time between recognizing the situation and activating the emergency shutdown valve. This scenario would result in the release of 1,000 m^3 (15,000 m^3/h ÷ 60 min/h x 4 min = 1,000 m^3) of LNG, likely into the marine environment (Det Norske Veritas 2013a). This scenario could result if the berthed vessel suddenly pulled away from the trestle or drifted off from its mooring during loading operations. A powered emergency release coupler protection system would be in place to limit the volume of LNG released; however, if this did not function properly, emergency shutdown is again assumed to take four minutes.

LNG has an atmospheric boiling point of −160ºC; thus, at atmospheric conditions, an LNG spill on land would result in a cloud of natural gas vapours extending up to 1,850 m from the release point. In the unlikely absence of strong winds, spilled LNG would initially sink and hug the topography as a result of the sub-cooled LNG vapour being denser than air. This could cause localized freezing of the immediate areas and potential frost damage to biota. As the cloud warmed, the vapour would become lighter than air and would rise into the atmosphere and disperse. The cloud would continuously dissipate as the natural gas diluted with the surrounding air. However, if the cloud was ignited by a spark or flame, portions of the cloud with a concentration of gas-in-air between 5% and 15% (i.e., between the LFL and UFL, see Section 22.5) would burn. Unlike gasoline and diesel fuel, an LNG spill would not result in soil contamination or leave any residue once evaporated.

An LNG spill that subsequently resulted in fire or explosion would involve an emergency response as detailed in Section 22.5. Potential environmental effects from fires and explosions are also described in this section.

22.7.2 Project Design Measures to Reduce Risk

Engineering controls will be incorporated into the Project for efficient operations and reduced risk of LNG spillage. Prior to the commencement of construction activities, a risk assessment will be conducted to establish high-risk locations and activities (including transportation and marine activities), identify measures to reduce identified risks to as low as reasonably practical, and develop site- and activity-specific response measures. Other engineering controls to be incorporated include:

- Impounding areas for LNG storage tanks will be designed as per the specifications of the CSA Z276-11 standard (e.g., 110% of the maximum volumetric holding capacity of the LNG container, for an impounding area serving a single container).
- Facilities will provide grading, drainage, or impoundment for vaporization, process, or transfer areas able to contain the largest total quantity of LNG or other flammable liquid that can endanger important structures, equipment, nearby property, or reach waterways.
- Facilities will be designed to reduce LNG congestion and contained spaces where LNG vapour could accumulate and explode if ignited.
- Flammable liquid and flammable refrigerant storage tanks will not be located within an LNG container impounding area.
- Material selection for piping and equipment that can be exposed to cryogenic temperatures will follow international design standards.
- LNG tanks will be fully contained within a primary and secondary containment system. The primary containment will be designed for low temperatures and will be manufactured of nickel steel for full containment tanks and corrugated stainless steel for membrane tanks. The secondary containment system is designed for isolation of leaks or spills from the primary containment tanks.
- All tank piping will enter and exit the tank from the top, above the liquid level, so that there is no side or bottom penetration, which removes the risk of LNG leakages at nozzle connections.
- Protection barriers (e.g., high and low temperature alarms, level and pressure controls, and emergency shutdown systems) will be incorporated to enable immediate isolation of a system in the event of a serious LNG leak. For example, powered emergency release coupler protection will be used at the vessel loading arm to limit the volume of LNG released in the event of an accident or malfunction.

- Facilities will be equipped with a system for the early detection of gas releases, designed to identify the existence of a gas release and to help pinpoint its source so that operator-initiated emergency shutdown systems can be rapidly activated, thereby minimizing the inventory of gas releases.

Administrative controls, such as safe work procedures and work permitting processes, will also be implemented as measures to prevent LNG spills.

As per industry standards and requirements, work sites and equipment will undergo regular maintenance and inspection, personnel qualifications will be maintained, and proper documentation will be reviewed and updated on a regular basis. Supervisors will conduct risk assessments for activities deemed necessary to identify the potential hazards and take appropriate conservative measures.

Industry standard PPE, specific to accidental spills, would be provided to staff and contractors to prevent worker injury should a spill occur.

In the event of an LNG spill, a post-incident investigation would be conducted to identify the cause of the incident and identify corrective and preventive action to prevent recurrence.

22.7.3 Emergency Response Approach

In the event of an LNG spill, the primary goal would be to protect human safety, and when safe to do so, contain the material at the source and keep it from moving offsite. Appropriate actions and best management practices, to be outlined in greater detail in the ERP for the Project, would follow the general steps described previously in Section 22.5.3 and would be scaled for the severity of the incident. An emergency response action specific to a spill of LNG would involve:

- Implementation of control procedures with available personnel and equipment to reduce effects, if risk is deemed low. Control procedures will include use of a fire water monitor to disperse the vapour cloud, water curtains around the source of leak, and a standby foam generator as precautionary measures.

Should the vapour cloud ignite, the emergency response approach used for fire or explosion would be followed (Section 22.5.3).

22.7.4 Clean-Up and Restoration Methods

Once the vapour cloud is fully dispersed and confirmed with a gas test, corrective action would follow to address the leak source. Upon rectification, associated equipment would be checked and confirmed to be fit for service prior to service resumption.

A thorough investigation would follow to identify the cause of the leak and other inherent failure to prevent recurrence. All necessary information, materials, witness accounts, and computer logs would be obtained through this process.

If sufficient volume is spilled to the marine environment, LNG could pool on the surface of the seawater, freezing the top layer of water beneath it, before vapourizing and dispersing. Given that LNG does not persist in the environment; is odourless, colourless, and non-corrosive; leaves no residue; and is non-toxic to marine biota, no clean-up actions are anticipated to be necessary as a result of an LNG spill. If the interaction of the cold liquid with marine habitats resulted in environmental effects (e.g., fish kills), these environments would be surveyed to determine the appropriate restoration or compensation activities required.

In the event of fire, appropriate clean up and restoration activities would be conducted (Section 22.5.4).

22.7.5 Potential Environmental Effects

22.7.5.1 Air Quality

The vaporized cloud generated by an LNG spill would consist almost entirely of methane (97% methane, 2% ethane and very small amounts of heavier hydrocarbons). Impurities will be removed by the facility during processing of incoming feed gas. Since methane gas is lighter than air, it would disperse quickly to the atmosphere without any serious effect on air quality. In the unlikely absence of wind, the cloud would disperse more slowly, but would still not have any serious effect on air quality.

22.7.5.2 Greenhouse Gas Management

A spill of LNG would result in an incremental increase in GHG emissions. These emissions would be negligible in comparison to GHG emissions during normal operations and in the context of the provincial and national GHG totals.

22.7.5.3 Terrestrial Wildlife and Marine Birds

An LNG spill could result in injury or acute mortality of terrestrial wildlife and marine birds through inhalation and asphyxiation from concentrated vapours in the immediate vicinity of the spill site or localized freezing. However, an LNG spill to the terrestrial environment would most likely be constrained within the boundaries of the terminal site, which is an industrial facility designed to exclude wildlife. Vapours are expected to rapidly dissipate from the spill site, as the natural gas dilutes into the surrounding air. The potential for mortality would decline rapidly as distance from the spill site increases. The magnitude for a potential effect would be low given that lethal effects from LNG vapours are localized to the vicinity of the spill site. Project design and emergency response activities are expected to further decrease the potential for an effect.

22.7.5.4 Marine Resources

A release of LNG to the marine environment is not expected to result in toxic effects on marine biota (refer to Section 22.7.5.7). An LNG spill could, however, result in injury or acute mortality of marine wildlife and vegetation through combustion, explosion, or localized freezing. Although these effects could be locally important (e.g., mortality of wildlife or sensitive marine vegetation, such as eelgrass beds), they would be localized to the spill area and decline rapidly with increased distance from the spill site. Project design, emergency response, and restoration activities are expected to further decrease the potential for a serious effect. However, if a spill were to occur over Flora Bank, at a low tide, during a period of high juvenile salmon abundance, there could be effects on local salmon populations.

22.7.5.5 Economic Environment

An LNG spill could result in injury or acute mortality of species that are of commercial economic importance, such as Dungeness crab, salmon, and shrimp (see Section 15 – Navigation and Marine Resource Use). Such effects would be localized to the spill area and decline rapidly with increased distance from the spill site. However, any concerns by regulators about viability of populations (Section 22.7.5.6) could lead to more long-term economic effects.

22.7.5.6 Navigation and Marine Resource Use

While it is not anticipated that an LNG release at the storage or loading facilities would result in an effect on marine navigation, there may be limitations on access and effects on harvesting of marine resources, such as marine fish and invertebrates. Such effects would be localized to the spill area and decline rapidly with increased distance from the spill site. However, if regulators closed a fishery over potential concerns arising from an LNG spill (see Section 22.7.5.4), a more long-term reduction in access to marine resources would result.

22.7.5.7 Human and Ecological Health

Low concentrations of methane are not harmful (CCOHS 2013). The main route of exposure to methane is through inhalation, which may cause drowsiness, headaches, dizziness, and possibly unconsciousness or asphyxiation at higher concentrations because of oxygen deficiency. Similar effects may be expected in wildlife and birds. Direct dermal contact with LNG may also cause frostbite or potential mortality resulting from freezing. Potential direct effects from exposure to LNG would be limited to the area very close to the spill site, as the LNG would rapidly evaporate and disperse.

The potential for adverse health risks to humans or to ecological receptors would be mitigated through appropriate spill response management to limit the potential for biological exposure. As a result, there are not anticipated to be any long-term effects on human and ecological health as a result of an LNG spill.

22.7.5.8 Current Use of Land and Resources for Traditional Purposes

Mortality of terrestrial or marine wildlife and marine birds from an LNG spill would diminish capacity for Aboriginal groups to use the area for traditional purposes. Any reduction in access to marine resources (Section 22.7.5.6) could also affect current use of these resources for traditional purposes.

22.8 Scenario 5: Marine Vessel Grounding, Collision, or Allision

22.8.1 Description of the Possible Scenario

Purpose-built LNG carriers will be used to ship the LNG product from the marine terminal on Lelu Island out through Chatham Sound and on to Asian markets using pre-established shipping routes to the Port of Prince Rupert. The first phase of the Project (beginning in 2019) will see one LNG carrier berthed at the terminal every two days. This will increase to approximately one LNG carrier per day (350 per year) berthing at the terminal at full build out (Phase 2). Although the marine terminal will accommodate a variety of vessel sizes, the largest will be the Q-flex LNG carrier, which is 315 m in length, 50 m in width, and has a deadweight tonnage (DWT) of 106,897 t. This vessel has the capacity to carry approximately 217,000 m^3 of LNG in five tanks (each tank having a capacity of approximately 43,000 m^3).

Three credible, worst-case scenarios related to the shipping of LNG in BC coastal waters discussed are:

- Grounding or allision with the marine terminal of an LNG carrier

- The collision of an LNG carrier with another vessel
- The collision of an LNG carrier with a marine mammal.

An allision describes the act of striking a stationary object, in contrast to a collision, which involves two moving objects. Such incidents could result from human error, mechanical malfunction, or coincidental timing (in the case of a collision between a vessel and marine mammal), and are considered to be possible although unlikely.

22.8.1.1 Scenario 5-A: Grounding or Vessel Allision with the Marine Terminal

Because LNG carriers will likely be the largest vessels operating near the Project, this credible worst-case scenario involves an LNG carrier. Because large vessels near the terminal will be moving slowly, and under the control of tugs and pilots, an allision with the terminal is considered very unlikely to occur and unlikely to result in damage. Thus, grounding of a Q-Flex LNG carrier (the largest associated with the Project) is considered the credible worst-case scenario.

LNG Carrier or Other Project Vessel Grounding

LNG vessels have an excellent safety record, with only two serious groundings in the last 30 years, neither of which resulted in the loss of any cargo. The grounding of the *El Paso Paul Kayser* in 1979 involved the vessel striking a pinnacle rock in the Mediterranean at a speed of 19 knots. In 1980, the *LNG Taurus* ran aground outside Tobata Harbour, Japan, at a speed of 12 knots. Both incidents resulted in damage to the outer hull, with the internal LNG tank of the *El Paso* vessel being compromised, but not leaking. These accidents demonstrate the inherent strength of double-hulled LNG carriers.

The majority of the sailing route for LNG carrier transit to and from the PNW LNG terminal is open and deep, making it largely free of navigational hazards. However, navigational challenges may be encountered in Brown Passage between the Tree Nob Group and Hanmer Rocks, and in the approach to the Triple Island Pilot Boarding Station (Det Norske Veritas 2013a). A powered grounding may result from navigational errors, propulsion or steering failure, or emergency manoeuvers to avoid collision with another vessel.

One of the hazards under such a scenario would be the release of heavy fuel oil to the marine environment. While Canadian regulations prohibit LNG tankers from using heavy oil fuel, most carriers still carry heavy fuel oil for use on the open sea. The worst-case credible consequence from the grounding of an LNG carrier would be the loss of the contents from one fuel tank. The vessels used for this Project would conform with 2010 International Maritime Organization requirements and, as such, would be designed with protected bunker tanks with individual sizes not exceeding 2,500 m^3. As it is assumed that no refueling will take place at the terminal and tanks will be half full, the maximum amount of bunker fuel that could be released during a grounding incident is 1,250 m^3 (Det Norske Veritas 2013a). As with the release of heavy fuel oil in the terrestrial environment, effects associated with a release of heavy fuel oil to the marine environment would depend on various factors unique to the specific incident, such as the quantity of deleterious substances released, the physical–chemical properties of the substance spilled, the environmental conditions at the time of the release (e.g., wind speed and direction, wave action, tidal activity), and the overlap of the release in space and time with marine species and their vulnerable life history stages (e.g., during juvenile salmon out-migration from the Skeena River).

An LNG spill is considered extremely unlikely but is also considered for this scenario. Should a loss of LNG containment occur, up to 43,000 m^3 (the capacity of single LNG carrier tank) could be spilled into the marine environment (Det Norske Veritas 2013a). It is estimated that the vapour cloud from such a release would be extend 1,700 m from the spill site, which could occur at any location along the shipping route (Det Norske Veritas 2013a), as shown in Figure 22-1 for the Chatham Sound portion of the shipping route. If the release rate from the spill were high enough, an RPT explosion could occur.

Given that the transit routes of construction-related vessels used for the Project would be primarily into the confined waters of Porpoise Channel that provide access to the material offloading facility (MOF), grounding of these vessels is also a potential concern. However, construction vessels will be under the control of BC Pilots from Triple Island and escorted by or tethered to tugs from the time the vessels enter the approaches of Porpoise Channel at Agnew Bank and after departure from the MOF. Furthermore, the grounding of a construction-related vessel is not expected to result in the release of any diesel or bunker oil (Det Norske Veritas 2013a) because the vessels will be maneuvered at such slow speeds into and out of Porpoise Channel that their bunker tanks could not be penetrated. Thus, the grounding of a construction vessel is not deemed to be a credible worst-case scenario and is not considered further.

LNG Vessel Allision with the Marine Terminal

It is possible that an LNG carrier could strike the dock structure during berthing operations because of human error or mechanical failure of the LNG carrier or support vessels. As berthing operations are supported by at least three tugs, the likelihood of high consequences is low given this is a low-energy allision. The worst-case credible scenario would involve a side-on impact of the LNG carrier with the dock structure. It is not likely that such an allision would have sufficient energy to result in a failure of the containment tanks or subsequent release of LNG, diesel fuel, or bunker oil (Det Norske Veritas 2013a).

Passing Vessel Allision with the Marine Terminal

If the impact of a passing, non-project vessel was sufficient, significant damage to the trestle or loading platform could result. A subsequent rupture in the loading pipeline or LNG circulation pipeline could occur if the impact energy was substantial.

The marine traffic in the terminal vicinity is comprised of medium- and large-sized dry bulk vessels, large container vessels, BC ferries, and smaller fishing and recreational vessels. The primary sailing route for the bulk and container vessels transiting to and from Prince Rupert Harbour is southeast of Kinahan Islands, then north towards Prince Rupert and Ridley Island. BC ferries transit north–south, passing within 500 m of the marine terminal during full speed phase of their passage. In accordance with the Pacific Pilotage Regulations, vessels over 350 gross tonnes (other than ferries) that are not pleasure craft would have a pilot on board to prevent them from travelling off-course, and container vessels would also have tug escorts while in the vicinity of the PNW LNG terminal to prevent potential striking incidents. Deep sea commercial cargo vessels transiting Porpoise Channel would be under the full control of tugs and pilots, and moving at slow speed in the vicinity of project marine structures due to hazards of the channel. Smaller vessels (e.g., fishing vessels) would not have the same risk reduction measures in place and are known to transit in shallow waters, such as Agnew

Bank (where the trestle will be located), en route to Flora Bank and the Skeena River estuary. These vessels, however, would not have nearly the same potential impact energy as a larger vessel, such as a ferry or container ship.

A relatively small quantity of LNG will be circulated through the loading pipeline to keep it cold when loading operations are not occurring. During loading operations, there would be a greater static load in the loading lines and higher flow rate through these lines. The magnitude of a potential spill in either of these scenarios would depend on the impact energy of the vessel that collided with the trestle, the size of the resultant puncture, the pressure in the line at the time of the incident, the time between detection and successful emergency shutdown, and the LNG flow rate in the pipeline. In the more conservative case, a potential allision could result in a spill similar to that described in Section 22.7.

22.8.1.2 Scenario 5-B: Vessel Collision

Historically, LNG carriers worldwide have experienced a similar number of accidents compared to other vessels in terms of minor collisions and striking, although none of these accidents to date has resulted in a containment failure or release of cargo (Det Norske Veritas 2013a). For example, on December 29, 2013, the Q-Flex LNG carrier *Al Gharaffa* collided with the 349 m container ship *Hanjin Italy* in the Strait of Malacca, off Singapore. While both vessels sustained some damage, there was no containment failure or release of LNG. However, it is possible that a project LNG carrier could be involved in a collision with another vessel transiting BC coastal waters that could result in the puncture of the double hull, and thereafter the LNG tank itself, given sufficient impact energy.

The proposed sailing routes are generally open, with the most congested marine traffic areas falling within the bounds of the Prince Rupert Port Authority (south and east of the Kinahan Islands) and around the Triple Island Pilot Boarding Station. In the event of a vessel-to-vessel collision along the sailing route, the likelihood of penetration of the hull and containment system of the LNG carrier would depend on several factors, namely the characteristics of the colliding vessels and the energy of impact. Det Norske Veritas (2013a) has calculated that a hit from a vessel of 30,000 DWT would likely be sufficient to penetrate an LNG tank, although a smaller vessel could also theoretically have enough energy to result in significant damage. Although a bow-to-bow collision would have the greatest impact speed, this is not deemed to be a credible scenario because the last action of the master would be to try to avoid a collision by attempting to turn the ship.

Thus, a credible, worst-case vessel collision scenario would involve the side-on hit of a project LNG carrier by another large vessel (e.g., bulk carrier) of sufficient mass, resulting in extensive hull damage to one or both vessels. As with an LNG carrier grounding or allision, this scenario could result in an LNG spill up to 43,000 m^3 and a heavy fuel oil spill of up to 1,250 m^3 from the LNG carrier. A fuel spill of up to 2,500 m^3 from the other vessel could also occur. LNG would pool on the surface of the sea and would form a vapour cloud that would extend to 1,700 m from the spill site (Det Norske Veritas 2013a). Also, if the spill rate was high enough, an RPT explosion could occur.

A vessel-to-vessel collision could occur at any location along the proposed shipping route. Simultaneous leaking from two or more membrane tanks within an LNG carrier is not deemed to be a credible scenario because of the size of each individual tank and the spacing between them (Det Norske Veritas 2013a).

22.8.1.3 Scenario 5-C: Marine Mammal Collision

All vessels associated with construction and operations of the Project have potential to collide with marine mammals. While the highest intensity of marine traffic (increasing likelihood of collisions) will likely be associated with disposal of dredged sediment, the short-term nature of this activity means that, overall, marine mammal collisions are more likely from LNG carriers, which will operate at 350 vessels per year (in Phase 2 of the Project) for at least 30 years.

Records of vessel-cetacean collisions from the late 1800s to 1998 compiled by Laist et al. (2001) demonstrate that vessel strikes typically involve large baleen whales (Mysticetes), with fin whales hit most commonly, followed by right, humpback, sperm, and then gray whales. Toothed whales (Odontocetes) and pinnipeds are more agile and smaller and are therefore rarely struck by vessels (Laist et al. 2001). Results of worldwide ship strike records from 1997 to 2002 (primarily resulting in fatality) compiled by Jensen and Silber (2003) also show that fin whales are most frequently hit, followed by humpback whales, at 75 and 44, respectively. Minke, gray, and killer whales, and species found outside the local assessment area (LAA) also have records of ship strikes, although only one strike was reported of a killer whale, and minke and gray whales had 19 and 24 strikes, respectively (Jensen and Silber 2003). Data show more ship strikes occurred in North America than anywhere else, likely because of underreporting elsewhere (Jensen and Silber 2003); however, it is expected that incidents may go unreported in North America, and they are not always noticed on large ships. In addition, reporting requirements vary between jurisdictions.

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 the *Species at Risk Act* and their likelihood of occurrence in the LAA (Appendix M, Marine Resources Technical Data Report), with peak occurrences between May and October during feeding. Although rarely struck by vessels, there ten records of a fatal ship strikes to a northern resident killer whales in BC waters, one of which occurred near Prince Rupert in 2006 (Williams 2009). Fin whales are also vulnerable, although they are less commonly found in the LAA. Thus, a credible worst-case marine mammal collision scenario is represented by a lethal accidental collision between an LNG carrier in transit to the project marine terminal and a humpback whale.

Vessel strikes are identified as a threat to humpbacks (DFO 2013), with a moderate relative risk to individuals and a low risk to the population. The strategy indicates there is potential to increase the risk to high with further studies required to clarify uncertainties (DFO 2013). In BC waters, humpback whales are the most common cetacean struck by vessels, with 21 reports between 2001 and 2008; however, mortalities as a result of vessel strikes in BC waters are largely unknown. There is one report in BC of a deceased humpback whale found with evidence of blunt force trauma and lacerations (DFO 2013). High probability areas of humpback-vessel interactions are noted in the strategy and include Dixon Entrance and the Inside Passage area, a network of passages that weave through the islands between northern Vancouver Island and Prince Rupert. These areas are outside the LAA.

22.8.2 Project Design Measures to Reduce Risk

The *Canada Shipping Act* and associated regulations provide for legislation that promotes safety in marine transportation and protects the marine environment from damage resulting from navigation and shipping activities. This includes provisions for collision-prevention devices (e.g., lights, soundsignaling devices, radar reflectors) and navigational safety aids (e.g., compasses, radar, emergency steering), hull construction standards for strength and stability, fire detection and extinguishing system requirements, and construction standards and inspection protocols for vessels carrying pollutants.

Additional measures taken to reduce the risk of an accident or malfunction will be common to the scenarios of a vessel grounding, allision, or collision with another vessel or marine mammal. Vessels calling on the project terminal will approach Prince Rupert Harbour in designated shipping routes from the open waters north of Haida Gwaii through Dixon Entrance to the pilot station north of Stephens Island. From there they will be guided by pilots and the Coast Guard Marine Communications and Traffic System to avoid collisions with other vessels, hazards of grounding, and where information is available, interaction with marine mammals or concentrations of fishing vessels. In accordance with the *Pilotage Act* (2011) and associated Pacific Pilotage Regulations, compulsory pilotage requirements for non-pleasure craft vessels over 350 gross tonnes transiting BC waters will be adhered to. All LNG carriers will be boarded at Triple Island by an experienced, licensed marine pilot who is intimately familiar with the local coastal conditions, navigational hazards, weather patterns, and maritime regulations governing shipping in BC. The pilots will use their maritime experience and knowledge for the safe navigation of the vessel to and from the marine terminal.

LNG vessels used for the Project will conform to the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, which specifies design and construction standards. Key safeguards of this code related to prevention of loss of containment from marine accidents and hazards, such as vessel grounding or collision, include:

- Type-specific LNG containment systems based upon either double-layered membrane tanks or independent self-supporting Moss tanks
- Double-bottom and double-sided hull
- Specified dimensions and types of construction materials to maximize resiliency of cargo containment systems.

The Q-flex carrier uses a membrane containment system with a thin primary barrier supported through insulation spaces surrounding the membranes, which are designed such that thermal expansion or contraction does not over-stress the membrane. These membrane tanks are not self-supporting (the inner hull is the load-bearing structure), are maintained under an atmosphere of nitrogen, and are constantly monitored for the presence of a leak.

Measures specific to reducing risk of vessel collisions with marine mammals will primarily involve established speed profiles for different route segments, exchange of information on marine mammal activity between pilots, and alteration of course if a marine mammal is sighted in the path of a vessel, when and where deemed safe to do so by the vessel master and marine pilot. Research suggests that the probability of a ship strike resulting in injury to a marine mammal is positively correlated with vessel speed (Kite-Powell et al. 2007; Vanderlaan and Taggart 2007). Vessels will transit to and from the pilot station at reduced speeds to reduce the likelihood of serious injury to large cetaceans from a vessel collision.

It should be noted that PNW LNG has opted to participate in the Technical Review Process of Marine Terminal Systems and Transhipment Sites (TERMPOL), as established by Transport

Canada. This is an extensive, voluntary review process applicable to proponents proposing to construct marine terminals and associated shipping infrastructure that will handle potentially hazardous cargo, including liquefied gases, among others (e.g., bulk oil and other chemicals). The TERMPOL process is intended to identify and improve upon elements of a project that could pose a threat to a ship's hull and cargo containment system, and the environment in the vicinity of the vessel, while it is navigating in Canadian waters (Transport Canada 2001). It may consider measures that go beyond existing safety regulations to address project-specific circumstances and stakeholder concerns. Thus, PNW LNG may identify further mitigation measures that relate to vessel collision, allision, and grounding as a result of the outcomes of the TERMPOL review, which is being conducted concurrently with this environmental assessment.

22.8.3 Emergency Response Approach

A ship-sourced hazardous materials spill resulting from a grounding or collision would involve the same response principles as a spill in the terrestrial environment. Human safety would be protected as a first priority, followed by measures to secure the source of the spilled material and reduce associated environmental effects. PNW LNG has no jurisdiction over the emergency procedures of a vessel involved in a grounding, collision, or allision, PNW LNG will require that vessels involved with the Project have their own ERP in place for such accidents and would assist as and when required.

Appropriate actions and best management practices for accident and malfunctions under PNW LNG jurisdiction, to be outlined in greater detail in the ERP for the Project, would include:

- Closing valves and securing hazardous material or LNG in its containment vessel to eliminate the source of the release (this may involve temporarily patching a tank or transferring to another tank if the original is severely compromised)
- Notification of the vessel master
- Notification of appropriate regulatory agencies, affected stakeholders, and Aboriginal groups
- Containment of spilled material to prohibit migration from the release site
- Assessment of spill response and clean-up options
- Implementation of spill response and clean-up measures (e.g., deployment of absorbent pads or booms), including disposal of recovered product at approved hazardous waste facilities
- Completion of incident reports (internal and external for regulatory authorities, as required).

Depending on the severity of the incident, PNW LNG may engage the services of a third-party spill response contractor, such as Western Canada Marine Response Corporation (WCMRC), to support the spill response, as necessary. WCMRC currently maintains a spill response vessel and associated equipment adjacent to the Fairview Terminal on Kaien Island, north of Lelu Island.

22.8.4 Clean-Up and Restoration Methods

LNG spilled to the marine environment would spread out on the surface of the seawater, freezing the top layer of water beneath it, before vapourizing and dispersing. Given that LNG does not persist in the environment; is odourless, colourless, and non-corrosive; leaves no residue; and is non-toxic to marine biota, no clean-up actions are anticipated to be necessary as a result of an LNG spill. If the interaction of the cold liquid with marine habitats could result in adverse environmental effects, such environments would be surveyed to determine appropriate restoration or compensation activities.

The response to a spill of heavy fuel oil to the marine environment would vary depending on factors such as the physical chemical characteristics of the hydrocarbons spilled, the nature of the affected environment (e.g., sensitive riparian habitat, rocky, impermeable shoreline, or open waters), and the quantity of the spilled substance. All clean-up and restoration activities would be approved by the appropriate regulatory agencies, and habitat compensation works would be implemented for all habitat that is destroyed or permanently altered, as required.

Effects from hazardous materials and LNG spills related to vessel grounding or collision will be effectively reduced through appropriate training in spill response for all operations staff and through the use of suitable PPE (e.g., respirators, gloves, personal flammable gas detectors) to protect against exposure to potentially toxic substances or very cold LNG.

22.8.5 Potential Environmental Effects

22.8.5.1 Air Quality

The vaporized cloud generated by an LNG spill from a vessel collision would consist almost entirely of methane (97% methane, 2% ethane, and very small amounts of heavier hydrocarbons). Impurities will be removed by the facility during processing of incoming feed gas. Since methane gas is lighter than air, it would disperse quickly to the upper atmosphere without any serious effect on air quality. In the unlikely absence of wind, the cloud would disperse more slowly but would still not have any serious effect on air quality.

22.8.5.2 Greenhouse Gas Management

In the unlikely event that LNG is spilled as a result of a vessel collision, emissions released to the atmosphere would be negligible in comparison to emissions generated during normal project operations and in the context of overall provincial and national GHG emissions.

22.8.5.3 Terrestrial Wildlife and Marine Birds

A marine vessel grounding or collision could result in the release of hazardous materials, including oil, fuels, and lubricants, into the marine environment. The magnitude of this effect would be influenced by the type and volume of materials released, the season and habitat in which the accident occurs, and the ambient conditions (e.g., wind, tide, and current) at the time of the accident (Piatt et al. 1990).

In a vessel grounding or collision, marine birds are most likely to experience effects from acute exposure to hazardous materials on the surface of the water through direct contact; ingestion of contaminated prey, water, or sediment; inhalation; or absorption through the skin (Leighton 1993). These effects would be greatest during seasons or in habitats that support large concentrations of marine bird species. Under certain weather conditions, hazardous materials released during a vessel grounding or collision might accumulate along shorelines. These materials could be encountered by terrestrial wildlife (e.g., deer, wolves) using these habitats for foraging or migration.

The magnitude of potential effects is expected to be low, given the low volume of hazardous materials (fuel) being transported by vessels. Project design, emergency response, and clean-up methods, described above, are expected to occur immediately following the accident and would prevent the dispersal of hazardous materials through marine and terrestrial habitats.

22.8.5.4 Marine Resources

The release of LNG or other hazardous materials (e.g., heavy fuel oil) associated with a vessel grounding, allision, or collision could result in effects on marine resources, as discussed in Section 22.6.5 and Section 22.7.5. The volume of LNG entering the marine environment could potentially be much larger than that which would be released at the terminal site (e.g., 43,000 m^3 of LNG could be released from a vessel tank, versus 1,000 m^3 of LNG resulting from a failure of the loading line at the terminal). Thus, effects on marine resources, such as fish mortality, have the potential to be experienced throughout a comparatively larger radius from the location of the spill.

Ship strikes to marine mammals may cause injury and potential mortality. The likelihood of a vessel striking a marine mammal depends on the species distribution, abundance, life history, behavioural characteristics, and the relative increase of vessel activity associated with the Project compared to existing vessel activity. A marine mammal may recover from a vessel strike or may succumb to the injuries sustained in the incident, depending on their severity. Project mitigation measures (such as vessel speed restrictions, 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.

22.8.5.5 Economic Environment

Economic effects could be experienced near a vessel grounding, allision, or collision that involved a release of hazardous materials or LNG in sufficient quantities to cause mortality to fish species. Resultant effects on harvesting could be experienced by the sport fishing and commercial fishing sectors, although such effects would be localized to the spill area and would be short term in duration. Recreationalists could also be excluded from the spill area until clean-up measures were completed. Adverse effects on fish populations could lead to adverse effects on the economy through effects on fisheries, especially if regulator concerns led to the closure of fisheries.

22.8.5.6 Navigation and Marine Resource Use

Effects on navigation and marine resource use may be experienced as a result of a vessel grounding, allision, or collision. Depending on the magnitude of the accident and the associated clean-up, additional vessels required to support emergency response efforts (such as spill response vessels or tugs required to render assistance to a vessel that has run aground) may temporarily impede navigation in the immediate vicinity of the incident. There may also be effects on harvesting of marine resources, particularly marine fish species, in the localized area of the incident. Regulator concerns about the viability of a fishery because of the spill may lead to fishery closures, which would reduce access to marine resources.

22.8.5.7 Human and Ecological Health

Ship accidents resulting in release of LNG to the marine environment may cause frostbite or mortality (freezing) in people or ecological receptors exposed to the LNG cloud. While methane is relatively non-toxic, when present in sufficient quantities, it can cause nausea, headaches, dizziness, or asphyxiation mortality. Spills of fuels from a ship accident could lead to potential health risks for ecological receptors and humans in the area. Potential exposure could occur through direct dermal contact, inhalation of vapours, or ingestion, although dermal contact would be the most likely exposure route.

The potential for adverse health risks to humans or to ecological receptors would be mitigated through appropriate spill response management to limit the potential for biological exposures.

22.8.5.8 Current Use of Land and Resources for Traditional Purposes

Aboriginal people could experience temporary, localized reduction in their ability to use areas in and around the grounding or collision for traditional purposes, including cultural practices and the harvesting of preferred or valued fish, shellfish, bivalves, and marine mammals. Any other reduction is access to marine resources (Section 22.8.5.6) could also lead to reductions in current use of these resources for traditional purposes.

22.9 Cumulative Effects of Accidents and Malfunctions

The Canadian Environmental Assessment Agency's Operational Policy Statement for Assessing Cumulative Environmental Effects under CEAA 2012, dictates that "the environmental effects of accidents and malfunctions must be considered in the assessment of cumulative environmental effects if they are likely to result from the designated project in combination with other physical activities that have been or will be carried out." By definition, accident and malfunction scenarios are unexpected occurrences or improbable failures that are not likely to occur, and thus, associated environmental effects from the accident and malfunction scenarios described herein are not likely to occur. Furthermore, environmental effects from the accident and malfunction scenarios described are not expected to overlap spatially or temporally with effects from other physical activities that have been or will foreseeably be carried out, with the exception of potential vessel collisions with marine mammals.

Cumulative effects on the marine VC are described in the assessment of routine project effects in Section 13. Although this section does not address cumulative effects of accident scenarios, such as a vessel collision with a marine mammal, it does present information that is relevant to such an assessment. In Section 13, Table 13-14 lists annual LNG carrier and cargo vessel traffic expected in the marine regional assessment area (RAA). With eight major development projects proposed for the area, future traffic in the RAA is expected to increase by 318% over 2009 levels, with the Project accounting for 19% of the total annual large vessel traffic in the area. Consequently, it is possible that vessel strikes on marine mammals may increase with a corresponding increase in cumulative vessel traffic in the RAA. Vulnerability of various marine mammals to vessel strikes is described in Section 22.8.1.3, and mitigation measures to prevent such occurrences (such as speed restrictions and course alterations) are described in Section 22.8.2.

22.10 Conclusion

Seven accident and malfunction scenarios involving equipment, device, or system failures, unexpected occurrences, or unintended actions, and their resultant effects on VCs, have been considered in this assessment. These scenarios, ranging from explosion or fire to marine vessel collisions, cover the breadth of potential accidents and malfunctions that may be associated with the Project. Interactions with VCs that have the potential to be the most serious are summarized below.

The effects of the **emergency flaring and LNG facility shutdown** scenario are relatively minor. Emergency flaring involves routing the gas stream to one or more flare stacks to prevent the accumulation of gases that could pose a hazard to humans or the environment. The primary concern with this scenario would be effects to air quality. Modelling conducted for the Project demonstrates that the volume of SO_2 and other hazardous emissions associated with a worst-case emergency flaring and shutdown scenario would be well below the ambient air quality objectives for both the 1-hour and 24-hour periods. Bird mortality may be affected by a flaring scenario. However, the rarity of the scenario means that flaring is expected to have a negligible effect on regional bird populations.

The risks posed by an **explosion or fire** would be most serious for terrestrial wildlife with limited dispersal abilities, which may be subject to injury (e.g., burns) or mortality. Fish in the immediate vicinity of a rapid phase transition may also be subject to mortality. However, given that the area affected would likely be limited to the facility or a small area around an LNG carrier, these deaths or injuries are unlikely to have population-level effects. Risks perceived by commercial, recreational, or Aboriginal fishers and other marine resource users may lead to avoidance of marine resource areas. This would affect both current use for traditional purposes and fishing by commercial, recreational, or Aboriginal fishers, with potential for subsequent effects on the economic environment.

A **fuel or hazardous material spill** is likely to be contained within the industrial facility footprint, which will be designed to exclude wildlife and contain very little vegetation. Regulator concerns leading to fishery closures may lead to reduced access to marine resources. This would affect both current use for traditional purposes and fishing by commercial, recreational, or Aboriginal fishers, with potential for subsequent effects on the economic environment.

An **LNG spill** could result in localized injury and mortality to plants, animals, or aquatic biota. Population-level effects are unlikely. Similarly to a fuel or hazardous material spill, concerns about fish population viability may lead to reduced access to marine resources, with subsequent effects on marine resource use, current use for traditional purposes, and the economic environment.

The **marine vessel grounding, allision, or collision** could result in the release of LNG or other hazardous materials (e.g., heavy fuel oil) to the marine environment and subsequent mortality to fish or other marine life in the localized area of the spill. Ship strikes to marine mammals could also result in injury or potential mortality. Other effects would be similar to those associated with fuel or hazardous material spills, or LNG spills.

These interactions highlight effects to VCs that may be experienced as a result of credible, worst-case scenarios, which are by definition unlikely to occur. The project design and mitigation measures described will be implemented in order to reduce the risk of these unlikely accidents and malfunctions from ever occurring. If an emergency does occur, PNW LNG would rapidly activate emergency response procedures with the objective of protecting and saving people, the environment, and the long-term operability of assets and reputation, in that order.

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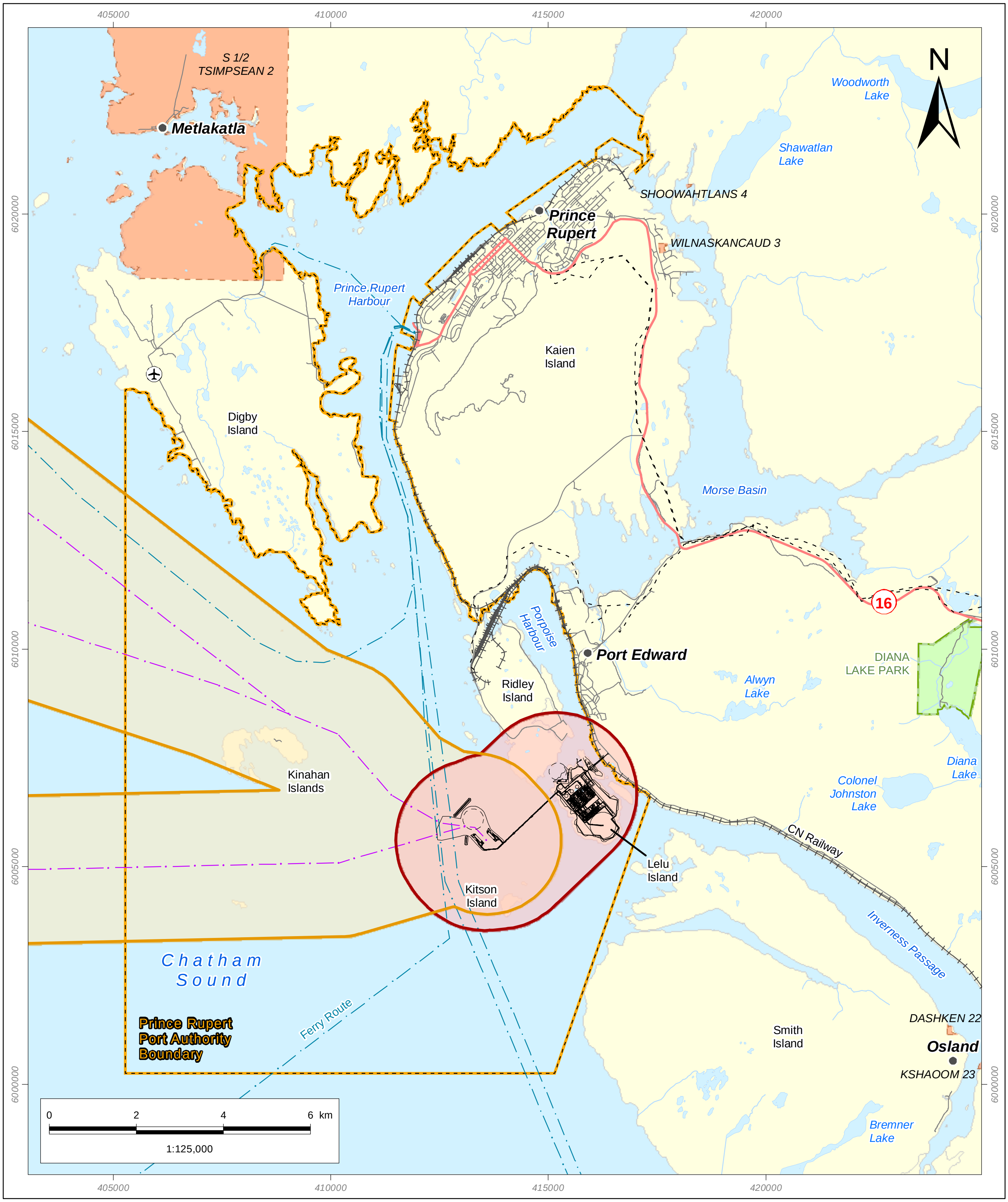
22.12 Figures

Please see the following pages.



Flammable Hazard Zone due to Release of LNG from the Following Sources:*	Turning Basin	Secondary Road
Marine Terminal Trestle Pipe or Loading Arm	Airport	Watercourse
LNG Vessel	City or Town	Indian Reserve
Potential Shipping Route	Electrical Power Transmission Line	Prince Rupert Port Authority Boundary
Project Component	Ferry Route	Protected Area
	Highway	Waterbody
	Railway	

* Maximum estimated flammable hazard zone associated with a credible release of LNG from the trestle pipeline or loading arm infrastructure at the marine terminal (1,850 m radius), or an LNG vessel along the shipping routes (1,700 m radius).
Source: Det Norske Veritas 2013a.

Pacific NorthWest LNG

Flammable Hazard Zone: Release of LNG from the Marine Terminal during Loading Operations or an LNG Vessel along the Chatham Sound Sailing Routes

Sources: Government of British Columbia; Prince Rupert Port Authority; Government of Canada, Natural Resources Canada, Centre for Topographic Information; Progress Energy Canada Ltd.; Det Norske Veritas, 2013a.

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: 17-FEB-14	PROJECTION: UTM - ZONE 9
FIGURE ID: 123110537-471	DATUM: NAD 83
DRAWN BY: K. POLL	CHECKED BY: M. BREWIS

PREPARED BY: Stantec

PREPARED FOR: Pacific NorthWest LNG

FIGURE NO: **22-1**