23.0 EFFECTS OF THE ENVIRONMENT ON THE PROJECT

The assessment of potential effects of the environment on the Project was provided in Section 23 of the EIS. This section of the EIS Addendum provides:

- An update to the potential effects of the environment on the Project as a result of the project changes
- Responses to requests for additional information from the federal government (August 14, 2014)
- An updated list of all mitigation measures for the Effects of the Environment on the Project VC
- Conclusions on the assessment of potential effects of the environment on the Project, taking into account project changes and the requested additional information.

Table 23-1 lists the documents that are applicable to effects of the environment on the Project submitted by PNW LNG as part of the environmental assessment process to date and identifies whether information is either *updated by EIS Addendum, superseded*, *not relevant*, or *not affected* by information in the EIS Addendum. The following sections of the EIS Addendum contain information that updates the documents classified as *updated by EIS Addendum* in Table 23-1.

Table 23-1 Status of Previously Submitted Documents

Document Name	Status
Section 23 of the EIS (February 2014)	Updated by EIS Addendum
Responses to the Working Group (June 2014)	Not affected

23.1 PROJECT EFFECTS ASSESSMENT UPDATE

23.1.1 Baseline Conditions

The physical environmental conditions with potential to affect the Project considered in Section 23 of the EIS were reviewed with respect to the project changes and additional information requests.

Baseline conditions described in the EIS are applicable to the marine terminal design mitigation. The design mitigation results in the relocation of the marine terminal berth by about 510 m from the location described in the EIS; however, the baseline conditions at the new location are similar to those originally presented in the EIS.

The potential effect of interstitial gas on the Project has been assessed in response to an Information Request (Section 23.2). Although baseline geotechnical studies did not indicate interstitial gas, the presence could have effects on the structural stability of the marine infrastructure; these effects would be mitigated through engineering design.

The physical environmental conditions considered in the EIS and applicable to the marine terminal design mitigation include precipitation, fog and visibility, wind, tides, tsunamis and climate change (changes in sea level rise, storm frequency and intensity). The baseline conditions described in the EIS apply to the marine terminal design mitigation.

23.1.2 Effects Assessment

The design of all facility components considers potential effects of the environment on the Project, as required by the National Building Code of Canada (2010) and the Canadian Standards Association (CSA) document for liquefied natural gas (LNG) production, storage and handling (CSA Z276-11 2011). The application of standards for the Project is described in Section 2.1.2 (Project Design Standards and Policies) of the EIS.

The marine terminal design mitigation includes a 1.6 km clear-span suspension bridge to support the 2.7 km jetty. The suspension bridge will be constructed to meet the following codes and standards:

- CAN/CSA S6-06: Canadian Highway Bridge Design Code
- CSA Z276: LNG - Production, Storage and Handling
- Canadian Institute of Steel Construction – Handbook of Steel Construction
- CSA W59: Welded Steel Construction (Metal Arc Welding)
- AASHTO LRFD Bridge Design Specifications, US 6th edition, 2012
- ACI 318-08 Building Code Requirements for Structural Concrete and Commentary
- AISC Steel Construction Manual, US 13th edition
- AASHTO/AWS Bridge Welding Code, US 6th edition, 2010
- Petronas Technical Standards, PTS, where applicable
- WorkSafeBC Guidelines for Workers Compensation Act and the Occupational Health and Safety Regulation.

The structural compliance of the suspension bridge will also rely on seismic and geotechnical data specific to the site conditions. The environmental loads included in the suspension bridge are discussed below.

23.1.2.1 Severe Precipitation

The severe precipitation effects on the Project described in the EIS apply to the marine terminal design mitigation including the suspension bridge. Mitigations for severe precipitation include environmental management plans (site drainage, sedimentation, and erosion control), collection of possible oil contaminated runoff in curbed facility areas, perimeter ditches to capture runoff in non-curbed facility areas, and surface ditches to divert clean water in wetlands bordering the project development area (PDA).

The final engineering design for snow loads for the suspension bridge will meet CAN/CSA S6-06 and National Building Code of Canada (2010) for Prince Rupert. The CAN/CSA S6-06 requirements regarding the formation of ice, frost or the presence of freezing rain or freezing drizzle will be met by the design.

The marine terminal design mitigation results in the relocation of the marine terminal berth by about 510 m from the location described in the EIS; however, severe precipitation effects reported in the EIS are representative of the assessed area and apply to the newly presented marine terminal.

23.1.2.2 Fog and Visibility

The effects of fog and visibility on the Project described in the EIS apply to the marine terminal design mitigation; including the suspension bridge. LNG carriers and pilots of aircraft will comply with all relevant international and Canadian regulations pertaining to conduct of navigation in reduced visibility, including standard of watch keeping and use of equipment such as radar, automatic identification systems, and fog signals.

23.1.2.3 Wind, Tides, and Storms

The effects of wind, tides, and storms on the Project described in the EIS apply to the marine terminal design mitigation, including the suspension bridge. Lelu Island and the marine terminal are unprotected from high waves, swell, dense blowing sea foam, heavy tumbling of the sea, and poor visibility winds from Chatham Sound.

LNG carriers will undertake transit, maneuvering and berthing activities only within the environmental limits established specifically for the Project (see Section 23.5.3.2 of the EIS). Environmental limits include criteria for wind and significant wave height as applicable to each activity type.

The suspension bridge will be designed for 100-year wind return periods and to be stable during extreme wind events. During construction, all structures will be secured to ensure stability. The suspension bridge will be designed to withstand wave forcing determined in accordance with CAN/CSA S6-06.

The marine terminal design mitigation results in the relocation of the marine terminal berth by about 510 m from the location described in the EIS; however, wind, tide and storm effects reported in the EIS are representative of the assessed area and apply to the newly presented marine terminal.

23.1.2.4 Seismic Activity and Tsunamis

The seismic activity and tsunami effects on the Project described in the EIS apply to the marine terminal design mitigation, including the suspension bridge.

The effects of a potential submarine generated tsunami on the Project have been assessed in response to an outstanding information request. The topography and bathymetry in the immediate vicinity of Lelu Island are unlike the steep fjord inlets that are susceptible to landslide events with potential to generate large tsunami waves. A tsunami generated from a nearby submarine failure would likely produce a wave height at Lelu Island substantially smaller than a seismic generated tsunami wave height of 5 m. The PNW LNG facility design has accounted for seismic generated tsunamis up to 5 m in height and for substantial wave energy acting on fixed marine structures. Existing observations, recent studies, and tsunami records indicate submarine slope failures have not been identified as a hazard for Lelu Island.

Design standards for this Project will comply with the requirements of CSA Z276-11. Bridge design criteria for both the access bridge between Lelu Island and the mainland and the suspension bridge will include collapse prevention for a 1 in 475 year earthquake event.

The marine terminal design mitigation results in the relocation of the marine terminal berth by about 510 m from the location described in the EIS; however, the seismic activity and tsunami effects reported in the EIS are representative of the assessed area and apply to the newly presented marine terminal.

23.1.2.5 Climate Change

The effects of climate change on the Project described in the EIS apply to the marine terminal design mitigation. Increasing concentrations of greenhouse gases in the atmosphere are predicted to enhance global climate change to include average temperature rise, average precipitation rise, wind speed and direction change, and sea level change.

The potential effects of climate change on the Project were assessed qualitatively following guidelines from the CEA Agency. The key potential effect is an increase of storms that may cause weather delays in LNG carrier berthing and loading. Project designs have accounted for extreme weather criteria, following the National Building Code and updates including applicable climate forecasts. Offshore infrastructure will be designed to accommodate a conservative estimate of sea level rise of 0.6 m, based on a 60-year design life.

The marine terminal design mitigation results in the relocation of the marine terminal berth by about 510 m from the location described in the EIS; however, the climate change effects reported in the EIS are representative of the assessed area and apply to the newly presented marine terminal.

23.2 RESPONSES TO THE OUTSTANDING INFORMATION REQUESTS

23.2.1 Effects of the Environment on the Project Information Request #1

23.2.1.1 Government of Canada - Outstanding Information

Provide the results of terrain mapping at an appropriate scale (i.e., at least 1:20,000) and the derivation of a terrain stability map at an approximate scale (e.g., scale of 1:20,000) based on the results of terrain/surficial map efforts.

23.2.1.2 Response

The requested information is provided in Appendix I.1 – Terrain Stability Mapping for Lelu Island, Smith Island and Port Edward Area.

23.2.2 Effects of the Environment on the Project Information Request #4

23.2.2.1 Government of Canada - Outstanding Information

While some information was provided, the potential effects of interstitial gas on the Project were not identified. Describe the effects that interstitial gas could have on the Project.

23.2.2.2 Response

Although boring taken during geotechnical studies for the Project did not indicate interstitial gas, there is a possibility that gas pockets exist around the marine terminal and berth. Details of the geotechnical studies can be found in Appendix I.2 and I.3. The presence of interstitial gas could have effects on the structural stability of the marine infrastructure; these effects would be mitigated though engineering design. Design mitigation measures would include either alignment changes to avoid gas lenses or the use of end bearing pile construction instead of soil friction based techniques. Specific design mitigations would depend on the size and location of gas pockets encountered, the type of infrastructure that could be affected, and the nature of the potential effects on the infrastructure. Final geophysical and geotechnical surveys will be conducted to support the final engineering design of marine infrastructure.

Associated risks with driving piles into potential gas pockets include:

- Prolonged pile driving of steel tubular sections may result in heating of the element to possibly cause combustion of gas resulting in a fire hazard
- Similarly, the hollow pile tube may allow contact between the gas and the atmosphere which may result in a fire hazard
- In the area where excessive gas pockets are present, prolonged pile driving may lead to development of a pathway for the gas to escape which may cause additional lateral pile movement.

Based on the geotechnical studies performed in this area the potential for occurrence of the above-listed items appears to be low; however, the Engineering, Procurement, Construction, and Commissioning (EPCC) contractor will be made aware of the potential risks including information based on the final geotechnical analysis.

23.2.3 Effects of the Environment on the Project Information Request #7

23.2.3.1 Government of Canada - Outstanding Information

Further consider the potential occurrence of submarine slope failures as a possible tsunami source for Lelu Island. Consult the Conway et. al., (2013) report to determine the threat of tsunamis from submarine slope failures to the site. Conway, K. W., Kung, R. B., Barrie, J. V., Hill, P. R., and Lintern, D. G., 2013, A preliminary assessment of the occurrence of submarine slope failures in coastal British Columbia by analysis of swath multibeam bathymetric data collected 2001-2011: Geological Survey of Canada, Open File 7348.

Discuss the likelihood of such an event exist and what effects it could have on the Project. Also provide any resultant environmental effects this might cause.

23.2.3.2 Response

Conway et al. (2013) reported slope instability in the form of relatively small slides and debris flows in the Skeena River delta. In consideration of this report and other relevant studies, the threat of a tsunami generated from a submarine slope failure greater than 5 m in height is ranked low for the project site on Lelu Island.

Background

Steep glacial scoured fjords and associated geomorphological features, such as deltas and channel systems, are prone to submarine slope instability in coastal British Columbia (Nemec and Steel, 1988; Bornhold and Prior, 1990). While small slope failures are common on such delta systems, large failures have the potential to generate a tsunami.

Compared to seismically generated tsunamis, land-slide generated tsunamis affects only the immediate vicinity of the failure but they can generate a significant wave run-up especially where the wave energy is trapped by the confines of inlets or semi-enclosed embayments. The landslide-generated tsunamic wave characteristics depend not only the volume of displaced material but also the following parameters of a given landslide (Murty, 2003).

- Depth of water above the slide
- Slope of the material
- Total distance travelled
- Duration of the event
- Density of the material
- Coherent nature of the slide
- Grain size and spectrum
- Characteristic speed with which the slide moves.

The slopes that face Lelu Island do not feature steep, fjord walls that are prone to landslide and submarine failures (Conway et al., 2012). Details of the terrain stability assessment completed for the PNW LNG facility can be found in Appendix I.1.

The potential effects of run-up caused by a tsunami on the project site would include mass wasting (i.e., landslides, debris flow), shoreline erosion and flooding, and possible damage to facility components. Details of historic tsunami records, tsunami run-up assessment, and detailed geotechnical studies are provided in the attached appendices.

Historic Tsunamis Resulting from Submarine Slope Failures

A tsunami hazard assessment and a detailed study of historic tsunami records have been completed for the PNW LNG facility; further details can be found in Appendix I.4 and Appendix I.5, respectively. These studies focus on seismically generated tsunamis. Tsunami wave heights mentioned in the following text refer to the wave crest height, the maximum elevation of the wave with respect to the ambient water level.

Inlets and narrow straits of the Pacific Coast of North America (e.g., Lituya Bay, Yakutat, Russel Fjord, Skagway Harbour, Kitimat Arm, Puget Sound) contain the greatest potential for landslide-generated tsunamis with relatively large run-up (Soloviev and Go 1975; Lander, 1996; Palmer, 1999; Evans, 2001).Figure 23-1 shows the known submarine landslides and landslide-generated tsunamis along the coasts of Alaska, British Columbia, and Washington.

Known tsunamis closest to Prince Rupert generated from submarine failures occurred in the Kitimat Arm, the head of the Douglas Channel near Kitimat, British Columbia. An investigation after the destructive landslide tsunami of April 27, 1975, in Kitimat Arm, British Columbia demonstrated that such events had repeatedly taken place in this fjord, in particular in 1952 – 1968, 1971 and 1974 (Murthy, 1979; Prior et al., 1981; Johns et al., 1986). The 1952 - 1975 Kitimat landslides and tsunamis occurred during seismically quiet periods. A 2.8 m high tsunami was recorded in Kitimat on October 17, 1974 (Murty, 1979). A 4.1 m high tsunami was observed in Kitimat on April 27, 1975 and it was generated from an estimated 26.0 million cubic meters of slide material (Murty, 1979). Given the geographic separation of the Douglas Channel to Lelu Island (see Figure 2-9 in Appendix I.5), it is expected that any tsunami waves reaching Lelu Island from a potential future landslide event in the Douglas Channel would be negligible.

On November 3, 1994 a submarine landslide resulted in a 5-6 m high tsunami with 9-11 m shoreline waves in the Skagway Harbour, located at the head of the Taiya Inlet (Kulikov et al, 1996). This study reported the tsunami to be confined to the Taiya Inlet and was followed by small-amplitude oscillations. Any potential effects of tsunamis in this area would likely be restricted to the Taiya Inlet.

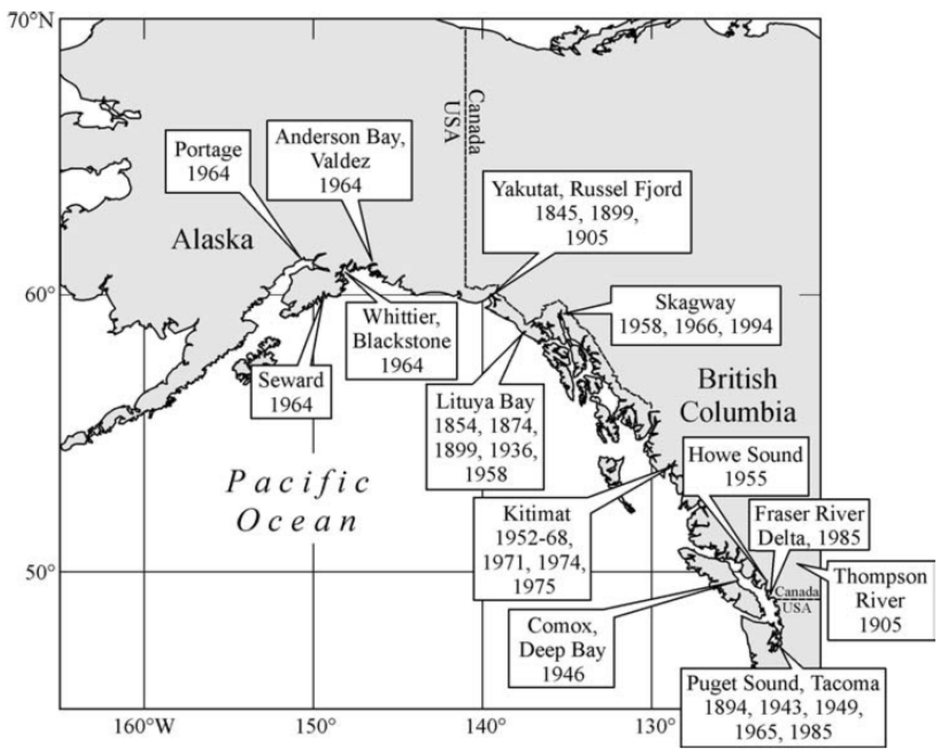

Figure 23-1: Locations of Submarine Landslides and Landslide-Generated Tsunamis (Rabinovich et al., 2003)

Relevant Studies

The multibeam bathymetry data collected from Conway et al. (2013) identified relatively small submarine debris flows and channel and delta systems on the inshore islands of Smith, Kennedy, and de Horsey islands in the Skeena River delta located south and southeast of the Lelu Island. The largest debris flow observed in this area is approximately 840 m long, 3.5 km south of Kennedy Island, 27 km south of Lelu Island. A tsunami generated from this area would likely be dissipated at Lelu Island due to the distance covered, the pathway it would travel, and the protection from Smith Island, located between Lelu Island and Kennedy Island.

A study of numerical modelling for tsunamis generated by hypothetical submarine landslides was conducted in the Strait of Georgia, British Columbia by Rabinovich et al. (2003). Their study included the Malaspina Strait on the eastern side of Texada Island, British Columbia, a relatively narrow (~8 km) body of water. The 1.25 million cubic meter slide was modelled from known seafloor morphology and sediment deposits using the viscous slide model. This slide is considered a major submarine failure and produced a maximum wave height crest of ~2.0 m that dissipated to 0.83 m over 8 km (Rabinovich et al., 2003).

Conclusion

The topography and bathymetry in the immediate vicinity of Lelu Island are unlike the steep fjord inlets that are susceptible to landslide events with potential to generate large tsunami waves. Existing observations, recent studies, and tsunami records indicate submarine slope failures have not been identified as a hazard for Lelu Island.

A tsunami produced from a submarine slope failure affects the immediate vicinity of the failure and does not travel large distances, unlike seismic generated tsunamis. Landslide generated tsunami wave height decreases as the waves propagate away from the landslide location except where the wave energy is trapped by the confines of inlets or semi-enclosed embayments. Therefore, landslides generated by tsunamis far away from the Lelu Island (e.g., Kitimat) are not expected to produce large tsunami waves at Lelu Island. Any resultant environment effects caused by tsunami run-up (e.g., mass-wasting, flooding) are also not expected at the project site. Lelu Island is protected by tsunami waves generated far away by Kaien Island and Digby Island from north; by Smith Island, Kennedy Island and Rochester Island from South; and Stephens Island from west.

A tsunami generated from a nearby submarine failure would likely produce a wave height at Lelu Island substantially smaller than a seismic generated tsunami wave height of 5 m (Appendix I.4). The PNW LNG facility design has accounted for seismic generated tsunamis up to 5 m in height.

23.3 MITIGATION

23.3.1 Changes to Mitigation Measures Presented in the EIS

Based on design changes to the Project and the feedback received during the environmental assessment process, the set of mitigation measures originally presented in the EIS to address potential effects to Effects of the Environment on the Project has been updated. The mitigation measures initially presented in the EIS have been refined to include:

- The suspension bridge design will account for tsunami wave energy acting on its fixed marine structures.

23.3.1 Complete List of Current Mitigation Measures

All of the technically and economically-feasible mitigation measures currently being presented by PNW LNG to address potential Effects of the Environment on the Project are listed below. This includes those originally presented in the EIS that remain relevant, as well as those that have been added or revised as a result of feedback received during the environmental assessment process, or as a result of the project changes. By implementing this full set of mitigation measures, PNW LNG is confident that the Project will not result in significant adverse Effects of the Environment on the Project.

- Environmental management plans (EMPs) will be developed to include provisions for site drainage, sedimentation and erosion control. In the event of a severe rain event, the design would prevent risk to facility structures
- Stormwater runoff from plant areas subject to oil contamination will be curbed or diked and collected by a segregated underground oily-water sewer system. This system will drain to an oil-water separator system for oil removal. Runoff water would then be treated through the Port Edward municipal waste water system
- Runoff from other, non-curbed areas of the facility will be collected by perimeter ditches draining to a first flush basin, which would collect the initial runoff. The excess will be diverted to the clean runoff system
- Clean runoff water will be collected by surface ditches for discharge to the ocean via pre-disturbance drainage pathways through the wetlands bordering the PDA
- LNG carriers will comply with all relevant international and Canadian regulations pertaining to conduct of navigation in reduced visibility, including standards of watch keeping and use of equipment such as radar, automatic identification systems and fog signals
- The Marine Communications and Traffic System (MCTS) will monitor LNG carrier movements in the Prince Rupert area. LNG carriers are accustomed to transit in fog and are equipped with the appropriate navigation equipment. LNG carriers underway within Chatham Sound will follow the direction of the MCTS during extreme weather events and reduce speed, as appropriate. LNG carriers would commence transit within the Prince Rupert area only if environmental limits for safe transit are not breached
- The Prince Rupert Port Authority area and its approaches are also subject to mandatory pilotage, which will further increase the safety associated with transit in fog and conditions of reduced visibility. This means each LNG carrier will be piloted between Triple Island and the marine terminal berth. The pilots would bring LNG carriers into the marine terminal only in safe weather conditions and in compliance with Terminal operations limits that will be set for wind and wave height
- LNG carriers will undertake transit, maneuvering and berthing activities only within the environmental limits established specifically for the Project (see Section 23.5.3.2 of the EIS). Environmental limits include criteria for wind and significant wave height as applicable to each activity type
- The berth will be designed to accommodate a significant wave height based on the upper 1st percentile mean wave height ($H_{1/100}$) for a 25-year return period
- The Project will be designed to meet the extreme weather criteria identified in the National Building Code of Canada (NBCC 2010). If site conditions are more severe and require higher standards than the National Building Code of Canada (NBCC 2010), PNW LNG will design to more stringent requirements. (e.g., winds of 29 m/s)

- The top of the deck for the project berth platform will be at least 13.5 m above Chart Datum. The design accounts for a high water level of 7.4 m, a potential sea level rise of 0.6 m over the 60-year design life, and a 100-year-return-period storm surge of 1.0 m
- LNG carriers that do not have the capability to let go and retrieve their anchor because of ice formed on the LNG carrier deck or bow will be refused pilotage
- Project specific environmental limits will apply to LNG carrier activities (see Table 23-1 of the EIS)
- Design levels defined for this Project will comply with applicable standards including the National Building Code of Canada (NBCC 2010) and the CSA document for LNG production, storage and handling (CSA Z276-11 2011)
- Project design will include earthquake engineering work in the form of a seismotectonic model, probabilistic seismic hazard analyses, development of design acceleration response spectra, and assessing the soil-liquefaction triggering hazard at Lelu Island
- Access bridge design criteria will include collapse prevention for the 1 in 475 years earthquake event. Access bridge design will comply with the BC Ministry of Forests, Lands and Natural Resources Operations Bridge Design, Construction Standards, Guidelines and Bulletins
- Tsunami risk on marine facilities, bridge and other project components will be mitigated by adapting a 5.0 m (tsunami), 0.6 m (sea level rise due to climate change), and 1.0 m (safety margin) above mean sea level rise
- The design of the structures incorporates an adequate factor of safety to address changes in weather severity during the lifetime of the Project, including storms and sea level rise resulting from climate change. Offshore infrastructure will be designed to accommodate a conservative sea level rise of 0.6 m, based on a 60-year design life
- The suspension bridge design will account for tsunami wave energy acting on fixed marine structures.

23.4 CONCLUSION

Project changes were assessed for potential effects of the environment on the Project. Based on the assessment of the marine terminal design mitigation, there are no changes to the physical environmental conditions considered for the effects of the environment on the Project. Potential effects of precipitation, fog and visibility, wind, tides, tsunamis and climate change on the Project (including on the suspension bridge) will be addressed as part of the final engineering design.

Since the Project will be designed to prevent or reduce the severity of potential effects of the environment, the likelihood of an adverse effect on the Project is low. Based on a consideration of the various mitigation strategies applied through design criteria it is concluded that the potential effects of the environment on the Project will not change the conclusions of the EIS. The effects are predicted to be not significant.

23.5 REFERENCES

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