ELLEN F. ROSENBLUM
Attorney General

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DEPARTMENT OF JUSTICE
GENERAL COUNSEL DIVISION

December 1, 2017

Ms. Kimberly D. Bose, Secretary
888 First Street, N.E., Room 1A
Washington, DC 20426

Re: *Jordan Cove LP Pacific Connector Gas Pipeline LP*
Docket Nos. PF17-4-000, CP17-494-000, and CP17-495-000

Dear Ms. Bose:

Please find the attached comments, submitted by the Oregon Department of Energy on behalf of the Oregon Department of Geology and Mineral Industries, in the above-referenced matters.

Sincerely,

/s/ Jesse D. Ratcliffe

Jesse D. Ratcliffe
Assistant Attorney General
Natural Resources Section

JDR:pjn/8643729

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November 6, 2017

Sean Mole
Jordan Cove Analyst
Oregon Department of Energy
550 Capitol St NE, 1st floor
Salem, OR 97301

Re: DOGAMI Comments Related to Geologic Hazards and the Proposed Jordan Cove LNG Terminal and Pacific Gas Connection Pipeline

Dear Mr. Mole:

The Oregon Department of Geology and Mineral Industries (DOGAMI) reviewed the materials relating to geologic hazards in:

- Resource Report 6 – Geological Resources Jordan Cove Energy Project, dated April 2017
- Resource Report 6 – Pacific Connector Gas Pipeline Project, dated May 2017
- Draft Resource Report 13 – Engineering and Design Material, Chapter 13.3 Natural Hazards and Conditions, Jordan Cove Energy Project, dated May 2017, which includes:
    - Appendix I.13 Natural Hazard Design Investigations and Forces, and
    - Appendix J.13 Site Investigation and Conditions, and Foundation Design

DOGAMI finds the information in the Resource Reports submitted by the Applicant to be incomplete, has comments about possible deficiencies in the scientific and engineering analyses related to geologic hazards; and at this point is not satisfied that geologic hazards will be adequately addressed to ensure public safety. Please see attached: 1) General Review comments, and 2) comments on the Resource Reports.

While DOGAMI has regulatory and statutory authority on mining operations and building in the tsunami regulatory zone, this letter is not intended to address those specific requirements. The Applicant must meet Oregon building code requirements and Oregon laws, including Section 1803.2.1 Tsunami Inundation Zone of the Oregon Structural Specialty Code (Oregon Revised Statutes [ORS] 455.446 and 455.447).

Thank you for the opportunity to assist with this project. If you have any questions, please contact me at 971-673-1555 (brad.avy@oregon.gov) or Yumei Wang at 971-673-1551 (yumei.wang@oregon.gov).

Sincerely,

Brad J. Avy
Director and State Geologist

cc: Jon Allan, Tsunami Lead
Bill Burns, Natural Hazards Section Supervisor
Laura Gabel, Geologist
Ian Madin, Deputy Director and Chief Scientist
Jed Roberts, Geological Survey and Services Program Manager
Yumei Wang, Engineer

General Review Comments

This proposed project is in a high seismic hazard area due to the Cascadia Subduction Zone, which can produce a magnitude 9 earthquake, and the proposed Liquefied Natural Gas (LNG) Terminal facility is located in the Cascadia tsunami inundation zone. Some specific concerns related to the performance of the proposed facilities and public safety include:

1. The long duration of shaking expected with a magnitude 9 earthquake and how it might impact the proposed facilities and safety of people;
2. Ground failure of the softer and looser soils in the nearby area and how it may impact the proposed facilities and safety of people;
3. How the proposed facilities may negatively impact the tsunami hazards in the surrounding areas and safety of people;
4. Tsunami scour in the nearby area and how the Maximum Considered Tsunami (MCT), that is, the design tsunami, may impact the local landforms, including the dunes, and proposed facilities and safety of people;
5. Dynamic erosion of the North Spit dunes in response to the design tsunami and how it may impact tsunami runup at the proposed facilities and safety of people;
6. Tsunami debris impacting the nearby area and how it may impact the local landforms, including the dunes, proposed facilities and safety of people;
7. Dependencies on existing infrastructure that may fail, such as roads and levees; and
8. Lack of discussion of instrument monitoring safety programs related to potential ground failures, including ground settlement of soft soils and movement of landslides.

DOGAMI encourages designing and building for disaster resilience and future climate using science, data and community wisdom to protect against and adapt to risks. This will allow people, communities and systems to be better prepared to withstand catastrophic events and future climate—both natural and human-caused—and be able to bounce back more quickly and emerge stronger from shocks and stresses.

Applicant should follow existing regulations (e.g., State of Oregon's Oregon Revised Statutes, Oregon Administrative Rules, Oregon building codes, federal laws, and local regulations):

- Use best practices supporting public safety;
- Use a long-term view to protect citizens, property, environment, and standard of living;
- Integrate resilience, where possible, by avoiding high risk areas or embracing higher performance standards than may be required by building codes and regulations. This will lessen damage and speed recovery after disasters, and improve continuity of operations.

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- Integrate resilience, where possible, by avoiding high risk areas or embracing higher performance standards than may be required by building codes and regulations. This will lessen damage and speed recovery after disasters, and improve continuity of operations.

DOGAMI Comments on Resource Reports

DOGAMI's comments pertain to the specific resource reports as presented by the Applicant. It is possible that some of the comments on Resource Report 6 are addressed in Resource Report 13; however, the Applicant has not explained nor organized the information in a manner that can be readily reviewed.

Resource Report 6 – Jordan Cove Energy Project

9. The Resource Report 6 Jordan Cove Energy Project is incomplete. For example, none of the Appendices for have been provided in Resource Report 6, including:
   - Appendix A.6 – Geotechnical Data Report, Jordan Cove LNG Project
   - Appendix B.6 – Seismic Ground Motion Hazard Study, Jordan Cove LNG Project
   - Appendix C.6 – Geotechnical Report, Jordan Cove LNG Project
   - Appendix D.6 – Estuary Flood Risk and Hazard Study, Jordan Cove LNG Project
   - Appendix E.6 – Tsunami Hydrodynamic Modelling, Jordan Cove LNG Project
   - Appendix F.6 – Tsunami Maximum Run-up Modelling, Jordan Cove LNG Project
   - Appendix G.6 – Tsunami Wave Amplitude Analysis, Jordan Cove LNG Project
   - Appendix H.6 – Design Wind Speed Assessment, Jordan Cove LNG Project

10. Section 6.4.1.1 Earthquakes of the Resource Report 6 – Jordan Cove Energy Project provides seismic ground motions that are both incomplete and unclear. For example, the Applicant states that there is a "comparison in Table 6.4.1 includes values for soft rock site conditions as well as the anticipated site soil conditions after construction." Please provide this information in a clear manner that includes informative labels for the reviewer.

11. Section 6.4.1.1 Earthquakes of the Resource Report 6 – Jordan Cove Energy Project provides seismic ground motions that have not used new building code reference documents, namely American Society of Civil Engineers (ASCE) 7-16. Please discuss why ASCE 7-16 has not been used, or provide and discuss design values using ASCE 7-16.

12. Section 6.4.1.3 Soil Liquefaction of the Resource Report 6 – Jordan Cove Energy Project refers to Appendix C.6, however, this appendix was not provided. As requested earlier, please provide information that is referenced.

13. Section 6.4.1.3 Soil Liquefaction of the Resource Report 6 – Jordan Cove Energy Project does not include information on the method used for the liquefaction triggering analyses. DOGAMI recommends that the Applicant conduct analyses consistent with the National

Academies Liquefaction Study Report (2016), available at https://www.nap.edu/catalog/23474/state-of-the-art-and-practice-in-the-assessment-of-earthquake-induced-soil-liquefaction-and-its-consequences.

For all of the liquefaction analyses, the assumptions, methods used, and uncertainties associated with them should be explicitly stated and presented for each step of the analysis. This includes the uncertainties associated with field investigations, lab testing, triggering analyses, settlement analyses, lateral spreading analyses, and proposed mitigation. This should also be a part of any future analyses including soil-structure interaction and other modeling of the structural responses to the hazards and for proposed mitigation. Results should be summarized so that it is clear which resulting values are being used for design purposes.

14. Section 6.4.1.4 Tsunamis of the Resource Report 6 – Jordan Cove Energy Project states: "The modeled rupture scenario XL1 has an estimated period longer than the 10,000-year event discussed in Volume 2, Section 13.I.2.4 of FERC's Guidance Manual for Environmental Report Preparation (February 2017)." DOGAMI's XL1 is a deterministic scenario. The DOGAMI XL1 scenario is not associated with a period longer than the 10,000-year event.

    Since 2016, there has been a national standard for tsunami resilient design in the American Society of Civil Engineers (ASCE) 7-16 Chapter 6 Tsunami Loads and Effects. This is the consensus-based engineering standard that is a referenced requirement in the latest (2018) International Building Code (IBC). The IBC is a model code that is widely adopted throughout the country including by the State of Oregon. ASCE 7-16 was extensively vetted by the American Society of Civil Engineers using an accredited and audited consensus process.

    DOGAMI recommends the Applicant comply with ASCE 7-16. DOGAMI recommends that the Applicant meet or exceed the inundation limit and other design parameters in the ASCE 7 Tsunami Design Geodatabase and select design procedures and parameters, such as design inundation depths and flow velocities, which would result in a proposed facility that will protect human safety. Any modeling procedure for determining site-specific tsunami design inundation and velocities should follow Section 6.7 of ASCE 7-16 and demonstrate that the tsunami input meets the Probabilistic Tsunami Hazard Analysis Offshore Tsunami Amplitude of the ASCE Tsunami Design Geodatabase. Maps and criteria in the ASCE 7-16 design standard are based on engineering risk analysis and reliability targets. The ASCE 7-16 Maximum Considered Tsunami (MCT) has a 2% probability of being exceeded in a 50-year period, or a 2,475 year average return period. The ASCE 7-16 MCT is a design basis event, characterized by the inundation depths and flow velocities at the stages of inflow and outflow most critical to the structure(s).

The Applicant should clearly present each step of the multiple tsunami analyses in a manner suitable for peer review by qualified professionals. All analyses, methods, assumptions and final values used for the structural design procedures for tsunami effects should be clearly documented so that results are reproducible. This includes, but is not limited to, identifying debris impact loads, foundation design factors, uplift forces, scour forces, and loads for all Tsunami Risk Category III and IV Nonbuilding Structures and designated nonstructural components.

15. Section 6.4.1.4 Tsunamis of the Resource Report 6 – Jordan Cove Energy Project refers to the existing Trans Pacific Parkway/US- 101 Intersection as being in the tsunami inundation zone. The Applicant states "To maintain grades, improvements to the intersection will not remove the intersection from the tsunami inundation zone." There appears to be only one access road for the proposed Jordan Cove LNG facility. This access road is in the tsunami inundation zone. In order for the access road to be reliably useable for safety purposes after a future tsunami disaster, it would need to incorporate both earthquake and tsunami resistant designs. These designs would need to factor in potential cyclic strain, liquefaction and lateral spreading from ground shaking. In addition, the designs would need to account for tsunami forces, including flooding, velocities, scour, buoyancy and debris impact. Has this roadway and access to the proposed facilities been evaluated for possible damage due to tsunami forces, such as tsunami scour and tsunami debris impact? Please provide analyses, results and, if needed, proposed mitigation that addresses both post-earthquake and post-tsunami safety for proposed berms, roadways and elevated ground. Related documents should be complete, clearly organized and presented to allow for peer review by qualified specialists.

Resource Report 6 – Pacific Connector Gas Pipeline Project

16. The Resource Report 6 – Pacific Connector Gas Pipeline Project is incomplete. For example, some of the Appendices for have not been provided, including:
    - APPENDIX C – Site-Specific Landslide Evaluation
    - APPENDIX H – Geotechnical Boring Logs
    - APPENDIX I – Laboratory Testing
    - APPENDIX J – Seismic Reflection Survey – Stukel Mt. Fault

17. The Applicant states (on page 7): "With the exception of those in the Klamath Falls area, these mapped surface faults are not considered active and are not believed to be capable of renewed movement or earthquake generation (USGS, 2002 interactive fault website)". DOGAMI considers Quaternary active faults as capable of generating potentially damaging earthquakes. DOGAMI has mapped late Quaternary faults in Coos Bay, which could impact the proposed project. Please refer to this publication: www.oregongeology.org/pubs/gms/GMS-094.pdf. DOGAMI recommends that a thorough literature review be conducted for known Quaternary active faults, as well as a site specific investigation that covers the proposed project area to evaluate if unknown Quaternary faults exist that may negatively impact the proposed facilities. Analysis of recently acquired lidar data throughout Oregon has identified numerous previously unidentified late Quaternary or Holocene fault scarps including in the Klamath Falls area. The entire pipeline right-of-way (ROW) should be evaluated thoroughly with lidar coverage of a broad area around the ROW to identify potentially hazardous faults.

18. The Applicant states (on page 8): "The PCGP Project is located in relatively sheltered areas of Coos Bay, where the effects of a tsunami on the pipeline are expected to be relatively minor". DOGAMI requests the tsunami analyses that supports this statement. What tsunami modeling was conducted for the proposed pipeline alignment? What are the tsunami flow depths used to estimate scour potential? Were tsunami scouring forces evaluated for both the incoming (inflow) and outgoing (outflow) tsunami waves?

19. The Applicant states (on page 9): "The recurrence interval between Cascadia events has been irregular and ranges from about 100 to 1,000 years (Atwater and Hemphill-Haley, 1997). Typical recurrence intervals are thought to be on the order of 400 to 600 years (Clague et al., 2000)." DOGAMI requests that the Applicant consider the most recent scientifically peer reviewed data on recurrence intervals for the Cascadia Subduction Zone (e.g., Goldfinger, et al, 2016). DOGAMI recommends that the Applicant consider the continually evolving scientific information on the Cascadia Subduction Zone and related seismic hazards.

20. The Applicant states (on page 10): " PGAs for the PCGP Project are listed in Table 2, based on USGS (2008) data compilation." DOGAMI requests that the Applicant consider the most recent USGS data, including the 2014 USGS seismic hazard maps.

21. The Applicant states (on page 10) "Higher PGAs are possible where soft soil overlies bedrock, such as in the vicinity of North Slough and Haynes Inlet MP 1.47H to 5.3H. We estimate Site Class D conditions are appropriate for the MP 1.47H to 5.3H areas." It is

common in estuaries to have soils that are softer than Site Class D conditions due to the presence of estuarine muds and river sediments, and these soils may amplify earthquake shaking. Rather than the Applicant estimating the Site Class type as D, DOGAMI recommends that both a literature review and site specific analyses are conducted to determine actual Site Class types and use those to determine PGAs and other relevant seismic ground motions and response. Downhole shear wave velocity measurements of Coos Bay estuarine sediments are available in the DOGAMI O-13-06 database.

22. The Applicant states (on page 11): " ...there is a low risk of pipeline damage from ground shaking in the absence of other deformation adversely affecting the pipeline. Based on these studies, the potential damage to buried pipelines from ground shaking intensity at the site is considered to be low." DOGAMI requests the Applicant to provide information on the vulnerability of buried pipelines in sloped areas without ground deformation during seismic shaking, such as along portions of the proposed corridor that crosses the Coast, Klamath and Cascade Ranges.

23. The Applicant states (on page 11): "ancient, inactive faults have no potential for rupture." DOGAMI finds this statement to be misleading. Weak planes or zones, such as ancient faults and bedding planes, can be displaced from earthquake shaking. DOGAMI recommends that the Applicant evaluate weak planes and zones for potential displacement that could impact the proposed pipeline.

24. The Applicant reviews faults that cross the proposed pipeline on pages 11 - 13 and includes "TABLE 3. MAPPED QUATERNARY AND HOLOCENE FAULTS CROSSING THE PCGP PROJECT". DOGAMI recommends that Applicant evaluate all faults that can impact the pipeline, including nearby active faults in Coos Bay. As stated in an earlier comment, DOGAMI has mapped late Quaternary faults in Coos Bay, which could impact the proposed project. Please refer to this publication: www.oregongeology.org/pubs/gms/GMS-094.pdf. DOGAMI recommends that a thorough literature review be conducted for known Quaternary active faults, as well as a site specific investigation that covers the proposed project area to evaluate if unknown Quaternary faults exist that may negatively impact the proposed facilities.

25. The Applicant states (on page 13): "As mentioned in the previous section, published maps are adequate for identifying the presence or absence of active faults, but are generally not detailed enough for pipeline design." DOGAMI disagrees with this statement—many areas have not been carefully mapped by geologists and it is highly likely that many active faults have not yet been identified. Furthermore, newer technologies that allow for identification

of active faults are now readily available whereas in the past they were not. As stated in an earlier comment, DOGAMI recommends that a thorough literature review be conducted for known Quaternary active faults, as well as a site specific investigation that covers the proposed project area to evaluate if unknown Quaternary faults exist that may negatively impact the proposed facilities.

26. The Applicant discusses a three phase liquefaction analysis approach and states (on page 15): "This second phase liquefaction analysis was completed using simplified methods (Seed et al., 2003; Idriss and Boulanger, 2008; and Boulanger and Idriss 2014)". DOGAMI recommends that the Applicant conduct analyses consistent with the National Academies Liquefaction Study Report (2016), available at https://www.nap.edu/catalog/23474/state-of-the-art-and-practice-in-the-assessment-of-earthquake-induced-soil-liquefaction-and-its-consequences. For the Applicant's second phase, conducting analyses using additional methods to estimate liquefaction triggering would be considered as standard-of-practice. As DOGAMI stated in earlier comments, for all of the liquefaction analyses, the assumptions, methods used, and uncertainties associated with them need to be explicitly stated and presented for each step in the analysis. This includes the uncertainties associated with field investigations, lab testing, triggering analyses, settlement analyses, lateral spreading analyses, and proposed mitigation. This should also be a part of any future analyses including soil-structure interaction and other modeling of the structural responses to the hazards and for proposed mitigation. Results should be summarized so that it is clear which results are being used for design purposes.

27. The Applicant states (on page 15): "If liquefaction will be triggered at previously identified susceptible pipeline segments under the maximum considered earthquake (MCE) per ASCE 7-10 code". As DOGAMI stated in an earlier comment, the Applicant has developed seismic ground motions that have not used newer building code reference documents, namely ASCE 7-16, which was published in 2016 as opposed to 2010. Ground motion values using ASCE 7-16 should be presented and used in the liquefaction analyses.

28. The Applicant states (on page 16): "the liquefaction and lateral spreading potential at Indian Creek (MP 128.58 – 128.62) remains unknown and access to the site remains restricted". DOGAMI requests that the Applicant keep DOGAMI informed on the status of this situation and data gap, and explain their next steps. For example, will the Applicant select another proposed route?

29. The Applicant states (on page 16): "The third phase analysis for the rerouted pipeline segment extending from MP 1.5H to 5.5H is in process and the results will be available for

the final submittal of this report." DOGAMI requests that the Applicant keep DOGAMI informed on the status of these analyses.

30. The Applicant states (on page 17): "Higher PGAs are possible where soft soil overlies bedrock, such as in the vicinity of North Slough at MP 1.47 to 3.2H and Haynes Inlet MP 4.7H to 5.5. We estimate Site Class D conditions are appropriate for the North Slough and Haynes Inlet areas." As DOGAMI stated earlier, it is common in estuaries to have soils that are softer than Site Class D conditions due to the presence of estuarine muds and river sediments, and these soils may amplify earthquake shaking. Rather than the Applicant estimating the Site Class type as D, DOGAMI recommends that site specific analyses are conducted to determine actual Site Class types and use those to determine PGAs and other relevant seismic ground motions and response.

31. The Applicant states (on page 20): "At the Coos River site, stresses exceed 100 percent SMYS but are estimated to be below the combined stress limit as shown in Figure 4.3.1 above. However, the analyses were based on elastic modulus and when the yield stress is exceeded, as in the case of the Coos River site, a fully plastic analysis is required to accurately assess the pipe stresses and strains. A fully plastic analysis requires modeling the stress-strain behavior of the pipeline under cyclic conditions in such a way as to capture strain-hardening effects, which requires a full-scale cyclic pipe load test to develop accurate model parameters. It also requires that the operational hoop, thermal, and internal pressures are accounted for during cyclic conditions. This type of analysis is beyond the scope and expertise of GeoEngineers." DOGAMI recommends that appropriate pipeline analyses are conducted by qualified specialists for the Coos Bay site, and potential impacts associated with liquefaction, lateral spreading, cyclic strain, and buoyancy forces be addressed to ensure public safety.

32. The Applicant states (on page 20): "with the potential for very large, long recurrence interval, Cascadia events". DOGAMI finds this statement as misleading. Seismologists and earthquake geoscientists, as professionals, would not generally consider earthquake recurrence intervals on the order of a few hundred years to be "very large, long". DOGAMI requests the Applicant to clarify, substantiate or change their statement.

33. The Applicant states (on page 20): "a fully plastic analysis of pipe strain will be completed to verify that the liquefaction and lateral spreading induced plastic deformation of the pipe at the Coos River crossing is tolerable." As stated earlier, DOGAMI recommends that appropriate pipeline analyses are conducted by qualified specialists for the Coos Bay site,

and potential impacts associated with liquefaction, lateral spreading, cyclic strain, and buoyancy forces are addressed to ensure public safety.

34. The Applicant states in their Conclusion sector (on page 21): "One Holocene (active) fault crossing and three Quaternary fault crossings were identified along the proposed pipeline alignment as listed in Table 3." As DOGAMI stated earlier, DOGAMI recommends that a thorough literature review be conducted for known Quaternary active faults, as well as a site specific investigation that covers the proposed project area to evaluate if unknown Quaternary faults exist that may negatively impact the proposed facilities. The faults should not be limited to locations of the proposed pipeline crossings.

35. The Applicant states (on page 25): "some of the later reroute alignments are currently outside the area of LiDAR and aerial photograph coverage". DOGAMI recommends the Applicant obtain high resolution lidar for all areas that may impact the proposed facilities along the proposed route. Lidar coverage should be collected with enough buffer distance to characterize potential seismic and landslide hazards. For example, for landslide hazards, the lidar should include from the valley bottom to the top of the ridge. Also, there is publicly available statewide aerial photography. Please evaluate the potential large landslides keeping in mind that landslides may extend from the tops of ridges and may move downslope to block rivers. In addition, lidar should be used to evaluate seismic sources.

36. The Applicant states (on page 27): "The DOGAMI study provides a broad-scale assessment and mapping of slopes potentially susceptible to RMLs along the portion of the pipeline within Coos, Douglas and Jackson counties (MPs 1.5H - 166). The potential for RMLs to occur east of MP 166 generally is considered to be relatively low based on geologic conditions, relatively little rainfall and statistically fewer past historical RML occurrences. However, the slopes east of MP 166 were reviewed for this hazards report to identify high-risk sites based on general guidelines provided in Forest Practices (FP) Technical Note 2 of the Oregon Department of Forestry (ODF, 2000). The ODF guidelines recommend screening for high-risk sites by identifying slopes that exceed 65 percent gradient on existing topographic maps, then performing surface reconnaissance to identify high risk site features." Both the DOGAMI RML and ODF RML methods are outdated. DOGAMI recommends that the Applicant use current state of practice methods that include lidar as a base map.

37. The Applicant states (on page 27): "Based on available topographic mapping, no slopes along the pipeline alignment east of MP 166 exceed 65 percent or appear to be at high

potential for RML occurrence." DOGAMI does not agree with the conclusion based on the fact that state-of-practice methods were not used to develop this conclusion. DOGAMI recommends that the Applicant use current state of practice methods that include lidar as a base map.

38. The Applicant states (on page 46): "As currently planned the portions of the pipeline that are crossing waterbodies that have the potential to be impacted by tsunami scour, will be installed using trenchless methods at depths well below the potential scour depths. Therefore, tsunami scour is not considered a hazard to the pipeline project." The Applicant further states "The modeling analysis showed that some temporary scour may occur in Coos Bay along the pipeline during inundation of the tsunami (approximately 1 to 2 hours)." The Applicant indicates that scour from tidal currents and river flows are approximately 3 feet at the pipeline crossing, and "it is recommended to use a 3-foot depth of scour resulting from tsunami impact". DOGAMI requests the Applicant provide information on maximum potential scour depth from a Cascadia tsunami. Also, DOGAMI requests information on the minimum factor of safety the Applicant applied to address the maximum potential scour depth from Cascadia tsunamis along the proposed alignment in greater Coos Bay area.

<u>Draft Resource Report 13 Engineering and Design Material, Chapter 13.3 Natural Hazards and Conditions, Jordan Cove Energy Project, dated May 2017, which includes:</u>

- <u>Appendix I.13 Natural Hazard Design Investigations and Forces, and</u>
- <u>Appendix J.13 Site Investigation and Conditions, and Foundation Design</u>

Based on the review of tsunami-related documents in Resource Report 13, DOGAMI requests additional supporting information that discusses and clarifies the following:

39. The Applicant, in general, found that their MIKE21 modeling matched the DOGAMI L1 first wave arrival (which reflects the largest wave), although wave amplitudes and phase differences were observed for later wave arrivals. No explanation is provided to account for the latter differences. DOGAMI requests further discussion of differences in the modeling results after the initial wave arrival to account for phase and amplitude differences observed in the modeling results.

40. DOGAMI requests that the Applicant provide peer reviewed documentation that describes the MIKE21 FM model and its ability to model tsunami inundation. Many issues are unclear, for example, does MIKE21 adequately account for the (vertical) wave runup on the wall and/or composite structure?

41. DOGAMI requests that the Applicant provide further explanation of the approach used to define the digital elevation model (DEM) that is recommended. In particular, how does the developed grid differ from the tsunami grids generated by NOAA's National Center for Environmental Information (NCEI). These data may be obtained here: https://www.ngdc.noaa.gov/mgg/inundation/tsunami/.

42. DOGAMI requests that the Applicant explain to what extent has the model been tuned to match the DOGAMI L1 scenario and inundation results.

43. DOGAMI requests that the Applicant provide a better depiction of the three cases used to define the design crests. It is unclear whether the design reflects a berm, wall, or a composite structure around the perimeter of the entire complex, or portions of the complex. Please provide figures that characterize the proposed design.

44. DOGAMI requests that the Applicant explain why mean high water (MHW) was used as opposed to MHHW (as used by DOGAMI).

45. Values of future sea level rise (SLR) presented by the Applicant are based on existing (historical) trends derived for the Charleston tide gauge. Based on its current rate, estimates were made out into the future (i.e. 30 years). This is an overly simplistic approach that assumes the past is the key to the future and hence discounts possible acceleration of SLR in the future. A more effective approach would be to base future estimates on the National Research Council (2012) SLR study that was completed for the US West Coast. National Research Council estimates account for expected local tectonic changes as well eustatic and steric responses and are a more reasonable (and current) estimates for the future. Please address SLR using current scientific data and methods.

46. Provide analysis of the potential role of sediment erosion of the North Spit dunes caused by the design tsunami. Research on the US East Coast suggests that sediment erosion during a tsunami may be significant and could impact inundation extents and runup (Tehranirad et al., 2015, 2016; Tehranirad, 2016). This notion is also supported by field studies following the March 11, 2011 Tohoku, Japan tsunami (Goto et al., 2012; Tanaka et al., 2012).

47. Provide analyses of the potential role of tsunami wave reflection/focusing/defocusing as the tsunami impacts the proposed LNG facilities and its possible public safety implications for the surrounding Coos Bay environment. Tsunami waves that impact against proposed protective structures (e.g., berm, wall or composite structure) and the subsequent transfer of that energy to other areas within the bay is a public safety concern. DOGAMI requests

additional modeling for the purposes of addressing public safety. All documents should be complete, clearly organized and presented to allow for peer review by qualified specialists.

48. DOGAMI requests that the Applicant provide analysis of maritime vessels and their potential to become ballistics within the bay. Maritime evacuation planning in response to the tsunami should be conducted and provided.

49. DOGAMI requests that the Applicant provide analysis on the potential for off-site debris impacting the facilities and the potential ramifications with respect to public safety.

50. DOGAMI requests that the Applicant provide information on each of the DEMs used for the tsunami model. For example, were three different DEMs used that reflect the three different case studies: berm, wall and composite structure? Please provide the DEMs.

51. Elevated structures, including elevated berms, used for assembly areas in the tsunami inundation zone are subject to ASCE 7-16 chapter 6 requirements. To ensure public safety, DOGAMI strongly recommends that the Applicant design all elevated structures to be used as assembly areas in the ASCE tsunami design zone in accordance with ASCE 7-16 chapter 6. Design documents should be complete, clearly organized and presented to allow for peer review by qualified specialists.

Document Content(s)

Jordan Cove LNG
A Pembina Company

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April 12, 2019

Mr. Todd Cornett
Division Administrator--Energy Facility Siting
Oregon Department of Energy
550 Capital St NE
Salem, OR 97301

Re: Jordan Cove -- Withdrawal of Application for Exemption

Dear Mr. Cornett:

By letter dated June 14, 2018, Jordan Cove Energy Project L.P. ("JCEP") submitted to the Oregon Department of Energy ("ODOE") an Application for Exemption from a Site Certificate for a high-efficiency cogeneration energy facility to be constructed at its proposed Liquefied Natural Gas Terminal in Coos Bay, OR (the "LNG Terminal"). This letter is to inform you that JCEP is withdrawing that Application for Exemption.

JCEP has made a minor modification to the LNG Terminal such that the nominal electric generating capacity is less than 25 megawatts. Consequently, the LNG Terminal does not meet the definition of an "energy facility" in ORS 469.300(11)(a) and is below the Energy Facility Siting Council's jurisdictional threshold applied to state jurisdictional energy facilities. Therefore, there is no basis (or need) for JCEP to request, or the Siting Council to issue, an exemption. As a result, please consider our Application for Exemption from a Site Certificate withdrawn.

Thank you for your assistance and that of your staff.

Sincerely,

Mike Koski
VP, External Affairs

cc: Ms. Janine Benner, Director

2019 ODFW Oregon Marbled Murrelet Habitat - DRAFT

Introduction and purpose

In furtherance of the Wildlife Policy (ORS 496.012) of the State of Oregon, the Oregon Fish and Wildlife Commission has directed Oregon Department of Fish and Wildlife (ODFW) staff to review land and water development actions for their consistency with the goals and standards of the Fish and Wildlife Habitat Mitigation Policy (hereafter, mitigation policy; OAR 635-415-0000 to -0025). ODFW strives for standardization and transparency in its application of the mitigation policy. To that end, it sometimes becomes necessary to articulate ODFW's reasoning and justification for certain policy interpretations. This can help to establish clear guidance for staff in their review of future projects, and to enhance communication with regulatory agencies and project developers.

The purpose of this white paper is to explain why marbled murrelet nesting habitat meets the Category 1 definition of the mitigation policy. This document is subject to update and revision and will retain a draft status until further notice.

Life History and habitat characteristic requirements

The Marbled murrelet (*Brachyramphus marmoratus*) is a small seabird that breeds along the Pacific Coast from Alaska to central California. Marbled murrelets spend most of their lives at sea and forage on small fish and invertebrates in nearshore marine waters. Throughout much of their range, they fly inland for nesting in old-growth and late-successional forests. Marbled murrelets do not construct nests, per se, but instead lay their single egg in a depression in moss, lichen, or tree litter on a large or deformed tree branch, generally high in the live canopy.

Marbled murrelets nest in Oregon from mid-April to mid-September. Their lifespan averages 15 years, reaching sexual maturity at age 2 or 3. Marbled murrelets have a naturally low reproductive rate because they lay only one egg per nest and not all adults nest every year.

Marbled murrelets in Washington, Oregon, and California were listed as threatened under the federal Endangered Species Act in 1992, and were subsequently listed as state-threatened in Oregon under the Oregon Endangered Species Act in 1995. The species is listed as state-endangered in both Washington and California.

Biological Status and Threats

Summary:

1. Marbled murrelets have narrow habitat requirements and limited geographic distribution. Occupied landscapes tend to have large amounts of cohesive (unfragmented) old-growth or mature forest

nesting habitat. Once nesting habitat is lost, high breeding site fidelity and limited flight range from the coast to inland forests may further restrict distribution. Contemporary events that remove old-growth or mature forests may be difficult or impossible for the species to compensate for in the short-term since suitable habitat takes many decades or centuries to develop.

2. Changes in late-successional forests in Oregon since European settlement, due to timber harvest, fire, wind, and other factors, have substantially reduced marbled murrelet nesting habitat from historical levels. Loss and degradation of old-growth and mature forest nesting habitat were the primary reasons for initial state and federal listings. Based on Northwest Forest Plan estimates, higher-suitability nesting habitat1 declined in Oregon from approximately 853,400 acres in 1993 to 774,800 acres in 2012, a net loss of 78,600 acres (-9.2% change). Losses were greatest on nonfederal lands during this period.

3. Remaining nesting habitat persists mostly on public lands, including the Siuslaw and Rogue River-Siskiyou National Forests, forests owned by the Bureau of Land Management, and the state-owned and managed Tillamook, Clatsop, and (formally) Elliott State Forests. Old-growth and mature forest remnants are highly fragmented and contain a high proportion (>70-90%) of edge.

4. While natural disturbances have always shaped Oregon forests, climate change is expected to increase potential for habitat loss from catastrophic wildfires, insect infestations, disease outbreaks, and severe storms, and to exacerbate conditions unfavorable to murrelets in the marine environment.

5. There are no available surveys that provide a continuous assessment of marbled murrelet population trends in Oregon since their listing in 1995. A significant decline (>50%) on Oregon's central coast was detected in 1996 through at-sea surveys conducted from 1992-1999 (Strong 2003). The Northwest Forest Plan's Marbled Murrelet Effectiveness Monitoring Program monitored murrelets at sea in Oregon nearly annually from 2000-2015, and did not find evidence of a population decline during that period for Oregon. The Northwest Forest Plan, Marbled Murrelet Effectiveness Monitoring (Pearson et al., 2017) indicated a positive trend for Oregon from 2000-2016 (Raphael et al. 2016). Based on this monitoring program, the Oregon population was estimated at 10,060 birds in 2015 and was likely somewhere between a range of 7,451 and 12,579 birds.

6. The marbled murrelet's life history strategy (e.g., long-lived, low annual reproductive potential, delayed reproductive maturity) requires high survivorship of adults, subadults, and young in order for breeding birds to successfully "replace" themselves over the course of their lifetimes and yield a stable or increasing population. Marbled murrelet generation time has been estimated at about 10 years, and this life history strategy allows some flexibility for poor or no breeding success during adverse conditions, but only for relatively short periods of time (years as opposed to decades). Adult or subadult mortality due to anthropogenic factors or catastrophic events, or cumulative or synergistic impacts that affect recruitment over long periods, could also lead to severe population declines or even extirpations.

7. Marbled murrelets require sufficient prey resources in the marine environment for survival and successful reproduction. Oceanic conditions influence the abundance, distribution, and timing of prey available to murrelets, and prey quality and availability in turn affect breeding propensity and success. A centennial shift in murrelet diet to lower (poorer quality) trophic levels has been documented in parts of the murrelet range. As with many other seabirds, low reproductive success has also been linked, in part, to El Niño years and other warm water events.

8. A large oil spill remains a serious threat and could kill hundreds or thousands of marbled murrelets in Oregon. For example, the New Carissa oil spill in 1999 released over 70,000 gallons of fuel into the marine environment near Coos Bay, Oregon, killing an estimated 262 marbled murrelets.

9. Other emerging natural or anthropogenic threats to the species include, but are not limited to, energy development projects; harmful algal blooms that produce biotoxins, feather-fouling surfactants, or low-oxygen "dead zones" in the ocean; and contaminants in prey that can bio-magnify through the food chain.

10. The threat posed by inadequate state and federal programs and regulations has decreased since state listing of the marbled murrelet in 1995 and federal listing in 1992. For example, implementation of the Northwest Forest Plan greatly reduced the rate of habitat loss due to timber harvest on federal lands. Nonetheless, existing state and federal programs and regulations have failed to prevent continued high rates of habitat loss on nonfederal lands in Oregon.

Habitat Requirements

Marbled murrelets are unique among North American alcids in that they nest primarily in coastal old-growth and late-successional forests. They do not construct a nest, per se, but rather lay their single egg on a large or deformed tree branch high in the canopy. Large platforms with moss, lichen, or other nesting substrate, foliage cover above and around the nest, high densities of large trees, multiple canopy layers, and proximity to openings in the canopy that provide flight access are among important habitat features (Nelson et al. 2006). Occupied stands in Oregon are mostly old-growth or fire-regenerated, naturally-planted stands dominated by Douglas-fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heterophylla*), or Sitka spruce (*Picea sitchensis*) (Grenier and Nelson 1995, Nelson and Wilson 2002). Most nests have been found in trees 80 years or older in Oregon (Hamer and Nelson 1995b, Nelson and Wilson 2002), though nesting has been documented in some younger and mature trees within the Sitka spruce/western hemlock forest type; these younger and mature trees had structural elements (deformities or dwarf mistletoe infestations) characteristic of older trees (Nelson and Wilson 2002).

Marbled murrelets use nearshore marine waters for resting and feeding on small schooling fish and marine invertebrates (Burkett 1995, Piatt et al. 2007, Nelson et al. 2006). They depend upon productive marine waters in close proximity to suitable forest nesting habitat for successful reproduction, and must commute from nest to sea when provisioning their chick. During the breeding season in Oregon (April through September), murrelets are typically concentrated within 2 km [1.2 miles] of the shore when at sea (Strong et al. 1995, Falxa et al. 2016). Highest murrelet densities during the breeding season have been observed offshore of large blocks of potential nesting habitat (Raphael et al. 2015, Raphael et al. 2016b).

Nesting Habitat Loss and Degradation

There is strong evidence of large-scale loss of older forests since European settlement within the marbled murrelet range in the Pacific Northwest and northwestern California (e.g., Booth 1991, Teensma et al. 1991, Bolsinger and Waddell 1993, Ripple 1994, Perry 1995, USFWS 1997, Wimberly et al. 2000, McShane et al. 2004, Strittholt et al. 2006, Ohmann et al. 2007, Davis et al. 2015). In the Oregon Coast Range, Wimberly and Ohmann (2004) estimated that large-conifer forests declined by 58% between 1936 and 1996, with corresponding increases in small-conifer forests during this period. Habitat loss and degradation were primary factors in the initial federal and state listings of the marbled murrelet in the 1990s (CDFG 1994, ODFW 1995, Desimone 2016, USFWS 1997, 57 FR 45328). Since the 1990s, further habitat losses have occurred, mainly due to timber harvest on nonfederal lands and wildfire on federal lands (Raphael et al. 2016a).

Past habitat removal has created large gaps that fragment population distribution within the core of the marbled murrelet range (Ralph et al. 1995a, USFWS 1997, RIT 2012); in Oregon, large habitat gaps occur in the northwest portion of the state as well as the coastal strip between Reedsport and the Siskiyou Mountains (RIT 2012; Fig. 2 in ODFW 2018). Most remaining nesting habitat persists on public lands in Oregon, including the Siuslaw and Rogue River-Siskiyou National Forests, forests owned by the Bureau of Land Management, and the state-owned and managed Tillamook, Clatsop, and Elliott State Forests (Raphael et al. 2016a; Fig. 2 in ODFW 2018). The full extent of occupied habitat on private lands is unknown since state regulations for forest practices do not require pre-project wildlife surveys by private landowners (Tucker and Weikel 2017a); it is generally assumed to be low given available forest stand inventory and harvest data (Greber et al. 1990, Ohmann et al. 2007) and the Department's examination of the 2012 habitat suitability data produced by Raphael et al. (2016a) for Oregon (see ODFW 2018 for details).

Key Threats, Stressors, and Climate Change Effects

Forest Habitat Alteration

As discussed above, marbled murrelets have experienced both past and contemporary habitat loss. However, it is also the distribution and quality (how far inland, how isolated, how fragmented, etc.) of remaining habitat that is important. Remaining habitat is highly fragmented in Oregon, and most of it persists on public lands. Raphael et al. (2016a) classified nearly 90% of potential habitat on nonfederal lands as "edge", whereas federal lands had lower (>70-80%) but still high proportions of edge. Edge effects can degrade otherwise suitable forest remnants through changes in abiotic or biotic conditions.

Lack of buffers and heavy thinning adjacent to murrelet habitat can also contribute to habitat loss and degradation (Raphael et al. 2016b). Examples of adverse edge effects that could result from recent clearcuts (and logging/thinning adjacent to occupied sites) include elevated predator densities and predation levels, greater windthrow damage, and reduced epiphyte abundance needed for nesting substrate relative to forest interiors (Nelson and Hamer 1995b, McShane et al. 2004, van Rooyen et al. 2011). Fidelity to breeding areas (Divoky and Horton 1995) as well as the time it takes for nesting habitat to develop (decades to centuries) (Falxa et al. 2016) may limit the ability for murrelets to colonize new sites, at least in the short-term.

Predation

Many known or potential murrelet nest predators have seen significant increases in abundance in recent decades (see Burger 2002, Piatt et al. 2007, Halbert and Singer 2017). Evidence throughout the range from both real and artificial murrelet nests indicates that predation is a leading cause of nest failure (Nelson and Hamer 1995b, USFWS 1997, McShane et al. 2004, USFWS 2009) and that corvids (jays, crows, ravens) have the greatest impact (USFWS 2009). Forest fragmentation may contribute to elevated predation rates by increasing predator densities or activity along forest edges (Nelson and Hamer 1995b). Anthropogenic food sources from campgrounds, trails, picnic areas, or other human settlements tend to support elevated levels of corvids, which can lead to higher nest depredation for nearby murrelets (Marzluff and Neatherlin 2006, Bensen 2017, Goldenberg et al. 2016), and perhaps for murrelets nesting further away (West and Peery 2017).

Recovering raptor (e.g., Bald Eagles *Haliaeetus leucocephalus*, Peregrine Falcons *Falco peregrinus*) populations pose a new potential threat to adult and juvenile murrelet survival (Piatt et al. 2007, RIT 2012). This is of particular concern given that murrelet population growth is thought to be influenced most by adult and subadult survival (McShane et al. 2004). Depredation of adult murrelets by Peregrine Falcons, Sharp-shinned Hawks (*Accipiter striatus*), Common Ravens (*Corvus corax*), Northern Goshawks (*A. gentilis*), and Bald Eagles has been documented, but there is no information on mortality rates (McShane et al. 2004).

Other environmental impacts such as adverse oceanic conditions, climate change, effects oil spills, and other large-scale disturbances such as catastrophic fire, are also serious additive threats to the species' survival and recovery (ODFW 2018).

Regulatory Framework

Federal Endangered Species Act

Under the federal ESA, take (to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or attempt to engage in any such conduct) of marbled murrelets is prohibited unless authorized by permit from the USFWS. This definition of take includes harm caused by significant habitat modification or degradation. It applies to nonfederal (private, state, other) and federal lands. While the federal ESA and other federal protections appear to have reduced the overall rate of habitat loss since the 1990s (see McShane et al. 2004, Raphael et al. 2016a), they have not prevented considerable harvest of potential murrelet habitat on nonfederal lands during that period (Raphael et al. 2016a) and impacts from adjacent harvest on all land ownerships. Existing federal protections have slowed but not halted habitat loss on both federal and nonfederal lands in Oregon.

Current Legal Status in Oregon

The Washington, Oregon, and California distinct population segment of the marbled murrelet was listed as threatened under the federal Endangered Species Act (federal ESA) in 1992 (57 FR 45328). The U.S. Fish and Wildlife Service (USFWS) determined that the species was threatened by loss and modification of older forest nesting habitat, mainly due to timber harvest, as well as mortality from gillnet fishing operations in Washington State and the effects of oil spills (57 FR 45328). Federal critical habitat for the marbled murrelet was first designated in 1996 (61 FR 26256), revised in 2011 (76 FR 61599), and reaffirmed in 2016 (81 FR 51348). The USFWS completed a recovery plan for the marbled murrelet in 1997 (USFWS 1997).

The marbled murrelet was listed as threatened under the Oregon Endangered Species Act (OESA) in 1995 (OAR 635-100-0125), also owing mainly to habitat loss (ODFW 1995).

Oregon Endangered Species Act

The most direct effect of listing a species as threatened or endangered under the OESA is through management decisions on state-owned, managed, or leased lands. Private lands are not directly affected by the OESA (ORS 496.192) except that no person is allowed to "take" a listed species anywhere in the state, and through the Oregon Forest Practices Act (FPA) (ORS 527.610-.992, OAR Chapter 629 Divisions 600-680), which requires special protection for both federal and state-listed species. Under the OESA, "take" is defined as "to kill or obtain possession or control of any wildlife" (ORS 496.004(16)).

State agencies work together to implement conservation measures adopted by the Oregon Fish and Wildlife Commission, and ODFW biologists act as scientific consultants to other land and water managers to advise whether a management action can affect survival or recovery of a listed species.

The OESA requires particular state agencies to develop plans for the management and protection of endangered species (ORS 496.182(8), OAR 635-100-0140(6)), and to comply with survival guidelines adopted by the Oregon Fish and Wildlife Commission for threatened species (ORS 496.182(2), OAR 635-100-0130). Survival guidelines are quantifiable and measurable guidelines necessary to ensure the survival of individual members of the species (OAR 635-100-0100(13)). They may include take avoidance and protecting resource sites such as nest sites or other sites critical to the survival of individual members of the species.

Habitat Categorization per the ODFW Fish and Wildlife Habitat Mitigation Policy

The mitigation policy is based on the premise that habitats can have varying levels of "relative importance" or influence on the survival of fish and wildlife species. This variability will depend on the ecological condition and physical setting of habitat at a specific site, and the needs and sensitivity of fish and wildlife species using the habitats. The policy also recognizes that opportunities and approaches for habitat mitigation can also vary accordingly. This recognition resulted in the mitigation policy's hierarchy of habitat categories. For example, Category 1 represents habitats that have the highest relative importance to the survival and production of fish and wildlife, and that are difficult to replicate. Reflecting this importance, habitats in this category require the highest level of conservation with limited opportunities for mitigation (mitigation is limited to avoidance of impacts). At the other end of the hierarchy, category 6 contains habitats that provide relatively minimal values for fish and wildlife with low potential for becoming significant; accordingly, the mitigation goal for these habitats is relatively low.

Following is a synopsis of the differences between the habitat categories contained within the mitigation policy.

Habitat Category 1: Irreplaceable, essential habitat for a fish and wildlife species, population, or unique assemblage of species that is limited on either a province or site-specific basis.

- To be Category 1, the habitat must be essential for the species of concern, and irreplaceable, and limited.

Habitat Category 2: Essential habitat for a fish and wildlife species, population, or unique assemblage of species that is limited on either a province or site-specific basis.

- To be Category 2, the habitat must be essential for the species of concern, and limited.
- These habitats are not irreplaceable (the distinguishing factor from Category 1 habitats).

Habitat Category 3: Essential habitat for species, or important habitat for a species that is limited on either a province or site-specific basis.

- Essential habitats that are not limited are Category 3.
- To be Category 3, important habitats must be limited.

Habitat Category 4: Important habitat for fish and wildlife species.

- Habitats important for species but that are not limited are Category 4.

Habitat Category 5: Habitat for fish and wildlife having high potential to become either essential or important habitat.

- Category 5 includes habitats that currently may not provide significant support for the needs of fish and wildlife species, but that have high potential to be restored to a condition that contributes to sustaining these species.

Habitat Category 6: Habitat for fish and wildlife that has a low potential to become either essential or important habitat.

- Category 6 includes habitats that currently do not provide significant support for the needs of fish and wildlife species, and that are not expected to have the opportunity or capability to be restored to a condition that contributes to sustaining these species.

There are a number of key terms contained within the category descriptions that must be interpreted and applied consistently for the successful application of this policy. The following discussion provides general guidance on the key components of these habitat category definitions.

Essential Habitat

"Essential habitat" refers to habitats that contain the physical and biological conditions necessary to support the most critical life history functions of the fish and wildlife species being considered. These habitats are those that species are dependent upon for long-term population maintenance, and are often termed as preferred or optimal for the species. To be essential, it must be reasonable to conclude that a reduction in the quality or quantity of the habitat would likely result in a decline of the species or population being evaluated. Generally, essential habitats will be those that provide critical support to the population or species for reproduction, rearing, forage and dispersal (migration) necessary for the completion of one or more life history functions.

Limited Habitat

"Limited habitat" refers to the lack of an adequate amount of habitat necessary to sustain, over time, the fish and wildlife species or populations being considered. This concept requires that the relative availability of suitable habitats to support important life history functions be considered at variable scales that may go beyond the project site. In the case of relatively mobile species, the presence and abundance of suitable habitats may need to be assessed at the watershed or regional scale. For species with small home ranges and limited mobility, the assessment may only consider the project site or area immediately surrounding the site.

Important Habitat

"Important habitat" refers to habitats with the physical and biological conditions that contribute to sustaining fish and wildlife populations over time, but that may not be necessary to support the most critical life history functions of the species being considered. These habitats may be commonly used by the species, but the species are less dependent on the conditions for the long-term maintenance of the species or population.

Irreplaceable

"Irreplaceable" means that it is unlikely that the habitat being considered could be replaced or recreated through mitigation actions within a reasonable time frame. To be replaceable, both the quantity and functional quality of the habitat to fish and wildlife species would be restored. It is reasonable to conclude that a habitat is likely to be "irreplaceable" if no method or technique has been shown to be successful at recreating the habitat being considered. While the policy does not preclude the use of any new or untested mitigation techniques, there must be some certainty that the project will be successful at restoring habitat quantity and quality before concluding that the habitat is replaceable. Where uncertainty is high, or the level of risk that the mitigation project will fail is unacceptable the habitat should be classified as “irreplaceable.”

Application of this concept requires a site- and resource-specific determination of what constitutes a “reasonable time frame.” This determination must be based on the predicted effects to fish and wildlife species. It is generally accepted that most mitigation involving the creation of habitat values includes a period of time when a loss of habitat function occurs. This loss occurs during the time between when the existing habitat is altered to a non-functional state, and when the recreated habitat becomes functional. This lag in habitat function, and most of the uncertainty regarding the likelihood for successful mitigation is usually associated with the habitat “quality” attribute (i.e. not habitat quantity).

Assessing whether a mitigation time frame is “reasonable” will require consideration of the life history stages and biology of fish and wildlife currently using the habitat, the relative importance of the habitat at maintaining these species, and the predicted amount of time that critical habitat functions will be lost. This determination must be based on site-specific conditions, and the availability of alternate habitats in the area that could support the same life history needs. Where critical life history functions could be supported in nearby areas during the time needed for mitigated habitat to become functional without impacting the species or population, the habitat should be deemed “replaceable” (assuming that it is technically feasible to recreate the habitat). The potential for a negative impact on the population or species should consider the total life history of the species. For example, where the loss of the habitat could interrupt a critical life history function over an entire generation of the species (and adequate alternate habitats are not available), the habitat should be considered irreplaceable since there would likely be impacts to the population or species. These determinations will require that the needs of the species be considered in context with the availability and condition of critical habitats in an area broader than the individual project site.

Category 1 Habitat for Marbled Murrelet

ODFW considers **occupied suitable habitat** for the marbled murrelet to be Category 1, meaning it is **essential**, **limited**, **and irreplaceable** within a reasonable time frame. The components of this determination are detailed below:

- **“Occupied suitable habitat”** (USFWS 2014) is defined the following manner:

  Suitable Habitat: generally, includes old-growth forests within 50 miles of the coast and characterized by large trees, multi-storied stands, and moderate-to-high canopy coverage. Nest trees can be remnant old-growth trees in a stand of younger forest, but nest trees must have large branches or deformities such as high, moss-covered branches or branches with growths of dwarf mistletoe, which serve as nest platforms.

    Occupied Suitable Habitat (OSH)- Habitat in the vicinity of the proposed project that meets any of the following criteria:

i. Occupied Stand: is a stand that has been surveyed by the applicant, landowner, or manager, or others following the Pacific Seabird Group (PSG) protocol (Mack et al. 2003) and that encompasses an "occupied site"
ii. Historically Occupied Stand: is a stand that was at any time known to be occupied by marbled murrelet. This includes stands where more recent surveys may have indicated that the status is not currently "occupied"
iii. Unsurveyed Suitable Habitat: is an area or forested stand identified as potential nesting habitat that has not been ground-truthed for suitable nesting structures or surveyed following the PSG protocol, including areas with incomplete survey data (*e.g*., where only one year of marbled murrelet surveys have been completed).

- The occupied suitable habitat in Oregon is **"Essential"** for the marbled murrelet because it supports reproduction for the species, which is a critical life history function. It is well-established that the decline in nesting habitat quantity and quality is the primary threat to marbled murrelet populations, and any further reduction would have significant impact to the population (see sources cited within ODFW 2018).

- The occupied suitable habitat in Oregon is also "**Limited**" for the marbled murrelet because they are tied to mature, late successional, old growth forest. As described above, an estimated 58% decline in late successional forests occurred between 1936 and 1996, and an estimated 9.2% further decline was documented between 1993 and 2012. What remains is highly fragmented, and at risk to fire, infestation, and disease.

- And finally, the occupied suitable habitat in Oregon is "**Irreplaceable**" because of the unreasonable time frame necessary to re-create late successional, old growth forests. While trees can be replanted and forests can be managed toward old growth condition, the time it takes to create the functions and values selected for by nesting murrelets (80-year old trees, multi-storied canopy, wide platform branches) interrupts nesting opportunity for at least 5 generations. This is not a reasonable mitigation time frame to allow for mitigation to replace the lost functions and values.

The extent of occupied suitable habitat follows the 'continuous habitat' descriptions in Mack et al. (2003), meaning the delineation of Category 1 habitat should include all of the sub-canopy detection area plus all of the area extending out from the sub-canopy detection until natural breaks in habitat 100 meters or larger are encountered. Therefore, a project that proposes to impact the edge of occupied suitable habitat is still impacting Category 1 habitat.

As per the mitigation policy, the mitigation goal for Category 1 habitat is no loss of either habitat quantity or quality. The Oregon Fish and Wildlife Commission directs ODFW to protect Category 1 habitats by recommending or requiring (a) avoidance of impacts through alternatives to the proposed development action, or (b) no authorization of the proposed development action if impacts cannot be avoided.

Category 2 Habitat for Marbled Murrelet

ODFW considers **unoccupied suitable habitat** as Category 2, meaning it is **essential** and **limited** habitat (see above for the discussion of how marbled murrelet nesting habitat meets the definitions of essential and limited).

This marbled murrelet habitat classification follows USFWS (2014):

- "**Unoccupied suitable habitat**" is a continuous stand of suitable habitat (see above) that has been surveyed by the applicant (per PSG protocol; Mack et al. 2003) and with a site classification of either "probable absence" or "[absence]"

As per the mitigation policy, if impacts to Category 2 habitat are unavoidable, the goal is no net loss of either habitat quantity or quality and to provide a net benefit of habitat quantity or quality. The Oregon Fish and Wildlife Commission directs ODFW to achieve the mitigation goal for Category 2 habitat by recommending or requiring (a) avoidance, (b) mitigation through reliable in-kind, in-proximity habitat mitigation to achieve no net loss of either pre-development habitat quantity or quality. In addition, a net benefit of habitat quantity or quality must be provided. This work is defined, measured against success criteria, and reported on a schedule agreed to in a mitigation plan. The mitigation measures should be implemented and completed either prior to or concurrent with the development action. If neither (a) nor (b) above can be achieved, ODFW shall recommend against the development action.

Category 3-6 Habitats for Marbled Murrelet

ODFW considers **recruitment** and **capable** habitat on a more case-by-case, site-specific basis. Habitat categorization will depend on the degree of forest habitat alteration and the position of the site on the landscape. Generally speaking, recruitment and capable habitats are going to fall in Categories 3 through 6. Categories 3 and 4 still maintain the goal of no net loss, but offer more flexibility in how offsets might be achieved.

These marbled murrelet habitat classifications also follow USFWS (2014):

- "**Recruitment habitat**" includes forested stands age 60 years or greater without MARBLED MURRELET nesting structure within 50 miles of the coast
- "**Capable habitat**" includes forested stands age 0 to <60 years within 50 miles of the coast that are capable of becoming suitable habitat within the life of the project's effects.

Literature Cited

References identified in this document are provided in the 'Literature Cited' section of the ODFW's Status Review. Only one additional citation was included in this document that cannot be found in ODFW 2018, and is provided below.

ODFW. 2018. Status review of the Marbled Murrelet (*Brachyramphus marmoratus*) in Oregon and evaluation of criteria to reclassify the species from threatened to endangered under the Oregon Endangered Species Act. Oregon Department of Fish and Wildlife, Salem, Oregon.).

USFWS. 2014. Revised Conservation Framework for the Northern Spotted Owl and Marbled Murrelet: Jordan Cove Energy and Pacific Connector Gas Pipeline Project. USFWS Ecological Services, Region 1 with support from PC Trask and Associates, Inc. in collaboration with Mason, Bruce, and Girard, Inc. 69 pp.

APPENDIX 10.B.

Dean Runyan Associates

Oregon Travel Impacts

Statewide Estimates

1992 - 2017p

June 2018

Prepared for the

Oregon Tourism Commission
Salem, Oregon

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OREGON TRAVEL IMPACTS, 1992-2017p

STATEWIDE PRELIMINARY ESTIMATES
DETAILED COUNTY ESTIMATES
OVERNIGHT VISITOR VOLUME

June 2018

Prepared for

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Executive Summary

This report provides detailed statewide, regional and county travel impact estimates for Oregon from 1992 to 2017. The report also provides average spending and volume estimates for overnight visitors for most counties. The estimates for 2017 are preliminary. Secondary impacts and travel industry GDP are provided at the state level.

Travel Spending, Employment and earnings continue to expand

The Oregon travel industry continued to exhibit strong growth in 2017, as all measures of travel activity were up over 2016.

- ***Spending.*** Total direct travel spending in Oregon was $11.8 billion in 2017. The annual increase from 2016 was 4.7 percent in current dollars. In real, inflation-adjusted, dollars travel spending increased by 3.2 percent. Visitor spending, excluding transportation, increased by 3.6 percent in current dollars. This is the eighth consecutive year of growth in travel spending following the recession.
- ***Travel Activity.*** An estimated 28.8 million overnight visitors traveled to Oregon destinations in 2017 (preliminary). This represents a 1.0 percent increase over 2016. Since 2010, overnight person-trips have increased by 2.2 percent per year. Domestic visitor air arrivals to Oregon (4.0 million) increased by 5.5 percent for the year. Room demand, as measured by STR, Inc., increased by 1.3 percent for the year.[1]
- ***Employment.*** Total travel generated employment was 112,200 in 2017. This represents a 2.2 percent increase over 2016, the seventh consecutive year of employment growth following the steep decline from 2008 to 2010. Employment has increased by 3.2 percent per year since 2010.
- ***Secondary Impacts.*** The re-spending of travel-generated revenues by businesses and employees generates additional impacts. In 2017, these secondary impacts were equivalent to 58,300 jobs with earnings of $2.8 billion. Most of these jobs were in various professional and business services.
- ***GDP.*** The Gross Domestic Product of the travel industry was $5.0 billion in 2017. Overall, the travel industry is one of the three largest export-oriented industries in rural Oregon counties (the other two being agriculture/food processing and logging/wood products).

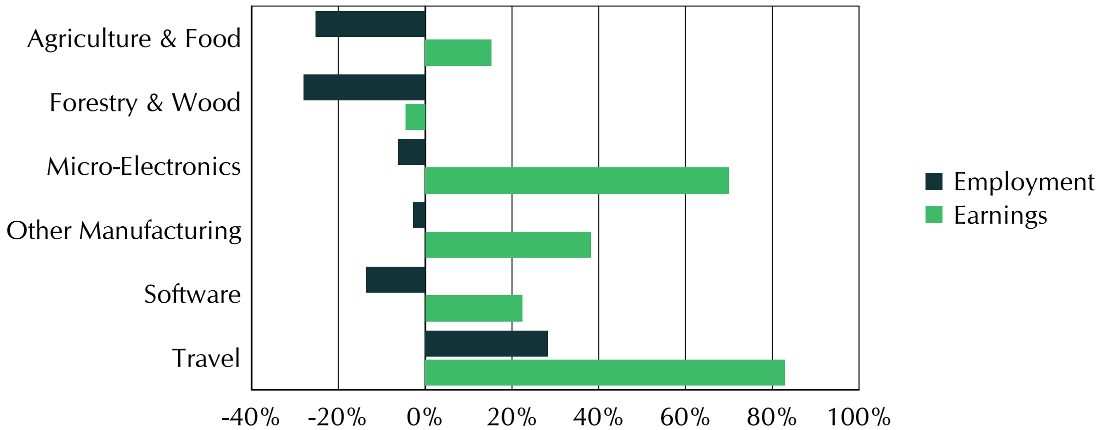
1. The STR reports were prepared for the Oregon Tourism Commission

The Oregon Travel Industry is A Leading Export-Oriented Industry

Travel and tourism is one of the most important ***"export-oriented"*** industries in Oregon. It is especially important in the non-metropolitan areas of the state, where manufacturing and traded services are less prevalent. Over the past decade, travel industry employment and earnings growth also compares favorably to other industries.

Change in Earnings and Employment (2003-2016)

Selected Export Oriented Industries



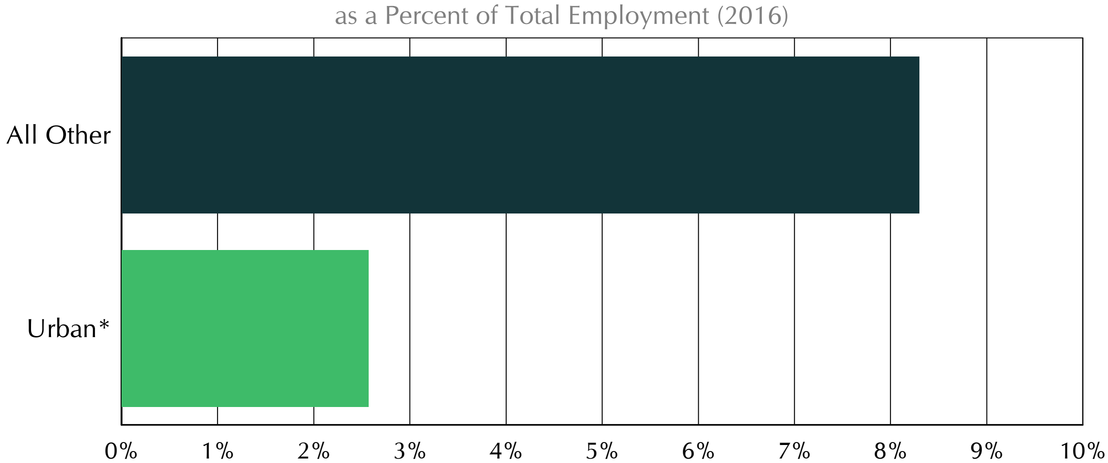
Note: The most current data is for 2016.

The Travel Industry Benefits All Regions of Oregon

Although most travel spending and related economic impacts occur within Oregon's urban areas, the travel industry is important throughout the state. In general, travel-generated employment is relatively more important in rural counties.

Travel Generated Employment

as a Percent of Total Employment (2016)



*The urban counties are Clackamas, Lane, Marion, Multnomah, and Washington. The most current data is for 2016.

Oregon Travel Impacts, 1992-2017

List of Tables & Figures

List Tables & Figures

List of Tables & Figures

Preface

The purpose of this study is to document the economic significance of the travel industry in Oregon and its thirty-six counties and seven tourism regions from 1992 to 2017. These findings show the level of travel spending by visitors traveling to and within the state, and the impact this spending had on the economy in terms of earnings, employment and tax revenue. Estimates of overnight visitor volume and average spending are also provided for all tourism regions and most counties. The estimates for 2017 are preliminary.

Dean Runyan Associates prepared this study for the Travel Oregon. Dean Runyan Associates has specialized in research and planning services for the travel, tourism and recreation industry since 1984. With respect to economic impact analysis, the firm developed and currently maintains the Regional Travel Impact Model (RTIM), a proprietary model for analyzing travel economic impacts at the state, regional and local level. Dean Runyan Associates also has extensive experience in project feasibility analysis, market evaluation, survey research and travel and tourism planning.

Many individuals and agencies provided information and advice for this report. The state agencies that provided essential information were the Parks and Recreation Department and the Department of Revenue. At the federal level, data was obtained from the U.S. Forest Service, the Department of Labor and the Bureau of Economic Analysis. Additionally, numerous local governments and visitor bureaus throughout Oregon provided information.

Finally, special thanks are due to Ladan Ghahramani, Research Manager, Michael Sturdevant, Director of Global Marketing Services , and Todd Davidson, Chief Executive Officer of Travel Oregon, for their support and assistance.

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I. U.S. TRAVEL

Oregon Coast Travel Impacts and Visitor Volume

Travel Indicators

Visitor Spending Impacts

Amount of Visitor Spending that supports 1 Job	$87,612
Employee Earnings generated by $100 Visitor Spending	$31
Local & State Tax Revenues generated by $100 Visitor Spending	$4.26

Visitor Volume

Additional visitor spending if each resident household encouraged one additional overnight visitor (in thousands)	$22,174
Additional employment if each resident household encouraged one additional overnight visitor	253

Visitor Shares

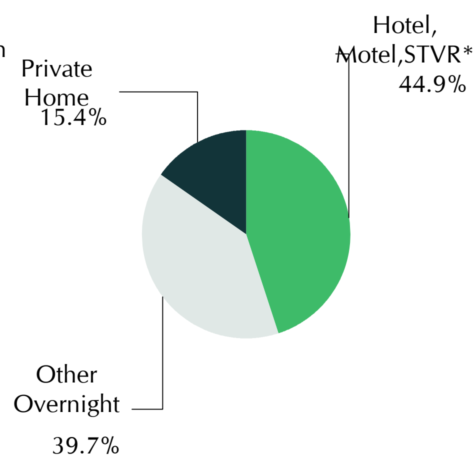
Travel Share of Total Employment (2016)*	18.5 %
Overnight Visitor Share of Resident Population (2017p)**	21.2 %

*Source: Bureau of Economic Analysis and Bureau of Labor Statistics. Estimates by Dean Runyan Associates.
**Annual Overnight Visitor Days divided by (Resident Population) *365.

Visitors who stay in private homes typically comprise the largest share of overnight visitor volume. Visitors who stay overnight in commercial lodging typically have the greatest economic impact. There is substantial variation among destinations, however. Most rural and suburban areas have high shares of private home visitation. Urban areas tend to have greater shares of hotel/motel stays.

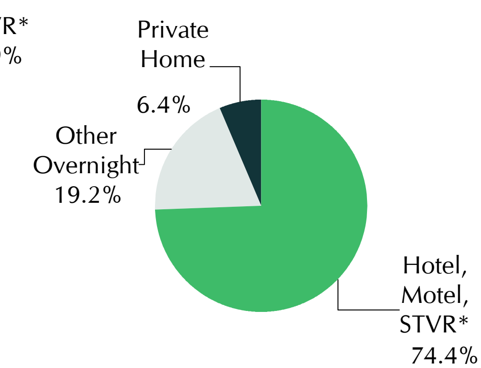
Overnight Visitor Spending and Volume

Person Nights



as a percent of total

Spending



as a percent of total

	Person Trips (Thousands)	Person Nights (Thousands)	Visitor Spending ($Millions)
Hotel, Motel, STVR*	3,348	7,650	992
Private Home	728	2,624	86
Other Overnight	1,941	6,763	256
All Overnight	6,018	17,037	1,334

Note: Person Trips and Person Nights are in Thousands. Visitor Spending is in $Millions. Details may not round to total due to rounding

Oregon Coast
Direct Travel Impacts, 2010-2017p

							Ave. Annual Chg.	
Spending ($M)	**2010**	**2012**	**2014**	**2015**	**2016**	**2017**	**16-17**	**10-17**
Total (Current $)	1,500	1,592	1,801	1,872	1,943	1,985	2.2%	4.1%
Other	28	31	20	23	25	26	2.7%	-1.0%
Visitor	1,472	1,561	1,780	1,849	1,917	1,959	2.2%	4.2%
Non-transportation	1,291	1,347	1,562	1,664	1,740	1,768	1.6%	4.6%
Transportation	181	214	218	185	178	192	7.8%	0.8%
Earnings ($M)								
Earnings (Current $)	427	452	506	545	580	614	5.9%	5.3%
Employment (Jobs)								
Employment	19,690	19,670	20,830	21,540	22,320	22,710	1.7%	2.1%
Tax Revenue ($M)								
Total (Current $)	55	60	68	73	79	83	6.0%	6.1%
Local	20	20	24	27	28	30	4.5%	6.1%
State	36	40	43	46	50	54	6.9%	6.0%

Other spending includes resident air travel, travel arrangement and reservation services, and convention and trade show organizers. **Non-transportation visitor spending** includes accommodations, food services, retail, food stores, and arts, entertainment & recreation. **Visitor transportation spending** includes private auto, auto rental, other local ground transportation and one-way airfares.
Earnings include wages & salaries, earned benefits and proprietor income.
Employment includes all full- and part-time employment of payroll employees and proprietors.
Local tax revenue includes lodging taxes, auto rental taxes and airport passenger facility charges paid by visitors.
State tax revenue includes lodging, and motor fuel tax payments of visitors, and the income tax payments attributable to the travel industry income of businesses and employees.
Federal tax revenue includes motor fuel excise taxes and airline ticket taxes paid by visitors, and the payroll and income taxes attributable to the travel industry income of employees and businesses.

Oregon Coast

Travel Impacts, 2006-2017p

Total Direct Travel Spending ($Million)	2006	2008	2010	2012	2015	2016	2017
Destination Spending	1,436.6	1,525.1	1,472.2	1,561.5	1,849.1	1,917.4	1,959.2
Other Travel*	26.4	25.6	28.0	30.9	22.7	25.4	26.1
Total	**1,463.0**	**1,550.7**	**1,500.1**	**1,592.4**	**1,871.9**	**1,942.8**	**1,985.4**

Visitor Spending By Commodity Purchased ($Million)	2006	2008	2010	2012	2015	2016	2017
Accommodations	317.8	340.0	334.7	350.9	445.7	468.9	489.5
Food Service	360.0	386.9	393.3	413.4	532.4	566.6	579.3
Food Stores	141.5	152.4	146.4	157.1	186.7	188.7	186.3
Local Tran. & Gas	174.2	215.0	178.6	211.1	180.7	174.2	188.7
Arts, Ent. & Rec.	218.3	216.9	208.2	212.1	252.2	262.2	261.8
Retail Sales	220.3	209.6	208.1	213.9	247.5	253.2	250.5
Visitor Air Tran.	4.6	4.4	2.9	2.9	4.0	3.6	3.0
Total	**1,436.6**	**1,525.1**	**1,472.2**	**1,561.5**	**1,849.1**	**1,917.4**	**1,959.2**

Industry Earnings Generated by Travel Spending ($Million)	2006	2008	2010	2012	2015	2016	2017
Accom. & Food Serv.	275.7	304.1	294.7	313.9	391.1	416.5	446.4
Arts, Ent. & Rec.	62.2	71.3	64.4	65.8	71.0	74.6	76.3
Retail**	48.1	49.6	47.7	49.9	60.9	64.0	65.7
Ground Tran.	5.3	5.7	5.4	5.8	7.5	8.3	8.7
Visitor Air Tran.	1.6	1.6	1.7	2.1	3.3	3.6	3.6
Other Travel*	12.2	11.9	13.4	14.9	11.5	12.8	13.3
Total	**405.1**	**444.2**	**427.4**	**452.5**	**545.3**	**579.8**	**614.1**

Industry Employment Generated by Travel Spending (Jobs)	2006	2008	2010	2012	2015	2016	2017
Accom. & Food Serv.	13,140	13,710	12,850	12,860	14,330	14,900	15,350
Arts, Ent. & Rec.	4,060	4,430	4,070	3,970	4,000	4,090	4,050
Retail**	2,410	2,410	2,260	2,280	2,620	2,690	2,680
Ground Tran.	190	190	180	180	220	230	230
Visitor Air Tran.	40	40	30	40	60	60	60
Other Travel*	290	320	300	340	320	350	340
Total	**20,140**	**21,110**	**19,690**	**19,670**	**21,540**	**22,320**	**22,710**

Tax Receipts Generated by Travel Spending ($Million)	2006	2008	2010	2012	2015	2016	2017
Local Tax Receipts	18.4	18.3	19.5	20.1	27.3	28.3	29.6
State Tax Receipts	34.6	37.2	35.7	39.5	46.0	50.4	53.8
Total	**53.0**	**55.6**	**55.2**	**59.6**	**73.3**	**78.7**	**83.4**

Details may not add to total due to rounding. * Other Travel includes ground transportation and air travel impacts for travel to other Oregon visitor destinations and travel arrangement services.** Retail includes gasoline. Federal tax receipts not included.

Oregon Coast Visitor Spending and Visitor Volume

Visitor Spending by Type of Traveler Accommodation ($Million), 2017p

	2008	2010	2012	2014	2016	2017
Total Destination Spending	**1,525**	**1,472**	**1,561**	**1,780**	**1,917**	**1,959**
All Overnight	1,030	990	1,042	1,191	1,298	1,334
Hotel, Motel, STVR*	724	696	729	863	962	992
Private Home	78	76	83	84	84	86
Other Overnight	227	218	230	244	252	256
Day Travel	496	482	520	589	619	626
Day Travel	496	482	520	589	619	626

Average Expenditures for Overnight Visitors, 2017p

	Travel Party		Person		Party	Length of
	Day	Trip	Day	Trip	Size	Stay (Nights)
Private Home	$84	$304	$33	$117	2.6	3.6
Other Overnight	$126	$440	$38	$132	3.3	3.5
All Overnight	$216	$597	$78	$222	2.8	2.8

Overnight Visitor Volume, 2015-2017p

	Person-Nights (000)			Party-Nights (000)		
	2015	2016	2017	2015	2016	2017
Hotel, Motel, STVR*	7,455	7,751	7,650	3,049	3,170	3,129
Private Home	2,595	2,619	2,624	1,006	1,015	1,017
Other Overnight	6,703	6,796	6,763	2,011	2,038	2,030
All Overnight	16,753	17,166	17,037	6,067	6,223	6,175

	Person-Trips (000)			Party-Trips (000)		
	2015	2016	2017	2015	2016	2017
Hotel, Motel, STVR*	3,514	3,646	3,348	1,437	1,491	1,369
Private Home	756	727	728	292	281	282
Other Overnight	1,973	1,999	1,941	592	600	582
All Overnight	6,242	6,372	6,018	2,322	2,372	2,233

"Hotel, Motel, STVR" category includes all lodging where a lodging tax is collected except campgrounds. "Other Overnight" category includes campgrounds and vacation homes.

Coos County

County Travel Impacts and Visitor Volume

Visitor Spending Impacts

Amount of Visitor Spending that supports 1 Job	$81,129
Employee Earnings generated by $100 Visitor Spending	$28
Local & State Tax Revenues generated by $100 Visitor Spending	$3.68

Visitor Volume

Additional visitor spending if each resident household encouraged one additional overnight visitor (in thousands)	$4,522
Additional employment if each resident household encouraged one additional overnight visitor	56

Visitor Shares

Travel Share of Total Employment (2016)*	10.5 %
Overnight Visitor Share of Resident Population (2017)**	11.0 %

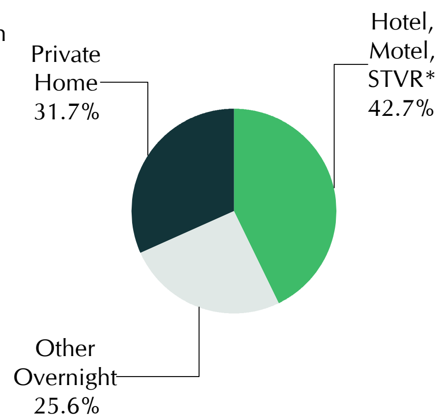
*Source: Bureau of Economic Analysis and Bureau of Labor Statistics. Estimates by Dean Runyan Associates.

**Annual Overnight Visitor Days divided by (Resident Population) *365.

Visitors who stay in private homes typically comprise the largest share of overnight visitor volume. Visitors who stay overnight in commercial lodging typically have the greatest economic impact. There is substantial variation among destinations, however. Most rural and suburban areas have high shares of private home visitation. Urban areas tend to have greater shares of hotel/motel stays.

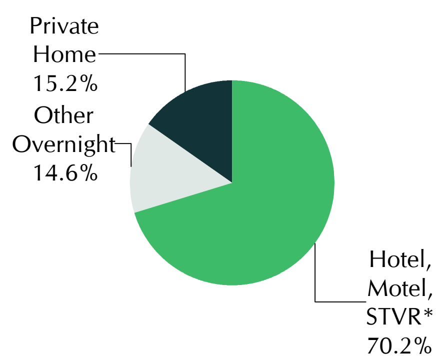
Overnight Visitor Spending and Volume

Person Nights



as a percent of total

Spending



as a percent of total

	Person Trips (Thousands)	Person Nights (Thousands)	Visitor Spending ($Millions)
Hotel, Motel, STVR*	579.7	1,096.4	121.2
Private Home	267.3	812.9	26.2
Other Overnight	203.4	657.6	25.3
All Overnight	1,050.4	2,567.0	172.7

Note: Person Trips and Person Nights are in Thousands. Visitor Spending is in $Millions. Details may not round to total due to rounding

Coos
Direct Travel Impacts, 2010-2017p

							Ave. Annual Chg.	
Spending ($M)	**2010**	**2012**	**2014**	**2015**	**2016**	**2017**	**16-17**	**10-17**
Total (Current $)	210.8	230.7	252.6	260.1	265.5	271.1	2.1%	3.7%
Other	11.9	12.6	11.2	9.4	9.1	10.0	9.7%	-2.5%
Visitor	198.9	218.0	241.3	250.8	256.4	261.1	1.8%	4.0%
Non-transportation	172.4	186.5	209.4	222.4	229.8	233.3	1.5%	4.4%
Transportation	26.4	31.5	31.9	28.4	26.6	27.8	4.4%	0.7%
Earnings ($M)								
Earnings (Current $)	56.3	60.4	66.6	72.0	76.5	79.0	3.3%	4.9%
Employment (Jobs)								
Employment	2,940	3,030	3,030	3,140	3,280	3,300	0.4%	1.6%
Tax Revenue ($M)								
Total (Current $)	6.5	7.3	7.9	8.4	9.0	9.5	5.6%	5.5%
Local	1.1	1.1	1.2	1.4	1.4	1.5	4.1%	3.9%
State	5.4	6.2	6.7	7.0	7.6	8.0	5.9%	5.8%

Other spending includes resident air travel, travel arrangement and reservation services, and convention and trade show organizers. **Non-transportation visitor spending** includes accommodations, food services, retail, food stores, and arts, entertainment & recreation. **Visitor transportation spending** includes private auto, auto rental, other local ground transportation and one-way airfares.

Earnings include wages & salaries, earned benefits and proprietor income.

Employment includes all full- and part-time employment of payroll employees and proprietors.

Local tax revenue includes lodging taxes, auto rental taxes and airport passenger facility charges paid by visitors.

State tax revenue includes lodging, and motor fuel tax payments of visitors, and the income tax payments attributable to the travel industry income of businesses and employees.

Federal tax revenue includes motor fuel excise taxes and airline ticket taxes paid by visitors, and the payroll and income taxes attributable to the travel industry income of employees and businesses.

Historical revisions have been made to correct for the assignment of visitor air travel to the other travel category total. This correction does not effect economic impact totals.

Coos County

Travel Impacts, 2006-2017p

Total Direct Travel Spending ($Million)							
	2006	**2008**	**2010**	**2012**	**2015**	**2016**	**2017**
Destination Spending	204.8	217.4	198.9	218.0	250.8	256.4	261.1
Other Travel*	13.2	14.9	11.9	12.6	9.4	9.1	10.0
Total	**218.0**	**232.3**	**210.8**	**230.7**	**260.1**	**265.5**	**271.1**

Visitor Spending By Commodity Purchased ($Million)							
	2006	**2008**	**2010**	**2012**	**2015**	**2016**	**2017**
Accommodations	42.7	44.7	40.7	45.3	55.5	58.8	61.5
Arts, Ent. & Rec.	36.1	35.9	33.1	34.8	39.8	40.7	40.6
Food Service	51.5	55.6	53.9	58.7	72.8	76.0	77.7
Food Stores	19.6	21.3	19.9	21.7	25.1	25.1	24.7
Local Tran. & Gas	23.7	29.6	23.5	28.6	24.4	23.0	24.8
Retail Sales	26.6	26.0	24.8	26.1	29.1	29.2	28.9
Visitor Air Tran.	4.6	4.4	2.9	2.9	4.0	3.6	3.0
Total	**204.8**	**217.4**	**198.9**	**218.0**	**250.8**	**256.4**	**261.1**

Industry Earnings Generated by Travel Spending ($Million)							
	2006	**2008**	**2010**	**2012**	**2015**	**2016**	**2017**
Accom. & Food Serv.	35.9	39.5	36.1	38.8	46.5	49.6	51.3
Arts, Ent. & Rec.	9.6	11.0	9.5	10.5	12.0	12.5	12.8
Ground Tran.	0.8	0.9	0.8	0.9	1.1	1.2	1.3
Other Travel*	3.5	3.5	3.8	3.8	4.8	5.2	5.5
Retail**	6.1	6.5	6.0	6.4	7.6	7.9	8.0
Total	**56.0**	**61.3**	**56.3**	**60.4**	**72.0**	**76.5**	**79.0**

Industry Employment Generated by Travel Spending (Jobs)							
	2006	**2008**	**2010**	**2012**	**2015**	**2016**	**2017**
Accom. & Food Serv.	1,930	2,010	1,700	1,750	1,860	1,950	2,000
Arts, Ent. & Rec.	770	840	830	870	830	860	820
Ground Tran.	30	30	30	30	30	30	30
Other Travel*	100	110	100	90	100	110	110
Retail**	300	310	280	290	320	330	330
Total	**3,140**	**3,300**	**2,940**	**3,030**	**3,140**	**3,280**	**3,300**

Tax Receipts Generated by Travel Spending ($Million)							
	2006	**2008**	**2010**	**2012**	**2015**	**2016**	**2017**
Local Tax Receipts	1.3	1.3	1.1	1.1	1.4	1.4	1.5
State Tax Receipts	5.5	5.9	5.4	6.2	7.0	7.6	8.0
Total	**6.9**	**7.3**	**6.5**	**7.3**	**8.4**	**9.0**	**9.5**

Details may not add to total due to rounding. * Other Travel includes ground transportation and air travel impacts for travel to other Oregon visitor destinations, travel arrangement services, and convention & trade show organizers.** Retail includes gasoline.

Historical revisions have been made to correct for the assignment of visitor air travel to the other travel category total. This correction does not effect economic impact totals.

Coos County Visitor Spending and Visitor Volume

Visitor Spending by Type of Traveler Accommodation ($Million), 2017p

	2008	2010	2012	2014	2016	2017
Total Destination Spending	**213.0**	**195.9**	**215.1**	**238.3**	**252.8**	**258.1**
All Overnight	**141.9**	**129.3**	**141.9**	**157.2**	**168.3**	**172.7**
Hotel, Motel, STVR*	94.5	83.9	93.7	107.1	117.3	121.2
Private Home	24.6	24.2	25.7	26.0	25.8	26.2
Other Overnight	22.8	21.2	22.5	24.1	25.1	25.3
Day Travel	**71.1**	**66.6**	**73.2**	**81.1**	**84.6**	**85.4**
Day Travel	71.1	66.6	73.2	81.1	84.6	85.4

Average Expenditures for Overnight Visitors, 2017p

	Travel Party		Person		Party	Length of
	Day	Trip	Day	Trip	Size	Stay (Nights)
Hotel, Motel, STVR*	$269	$510	$111	$209	2.4	1.9
Private Home	$83	$253	$32	$98	2.6	3.1
Other Overnight	$131	$425	$38	$124	3.4	3.2
All Overnight	$180	$431	$67	$164	2.7	2.4

Overnight Visitor Volume, 2015-2017p

	Person-Nights (000)			Party-Nights (000)		
	2015	2016	2017	2015	2016	2017
Hotel, Motel, STVR*	1,095	1,109	1,096	450	456	450
Private Home	815	816	813	319	319	317
Other Overnight	656	667	658	192	196	193
All Overnight	2,565	2,592	2,567	961	970	960

	Person-Trips (000)			Party-Trips (000)		
	2015	2016	2017	2015	2016	2017
Hotel, Motel, STVR*	579	586	580	237	241	238
Private Home	268	268	267	104	104	103
Other Overnight	203	206	203	59	60	60
All Overnight	1,050	1,061	1,050	401	405	401

"Hotel, Motel" category includes all lodging where a lodging tax is collected except campgrounds.
"Other Overnight" category includes campgrounds and vacation homes.

U.S. Department of Homeland Security
United States Coast Guard

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16611
July 1, 2008

Lauren O'Donnell
Director of Gas – Environmental & Engineering, PJ-11
Federal Energy Regulatory Commission
888 First Street, N.E., Room 62-45
Washington, DC 20426

WATERWAY SUITABILITY REPORT FOR THE JORDAN COVE ENERGY PROJECT

Dear Ms. O'Donnell:

This Waterway Suitability Report (WSR) fulfills the Coast Guard's commitment under the Interagency Agreement among the Federal Energy Regulatory Commission (FERC), the Research and Special Programs Administration (RSPA), and the Coast Guard for the Safety and Security Review of the Waterfront Import/Export Liquefied Natural Gas Facilities that was signed in February 2004. Under this agreement, our agencies work together to ensure that both land and maritime safety and security risks are addressed in a coordinated and comprehensive manner. In particular, the Coast Guard serves as a subject matter expert on maritime safety and security issues.

On June 11, 2008, the Coast Guard completed a review of the Waterway Suitability Assessment (WSA) for the Jordan Cove Energy Project (JCEP) that was submitted in September of 2007. This review was conducted following the guidance provided in Navigation and Vessel Inspection Circular (NVIC) 05-05 of June 14, 2005. The review focused on the navigation safety and maritime security risks posed by LNG marine traffic, and the measures needed to responsibly manage these risks. During the review, the Coast Guard consulted a variety of stakeholders including state and local emergency responders, marine pilots, towing industry representatives, members of the Ports and Waterways Safety Committee and the Area Maritime Security Committee.

Based upon this review, I have determined that Coos Bay is not currently suitable, but could be made suitable for the type and frequency of LNG marine traffic associated with this proposed project. Additional measures are necessary to responsibly manage the maritime safety and security risks. The specific measures, and the resources needed to implement them, where applicable, are described below and in a separate supplementary report which is being provided to you under the terms and conditions established for handling Sensitive Security Information (SSI). This supplemental report includes a copy of the Jordan Cove Waterway Suitability Assessment. This determination is preliminary as the NEPA analysis has not yet been completed.

The following is a list of specific risk mitigation measures that must be put into place to responsibly manage the safety and security risks of this project. Details of each measure, including adequate support infrastructure, will need further development in consultation with the Coast Guard and state and local agencies through the creation of an Emergency Response Plan as well as a Transit Management Plan that clearly spell out the roles, responsibilities, and specific procedures for the LNG vessel and all agencies responsible for security and safety during the operation.

Navigational Measures:

LNG Tanker Size Limitations: Based on the Ship Simulation Study conducted by Moffatt & Nichol on March 17-20, 2008, the maximum size LNG tanker permitted to transit through the Port of Coos Bay is a spherical containment LNG carrier with the physical dimensions of a 148,000 m^3 class vessel. The ship dimensions used in the study reflect a length overall of 950 feet, beam of 150 feet and a loaded draft of 40 feet. The channel must demonstrate sufficient adequacy to receive LNG carriers for any single dimension listed. Consequently, prior to approving the transit of an LNG ship larger than 148,000 m^3, or any increase in the physical dimensions cited, additional simulator studies must be conducted in order to assure the sufficiency of the channel.

- Safety/Security Zone: A moving safety/security zone shall be established around the LNG vessel extending 500-yards around the vessel but ending at the shoreline. No vessel may enter the safety/security zone without first obtaining permission from the Coast Guard Captain of the Port (COTP). The expectation is that the COTP's Representative will work with the Pilots and patrol assets to control traffic, and will allow vessels to transit the Safety/Security zone based on a case-by-case assessment conducted on scene. Escort resources will be used to contact and control vessel movements such that the LNG Carrier is protected.

  While the vessel is moored at the facility there shall be a 150 yard security zone around the vessel, to include the entire terminal slip. In addition, while there is no LNG vessel moored, the security zone shall cover the entire terminal slip and extend 25-yards into the waterway.

  Resource Gap: Resources required to enforce the safety/security zone are discussed under Security Measures in the supplemental report.

- Vessel Traffic Management: Due to a narrow shipping channel, navigational hazards, and the proximity to populated areas, LNG vessels will be required to meet the following additional traffic management measures:
  - A Transit Management Plan must be developed in coordination with the Coos Bay Pilot Association, Escort Tug Operators, Security Assets and the Coast Guard prior to the first transit.
  - This plan must be submitted to the COTP no less than 6 months to initial vessel arrival, and followed by an annual review to ensure that it reflects the most current conditions and procedures.
  - For at least the first six months, all transits will be daylight only, unless approved in advance by the COTP.
  - The LNG Vessel must board Pilots at least 5 miles outside the sea buoy.
    - Overtaking or crossing the LNG tanker within the security zone is prohibited for the entire transit from the Coos Bay Sea Buoy to mooring the vessel at the LNG terminal.
  - Vessel transits and bar crossings will be coordinated so as to minimize conflicts with other deep draft vessels, recreational boaters, seasonal fisheries, and other Marine Events.
  - 24 hours prior to arrival, the Coast Guard, FBI, Coos Bay Pilot Association, Escort Tug Masters, and other Escort assets will meet to coordinate inbound and outbound transit details.

Resource Gaps: The Vessel Transit Management Plan must be approved by the COTP at least 60 days prior to the first vessel arrival.

- Vessel Traffic Information System /Vessel Traffic System: The Port of Coos Bay does not have the capacity to receive Automatic Identification System (AIS) signals. AIS receiving capability must be established and must have the capacity to be used by appropriate agencies, port authorities and ship husbandry companies. Additionally, the Port does not have any means for continuous monitoring the navigable waterway. In order to ensure vessel safety and security, a robust camera system capable of monitoring the entire transit route must be established. Due to weather concerns, these cameras must be equipped with the means to adequately monitor vessel traffic in wind, rain and fog conditions.

  Resource Gaps: AIS receiver and camera systems including necessary hardware, software, staffing and training. Camera system must have complete coverage of the entire transit route, capable of detecting vessel traffic in wind, rain, fog, and dark conditions. Equipment and access to data feed of video imagery must be provided to state and local emergency operations centers impacted by the project.

- Tug Escort and Docking Assist: Due to the confined channel and high wind conditions, each LNG Carrier must be escorted by two tractor tugs, which will join the vessel as soon as safe to do so. The primary tug will be tethered at the direction of the pilot. A third tractor tug is required to assist with turning and mooring. Based on the Ship Simulation Study conducted by Moffatt & Nichol on March 17-20, 2008, vessels are limited to transiting during periods of high tide and 25 knot winds or less. While unloading, all three tugs will remain on standby to assist with emergency departure procedures.

  All three tractor tugs must be at least 80 Ton Astern Bollard Pull or larger and equipped with Class 1 Fire Fighting equipment.

  Resource Gaps: Three 80 Bollard Ton Tractor Tugs with Class 1 Fire Fighting capability.

- Navigational Aids:
  - Based on the Ship Simulation Study conducted by Moffatt & Nichol on March 17-20, 2008, four aids to navigation must be added and eight aids to navigation relocated on the waterway (pg. 12-17).
  - Physical Oceanographic Real-Time System (PORTS) must be contracted with NOAA to provide real time river level, current and weather data.

- LNG Carrier familiarization training for Pilots and Tug Operators: Prior to the arrival of the first vessel, simulator training must be provided for pilots and tug operators identified as having responsibility for LNG traffic.

Safety Measures:

Emergency Response Planning: Regional emergency response planning is limited in the region. Emergency response planning resources will need to be augmented to adequately develop emergency response procedures and protocols as well as continuously update those plans as conditions change.

Resource Gap: To be determined in conjunction with local and regional response agencies through the Emergency Response Planning process.

- Vessel and Facility Inspections: LNG tankers and facilities are subject to (at a minimum) annual Coast Guard inspections to ensure compliance with federal and international safety, security and pollution regulations. In addition, LNG vessels and facilities are typically required to undergo a pre-arrival inspection, and transfer monitor.

  Resource Gap: Additional Coast Guard Facility and Vessel Inspectors.

- Shore-Side Fire-Fighting: Firefighting capability is limited in the area surrounding the proposed LNG terminal. Shore side firefighting resources and training will need to be augmented in order to provide basic protection services to the facility as well as the surrounding communities along the transit route.

  Resource Gap: To be determined in conjunction with local and regional response agencies through the Emergency Response Planning process.

- In-Transit Fire-Fighting: Firefighting capability is limited along the entire transit route for proposed LNG vessels.

  Resource Gap: A plan must be developed for managing underway firefighting, including provisions for command and control of tactical fire fighting decisions as well as financial arrangements for provision of mutual aid and identification of suitable locations for conducting fire fighting operations along the transit route. To be determined in conjunction with local and regional response agencies through the Emergency Response Planning process.

  Public Notification System and Procedures: Adequate means to notify the public along the transit route, including ongoing public education campaigns, emergency notification systems, and adequate drills and training are required. Education programs must be tailored to meet the various needs of all waterway users, including commercial and recreational boaters, local businesses, local residents, and tourists.

  Resource Gap: A comprehensive notification system, including the deployment of associate equipment and training, must be developed. To be determined in conjunction with local and regional response agencies through the Emergency Response Planning process.

- Gas Detection Capability: No gas detection capability exists at the Port of Coos Bay, along the transit route and at the site of the proposed facility. Emergency response personnel require appropriate gas detection equipment, maintenance, and training. Additionally, the use of fixed detection equipment will ensure accurate and expedited gas detection in the event of a large scale LNG release. The installation of these detectors at strategic points along the waterway must be developed.

Resource Gap: Gas Detectors, appropriate training, and maintenance infrastructure. To be determined in conjunction with local and regional response agencies through the Emergency Response Planning process.

Security Measures:

- Security Boardings, Waterway Monitoring, and Vessel Escorts: Extensive security measures will be required to provide adequate protection for LNG vessels in transit to and while moored at the facility. The details of these measures are SSI, and are outlined in a separate supplementary report.

- Facility Security Measures: LNG facilities are subject to the security regulations outlined in 33 CFR 105, and are required to submit a Facility Security Plan (FSP) for Coast Guard approval, and undergo (at a minimum) an annual Coast Guard security inspection. The facility shall also develop a plan to provide for appropriate security measures from the start of construction through implementation of the Coast Guard approved FSP.

- Sandia Study: The WSA proposes the potential to receive vessels with up to 217,000 m^3 cargo capacity. The Sandia Report is based on consequences of LNG breaches, spills and hazards associated with LNG vessels having a cargo capacity no greater than 148,000 m^3 and spill volumes of 12,500 m^3. There remains some question as to the size of hazard zones for accidental and intentional discharges and the potential increased risk to public safety from LNG spills on water for larger vessels. Based on these existing uncertainties, Jordan Cove must either complete a site-specific analysis for the largest sized LNG vessel or limit arrivals to vessels with a cargo capacity no greater than 148,000 m^3 until additional analysis addressing vessels with higher cargo capacities is completed. However, this requirement is contingent on the requirement for US Coast Guard approval to receive LNG tankers larger than 148,000 m^3.

In the absence of the measures described in this letter and the resources necessary to implement them or changes in Coast Guard policy upon which the resource decisions are based, Coos Bay would be considered unsuitable for the LNG marine traffic associated with the Jordan Cove LNG Terminal. The applicant shall be required to submit an annual update to the Waterway Suitability Assessment to the Coast Guard which shall be revalidated by the COTP and AMSC. For further information, please contact Mr. Russ Berg of Coast Guard Sector Portland at (503) 240-9374.

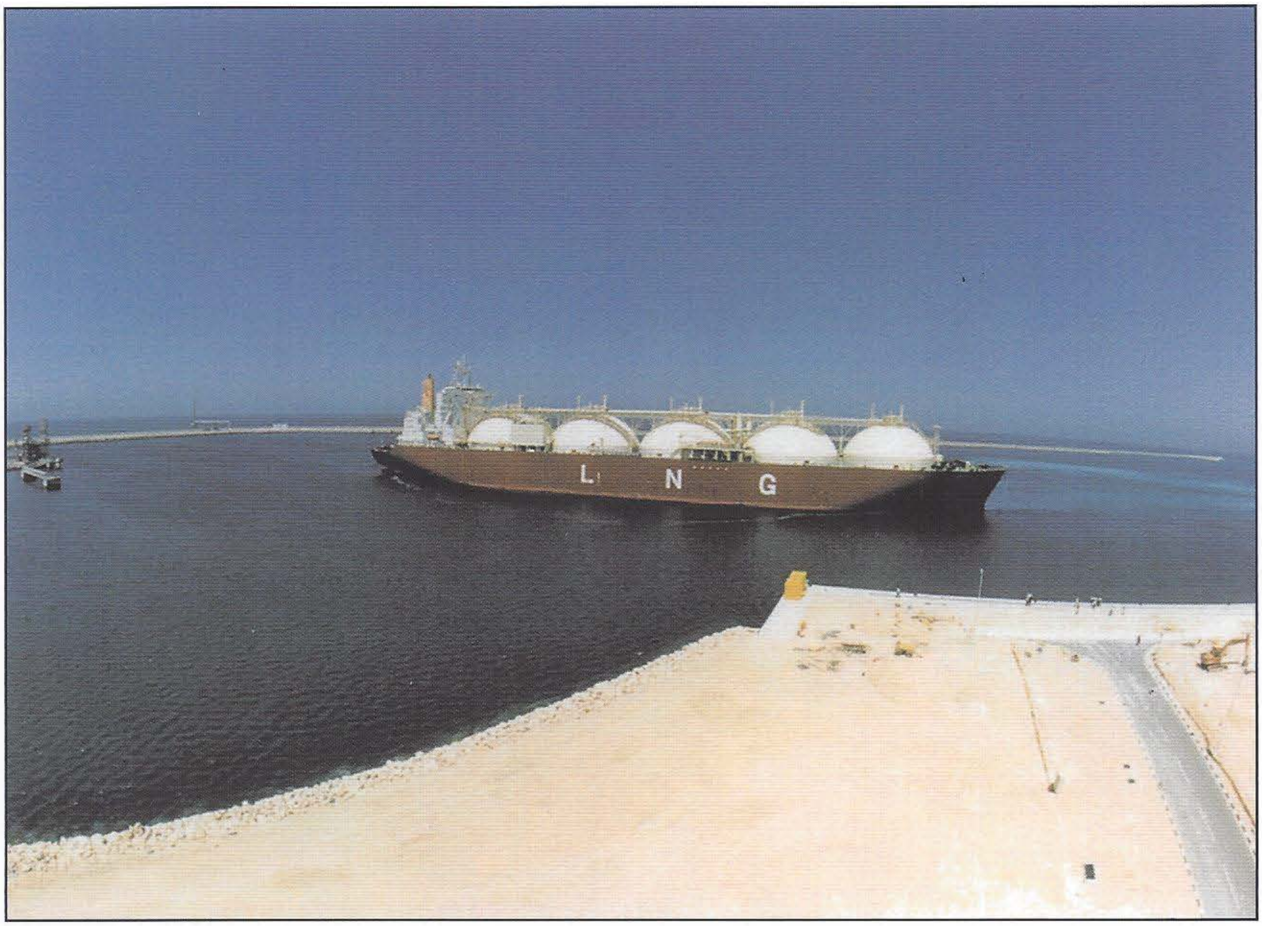
Sincerely,

F. G. Myer
Captain, U.S. Coast Guard
Captain of the Port
Federal Maritime Security Coordinator

Copy: Thirteenth Coast Guard District (dp)
Coast Guard Pacific Area (Pp)
Commandant, Coast Guard Headquarter (CG-52), (CG-522), (CG-544)
Maintenance and Logistics Command Pacific (Sm)

APPENDIX 10.D.

Site Selection and Design for LNG Ports and Jetties



Information Paper No. 14

SIGTTO

Site Selection and Design for LNG Ports and Jetties

with views on

RISK LIMITATION during PORT NAVIGATION and CARGO OPERATIONS

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SIGTTO

The Society of International Gas Tanker and Terminal Operators (SIGTTO) is a non-profit making organisation dedicated to protect and promote the mutual interests of its members in matters related to the safe and reliable operation of gas tankers and terminals within a sound environment. The Society was founded in 1979 and was granted consultative status at IMO in November 1983. The Society has over 160 companies in membership who own or operate over 95% of the world's LNG tankers and terminals and over 55% of the world's LPG tankers and terminals.

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Contents

NOMENCLATURE

BSI	British Standards Institute
CEN	Comité Européen de Normalisation
ESD	Emergency Shut-Down
ERS	Emergency Release System; a system comprising all ESD and PERC measures
IALA	International Association of Lighthouse Authorities
IAPH	International Association of Ports and Harbors
ICS	International Chamber of Shipping
ISGOTT	International Safety Guide for Oil Tankers and Terminals
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas (butane and propane)
OCIMF	Oil Companies International Marine Forum
PERC	Powered Emergency Release Coupler, with its adjacent quick-acting block valves. This is a device providing a virtual spill-free means of quick disconnection of the hard arm in emergency situations. The block valves are interlocked with the coupler to ensure dual action.
PIANC	Permanent International Association of Navigation Congresses
SIGTTO	Society of International Gas Tankers and Terminal Operators Ltd
TSS	Traffic Separation Scheme
VTS	Vessel Traffic Services

1 SUMMARY

This paper addresses safety issues for LNG ports. It focuses on the elimination of spillages both at the ship/shore interface and in navigational approach channels. The paper concentrates on issues which can be solved when a port is being designed and is, therefore, of benefit to harbour planners and port authorities. Flowing from these considerations, the paper outlines a way forward for the site selection of LNG terminals, establishes a basis for safe jetty design and considers safety factors in the port approach. In developing its first aim, the paper examines existing industry guidelines covering cargo operations at the ship/shore interface. Indeed, the paper suggests that LNG's excellent safety record owes much to the adoption of existing standards. However, with the industry becoming more widespread, as a second aim, continuing success depends not only on better acceptance of existing standards but also on future improvements. Some of these newer aspects are described and a check list is presented in the Appendix giving an overall package of the items considered most essential for LNG.

Bearing in mind the high commercial exposures within LNG projects, the need to maintain its good safety record is vital to all companies concerned. Furthermore, an incident in one port could have serious knock-on effects in others, and may herald constraints in new projects elsewhere. These concerns, coupled with the dangers perceived during public inquiries into LNG transport, make a very strong case indeed for a continuing high level of safety to be applied.

On ships the good safety record for LNG operations is predicated on an excellent standard of management, high quality crews, the structural robustness of ships' hulls and back-up control systems. On shore, also of importance, are the select number of well managed terminals. At these plants the focus of national agencies, port authorities and terminal managers ensure that safety in operations is always an important element.

However, although LNG has an enviable record it is not risk free. Not only are some hazards difficult to eradicate; an accident, albeit rare, is possible as a result of human error or catastrophic event such as an earthquake. Moreover, technical limitations can have an effect and site location may not always achieve a port design which is entirely risk-free. It can be seen, therefore, that there can remain a very remote chance for some incidents to occur. However, a large release of LNG such as through a damaged hard arm or a ruptured cargo containment system — central themes in this paper — should be specially addressed during port design.

Important matters which should be dealt with when choosing the location of a new terminal are covered in the paper. Apart from general considerations, these emphasis the need for the introduction of risk management techniques. A fact which helps to ease the acceptance of these newer concepts in the LNG trade is its relatively close-knit nature and because most of the trade is held by only a few companies within well-defined limits. Also, investments in LNG projects are such that equipment quality can be planned to a high standard.

This paper proposes the adoption of the recommendations outlined in chapter 2. However, criteria such as that for channel width, should not be understood as absolute values; these recommendations are just basic guides to prompt special enquiry into particular aspects. Furthermore, the actual values quoted together with their risk reduction effect, still depend on local conditions which have to be covered individually, port by port.

2 PRINCIPAL RECOMMENDATIONS

2.1 PORT DESIGN

Approach Channels. Harbour channels should be of uniform cross-sectional depth and have a minimum width, equal to five times the beam of the largest ship.

Turning Circles. Turning circles should have a minimum diameter of twice the overall length of the largest ship, where current effect is minimal. Where turning circles are located in areas of current, diameters should be increased by the anticipated drift.

Tug Power. Available tug power, expressed in terms of effective bollard pull, should be sufficient to overcome the maximum wind force generated on the largest ship using the terminal, under the maximum wind speed permitted for harbour manoeuvres and with the LNG carrier's engines out of action.

Traffic Control. A Vessel Traffic Service (VTS) System should be a port requirement and this should be able to monitor and direct the movement of all ships coming within the operating area of LNG carriers.

Operating Limits. Operating criteria, for maximum wind speed, wave height, and current, should be established for each terminal and port approach. Such limits should match LNG carrier size, manoeuvring constraints, and tug power.

Speed Limits. Speed limits should be set for areas in the port approach presenting either collision or grounding risks. These limits should apply not only to LNG carriers but also to any surrounding traffic.

2.2 THE JETTY

Exclusion of Ignition Sources. No uncontrolled ignition source should be within a predetermined safe area centred on the LNG carrier's cargo manifold.

Mooring Layout. The terminal should provide mooring points of a strength and in an array which permits all LNG carriers using the terminal to be held alongside in all conditions of wind and current.

Quick Release Hooks. All mooring points should be equipped with quick release hooks. Multiple hook assemblies should be provided at those points where multiple moorings lines are deployed so that not more than one mooring line is attached to a single hook.

Emergency Release System. At each hard arm the terminal should fit an ERS system, able to be interlinked to the ship's ESD system. This system must operate in two stages: the first stage stops LNG pumping and closes block valves in the pipelines; the second stage entails automatic activation of the dry-break coupling at the PERC together with its quick-acting flanking valves. The ERS System should conform to an accepted industry standard [15].

Powered Emergency Release Couplers (PERCs). The terminal should fit a PERC in each hard arm together with quick-acting flanking valves so that a dry-break release can be achieved in emergency situations.

Terminal Security. An effective security regime should be in place to enforce the designated ignition exclusion zone and prevent unauthorised entry into the terminal and jetty area, whether by land or by sea.

Operating Limits. Operating criteria, expressed in terms of wind speed, wave height, and current, should be established for each jetty. Such limits should be developed according to ship size, mooring restraint, and hard arm limits. Separate sets of limits should be established for (a) berthing, (b) stopping cargo transfer, (c) hard arm disconnection and (d) departure from the berth.

3 ACKNOWLEDGMENTS

The content of this paper is based on reports from a company having SIGTTO membership and, in this respect references [1] and [2] were most valuable. The navigational aspects, as detailed in chapters 9 and 10, came about as personnel in that company assessed marine operational risks for new LNG terminals. In one case, the new project was in Europe where the project analysis was carried out in accordance with a European Council Directive for assessing risks and environmental impacts. This is a process which, while being driven by national law, is also of direct concern to the companies involved.

These requirements led the project leaders to consider how the risk of some classes of accident might be better established and, in particular, what the consequences of a large LNG release might be, either in the port approach — due to grounding or collision; or alongside — due to fracture of the hard arm.

The company concluded that such a large release of LNG had never happened. Nevertheless, in some situations such an event was found to be feasible. From a marine viewpoint the scenarios which could lead to a major release were identified and recommendations were prepared to further reduce the chance of any such happening.

This paper also draws on earlier publications from SIGTTO and similar societies which are relevant to the management of port risks.

4 INTRODUCTION

At the time of site selection, the level of marine risk is determined by the position chosen for the terminal and this is especially true of terminals handling hazardous cargoes such as LNG. Once the port is in operation, the risks identified during planning should be controlled by suitable equipment and pre-arranged procedures. This should include the on-going need to keep other industry or populations remote from the plant.

As can be seen from much of its earlier work, SIGTTO urge acceptance of a wide range of equipment and procedures for the reduction of operational risk. To supplement past work, this paper recommends that for new sites the LNG terminal, and its port area, should be examined as a unique risk system. This paper focuses, therefore, on accident exposure and risk management not only during cargo operations alongside, but also during the port transits of LNG carriers.

Implicit in site selection is the recognition of risk. As described elsewhere [3], risk consists of a combination of event frequency and consequence. Thus, port designers are often faced with a number of choices when selecting a site, and these choices can arise from a variety of competing pressures. As described in risk assessment theory, operational solutions are found by acceptance, or non-acceptance, of some categories of risk. However, whatever remote frequencies may be tolerated for a smaller release, there is no acceptable frequency for a large release.

In essence, the issue being addressed is how best to minimise port risks by design factors at the start of a project. As can be seen in the paper there are three components in this equation. Initially questions on satisfactory jetty position and design are covered. Operational procedures are then addressed. Thereafter, having questioned the robustness of these procedures with respect to human elements, the consequences of collisions and groundings are studied and methods of limiting the effect of such accidents are considered. By this means, any high risk scenario is identified during design and this then requires special handling to restrict occurrence.

From a navigational standpoint and as alluded to in the above paragraph, the paper suggests that while the human controls called upon during ship manoeuvring deserve high ranking, of themselves, they can never be considered one-hundred per cent secure: this is because questions of human error can prevail. However, back-up is achieved if it is known that, in a grounding or collision, an LNG carrier's cargo containment system is most unlikely to be breached. To achieve this end, a detailed study of each port approach is needed and, to give this subject greater clarity, examples are given at section 10.3.

To cover the main risks (as identified), the possibility of liquid spillage during cargo operations at the jetty is also discussed. Here, a three stage solution is offered. First, well deployed moorings. Second, well engineered and interlinked ESD systems. Third, the fitting of PERCs, with quick-acting valves included on either side; all controlled by an ERS system.

Having addressed all risks — big and small — alongside and in the port approach, an outcome from the risk analysis which makes an accident virtually impossible is clearly the most satisfactory. If, however, the outcome shows consequences of a serious nature then, clearly, it is necessary to draw up detailed contingency plans. But, in some circumstances, such as a large LNG release close to a populated area, it may be impossible to devise a realistic contingency plan because of the nature of the problem. Herein lies a conundrum which may only be resolved by further reducing the chance of a major release by designing-out the problem.

The precautions, as recommended by SIGTTO in this paper, do not offer a single package that reduces operational risk to some quantifiable and acceptable level; indeed it is suspected that the pattern of operational risk is too complex to be easily handled in this way. However, this cautionary note aside, the industry's objective must be to further reduce risk whenever possible.

Of course, the safety of life is vital, and so also is continuing public confidence in the trade. However, the enormous financial exposures of LNG projects also must be safeguarded. In some circumstances it is found that the protection given to save life also protects the commercial exposure. In other cases, however, personal safety can be assured while unacceptable business risks remain - so suggesting the improved standards, as recommended in this report, are necessary not only due to personnel hazards but also to protect the business risk.

Important factors such as personnel training, contingency planning or matters of a general safety nature are not covered in this paper; the aim has been to focus more on matters of equipment and issues of navigational interest. Nevertheless, these extra factors are fundamental to future safety in the LNG sector and, as a matter of course, should always be taken into account.

5 DEVELOPMENT OF LNG STANDARDS

The history of developments in the LNG industry has been marked by two separate but interwoven strands. Firstly there was a continuous effort to design systems to reduce the probability of large escapes of gas. On the other hand extra standards — often oil industry based — were re-specified in light of experience and technological improvement. Indeed, as the LNG industry moves into the 21st century it remains true that future improvements should not be altogether separated from progress in the oil world and, where possible, LNG terminalling standards should continue to grow in parallel with port operations generally.

An example of an LNG standard having developed along technological lines is that covering on-shore storage tanks. For a period, earthen embankments were used for support against the force of sudden release from the inner tank. Subsequently, through adoption of improved inner tank material, the probability of catastrophic crack propagation was much reduced. Now, earthen bunds are no longer needed. Similar changes occurred in the design of LNG carriers, where sophisticated methods for assessing crack propagation now allow the secondary barrier to be omitted in two free-standing cargo containment systems - the Moss Rosenberg spherical design and the IHI prismatic design.

To date, the greatest investment to reduce port risks is the limitation of gas escape at the ship/shore interface and on the jetty. Here the application of industry recommendations for jetty design and mooring systems [4] provides a secure base for LNG transfer. Furthermore, the references mentioned in chapter 6 direct port designers to construct jetties handling hazardous cargoes in remote areas where other ships do not pose a (collision) risk and where any gas escape cannot affect local populations. When this advice is combined with that from SIGTTO [5] — as outlined in section 7.2.2 — risks at the jetty are vastly reduced.

It can be seen, therefore, that progress in defining LNG standards have taken a step-by-step pattern which can be summarised as follows:

- a start was made with the existing framework of standards for oil
- these were then adapted for the characteristics of LNG
- changes in shipping and terminalling standards were then addressed, and
- finally the engineering challenges for cryogenic systems were answered

Present day standards for limiting problems are thus the result of sensible evolution rather than a well-focused set of risk related measures. Indeed, experience shows that the process was, simply, one of progressive improvement, the motivation being a desire to make operations safer. However, it is at the time of site selection that the foundations of high quality risk management can be laid and where overall cost/benefit judgements are best formed and it is in these areas where this paper recommends the introduction of risk management techniques.

Although the criteria for site selection may differ between LNG terminals, the majority are common to all. Some, such as the proximity of the plant to centres of population, lie beyond the pure marine interest and outside the main scope of this paper. But others, including the harbour movements of LNG carriers, the density of marine traffic (covering the nautical risks to LNG carriers) and the terminal itself, much influence the overall risk which eventually has to be controlled and these concepts are covered in more detail in the following chapters.

6 SITE SELECTION

6.1 GENERAL

At its most elementary level, site selection for LNG loading terminals is predicated by the location of production areas and, at receiving terminals, the situation is dependant upon the location of markets. Thereafter, fine tuning within the selection process is influenced by the optimisation of infrastructure costs such as gas transmission systems, access to trunklines and other distribution networks.

Hence, site selection is driven largely by factors aimed at minimising transportation and storage costs. With this in mind, it can be appreciated that marine criteria are only a part of the overall process. Therefore, at the stage of site selection, input from marine experts consists mainly in optimising fleet capacity (numbers and sizes of ships) and checking civil engineering matters at the ship/shore interface, at the terminal and in the terminal/port approach. This latter aspect is achieved by obtaining the required depth of sheltered water, providing good access to the sea and achieving immediate adjacency to the LNG terminal.

From a marine viewpoint there is little prospect to escape from these basic factors. Prices and hence, to a large extent demand, remain linked to the costs of alternative energies and, LNG's unique environmental benefits notwithstanding, the product must retain market competitiveness. Thus, as the future unfolds, continuing efforts to economise on handling costs and freight rates are likely.

In the site selection process the challenge, therefore, is to limit marine risks while positioning the jetty within realistic limits. Already there are generally accepted criteria and regulatory requirements to guide port designers in achieving this synthesis and most are covered in this paper.

6.2 JETTY LOCATION

The recommended site selection process removes as many risks as possible by placing LNG terminals in sheltered locations remote from other port users. References [6], [7] and [8] all direct port designers to construct jetties handling hazardous cargoes in remote areas where other ships do not pose a (collision) risk and where any gas escape cannot affect local populations.

Furthermore, choosing a jetty position within a sheltered location limits the dynamic forces acting on a ship from sea-waves which, in turn, could break a ship's mooring lines. Considering the standard LNG carrier of about 135,000 m^3 capacity, the waves likely to have such effects are those approaching from directly ahead or astern, having *significant heights* exceeding 1.5 metres and *periods* greater than 9 seconds. Seas approaching the berthed ship from an incidence angle of 90° (to the bow) have much lower cut-off points. It is, therefore, recommended that harbour protection be provided against low frequency waves, either by choice of location or by construction of an effective breakwater. Alternatively, an enhanced mooring system may be designed, suited to dynamic effects (but also taking into account the suitability of gangway access for the moving ship). Without such assurance the mooring system, which is the only defence against ship break-out, could be put at risk.

Jetty location should also be chosen to reduce the risk of passing ships striking a berthed LNG carrier but subjective judgement comes into assessing safety from this standpoint. The acceptability of such positions should be determined only after detailed consideration of local circumstances. However, as far as port design is concerned, some features are clear cut. For example, positioning an LNG terminal on the outside of a river bend raises the risk that a passing ship may strike the berthed carrier if the manoeuvre is not properly executed. This is possible because, at some point on the bend, the manoeuvring ship must head directly at the berthed LNG carrier. In this respect, and following the reasoning in reference [3], ships of over 10,000 tonnes displacement operating at normal harbour speeds — say 10 knots — when striking at 90°, present a hazard to a berthed LNG carrier's containment system. It follows, therefore, that building a jetty in such locations is normally considered unsuitable.

Furthermore, large ships passing near to a berthed LNG carrier can cause surging or ranging along the jetty, with consequential risks to the moorings and this phenomenon should be guarded against. This can occur at jetties located in channels used by large ships and, because of this, these positions are not recommended.

The added risks from increased traffic encounters, and extended shallow-water navigation, when positioning an LNG jetty farther inside a port, must also be considered — but these risks are covered more fully in chapters 9 and 10.

As can be seen, choosing the site for an LNG jetty comprises a mixture of checks, some derived from quantitative analyses, others owing more to subjective judgement. However, when considering an LNG carrier alongside, site selection is directed mainly at minimising the risks of ship strikings, limiting interactive effects from passing ships and reducing the risks of dynamic wave forces within mooring lines.

7 DESIGN CRITERIA FOR JETTIES

When the site selection process finally establishes the best position for an LNG terminal, its design is set within two sets of criteria — root criteria and specific criteria. These are categorised as shown below.

7.1 ROOT CRITERIA FOR HAZARDOUS LIQUID CARGOES

Basic safety for gas, chemical or oil tankers and their respective terminals is governed by ISGOTT [9]. This book contains an essential list of design and operational practices and is amended from time to time in accordance with new experience. In addition to ISGOTT, in establishing safe designs, the use of other guidelines published by SIGTTO, OCIMF, IAPH, PIANC, IALA, and BSI is encouraged. Some of these documents are referred to in chapter 11 — see references [10], [11] and [12]. However, most of these industry documents are general in nature and seldom discuss event frequency nor, for that matter, specific ship-types. In order to cover the hazards more effectively, reference [13] is of help in the gas trades — although written more from the viewpoint of existing plant.

Until the publication of this paper, within the standard suite of industry publications, the possible consequences of an accident are also left largely unaddressed. Previously, it was only reference [14] which gave some guidance on this subject. However, taken together, these older sources provide a robust framework of root criteria around which jetty designs are established and other standards (specific criteria — see below) are then specially tailored to the needs of LNG.

Thus, existing recommendations provide the root criteria for jetty design, in terms of:

- strength of mooring systems
- positioning breasting dolphins
- position, size, and spacing, of hard arms
- depth, width, and alignment, of harbour channels

Such recommendations provide terminals with a good set of design standards. They are not, however, exhaustive nor can they be applied without knowledge of local conditions, so they can rarely be used to prepare a complete checklist for LNG — other measures must be adopted (see section 7.2).

It can be seen, therefore, that within the root criteria, a system is established for securing a safe berth; but this is one within which there may remain a significant, albeit remote, probability for an accident to happen. In developing criteria suited to LNG the separation of each risk into its frequency and consequence is crucial. Thus, when considering even the remote possibility of major accidents, the application of existing standards, though relevant, is insufficient to obtain suitable assurance. Accordingly, at LNG jetties, risk related methods should be adopted which address event probabilities, and seek, as far as possible, to quantify the frequency of occurrence.

7.2 SPECIFIC CRITERIA FOR LNG

7.2.1 General

Although the root criteria, as discussed above, are included in LNG terminal design, risk considerations usually identify the need for yet other equipment or procedures — the site specific criteria. These methods can be more demanding than the root criteria and are often applicable to operational practices and geographical areas for which industry guidance is not yet fully established. However, a new series of standards from CEN, entitled Installations and Equipment for Liquefied Natural Gas, will be appropriate to European usage — perhaps even further afield.

Additional specific criteria are also found from risk factors lying beyond normal operations at the ship/shore interface. These conditions can include hazards from outside influences such as other marine traffic and nearby ignition sources. As an example, some LNG terminals patrol the perimeter of the offshore safety zones with guard boats — see section 7.2.4. A further example is to declare the air-space over an LNG terminal as being a restricted zone where no aircraft is allowed to fly without written permission.

The specific criteria have thus grown through experience in analysing and managing terminals. They have wide application in the reduction of risks at LNG terminals and are therefore included among the recommendations to be applied during terminal design. In the following sections some specific criteria are discussed in greater detail.

7.2.2 Mooring

For the LNG trades, site selection includes extensive collection of environmental data, including wave spectra. From this, the oscillations of berthed ships are estimated and the individual loads in each mooring line are pre-calculated for critical conditions. Within the trade, this means that not only mooring standards [4] should apply but also the additional force of dynamic wave action should be taken into account. So, while the root criteria for mooring systems act as the design basis, the behaviour of mooring and cargo handling equipment is made site specific for the prevailing conditions. These analyses establish jetty specifications for:

- mooring bollard strength and position
- mooring load-monitoring equipment, and
- hard arm envelopes and cut-off points for automatic operation of the ERS system

7.2.3 Cargo Transfer Operations

All LNG companies ensure that gas carriers can lie safely alongside while transferring cargo. Here, references [14] and [15] are of great value in achieving this aim. By adding the standards for ship's cargo manifolds and detail on surge pressure control [16], which are among the many valuable contributions made in recent years, even greater assurance is provided. Yet experience shows that specific criteria should be adopted to adequately control risks over the whole spectrum of port and terminalling operations and these should find a place in the design. In this respect, to guard against the consequences of hard arm failure, specific criteria should limit the possibility of significant LNG spills. This question is addressed in reference [15] where the following equipment is recommended to be fitted at hard arms:

- interlinking of ship and shore ESD systems
- establishing a common standard of linkage for ship/shore ESD control
- fitting PERCs and their quick-acting valves
- linking ESD systems and PERCs into a unified control system called ERS

In addition to other matters, reference [5] takes a fresh look at the operation of Emergency Release Systems (ERSs) where it will be found that many events can cause triggering of the system. For the purposes of this paper it should be noted, however, that the ERS is expected to function in two distinct steps. The first step is cargo pump stoppage and closure of the ESD valves in pipelines, both on-board ship and on shore. The second step is closure of the quick acting valves (at the PERC) and the release of the PERC by automatic means. More detail may help to explain this two-stage operation. Here, it should be appreciated that within the ERS's electronic logic for the hard arm, sensors are installed to detect ship movement. Some movements are within the proscribed limits; others are of significance; and yet others are dangerous. Ship movements to the outer edge of the safe area may trigger an alarm. However, movements into the first ERS area activate valve closure and pump stoppage (ESD) — this is still an intermediate area but one in which automatically initiated controls are considered necessary. Finally, if the ship moves beyond this intermediate zone — into the danger area — automatic release of the PERC is actuated quite independently from human intervention.

To illustrate this concept a diagram is provided below.

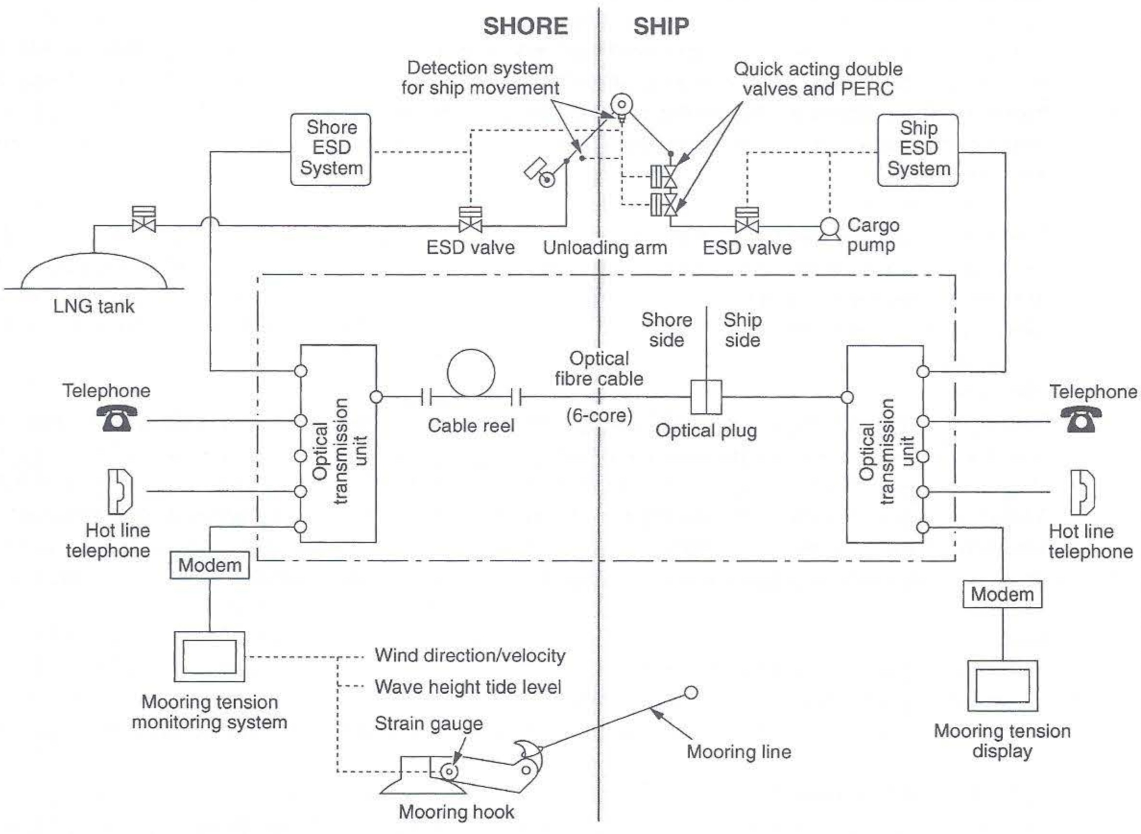

Figure 1: Interlinkage of ESD Systems and PERC Operation - The ERS

In developing these criteria, the underlying rationale is that the mooring lines must provide secure attachment between ship and shore allowing very little relative movement. This means the hard arms also remain secure and the risk of arm rupture, caused by ship break-out, should not occur. However, although this basic framework underpins safety at the ship/shore interface, it provides only a single defence against risk of spillage and the generation of dangerous gas clouds.

Therefore, a second defence comprising an interlinked ESD system is used, this being manually activated by the jetty operator or automatically by ship movement beyond the limits of a predetermined envelope. Automatic activation is triggered (amongst other alarms — see reference [5]) when sensors in the ERS system detect unacceptable ship movement so allowing the ESD controls to stop cargo flow and close pipeline valves — usually within 30 seconds. The progress of activation must be first to stop the pump and then to close the valve nearest to the pump — this restricts the magnitude of surge pressures so limiting any risk of hard arm damage because of high transient over-pressures.

However, and as mentioned above, it is recommended that a third defence be provided to ensure protection for the hard arms against damage from ship break-out and further reduce the maximum quantity of LNG spilled. This is the inclusion of PERCs (fitted within the arms) which allow hard arms to be safely, quickly (about 5 seconds), and automatically disconnected if an LNG carrier should break-out from its jetty. Hence, if all else fails and an LNG carrier breaks away from a jetty the maximum spill is no more than about 15 litres of liquid for the standard 16 inch diameter arm.

Safety issues apart, the PERC (and its accompanying ERS system) is a highly desirable protection of business interests. Often the jetties at LNG installations are but single entities, and if put out of action, total supply can be severely jeopardised. It will be seen, therefore, that in LNG projects, where massive investments are involved and the income of many parties depend on uninterrupted cargo deliveries, any risk of damage to jetties must be eliminated as far as possible. For these reasons, SIGTTO believe that such equipment is an essential risk reduction technique.

Further measures to prevent gas release include surge pressure control systems. Because surge pressures can cause hard arm and pipeline damage, the cargo handling system must be designed by keeping the possibility of surge in mind. This may lead to increased scantlings for pipelines, the fitting of bursting discs with surge pressure drums, or quick-acting relief lines returning surge pressures to the cargo tank.

7.2.4 Ignition Risk

In the event of an LNG spill the possible extent of a gas cloud must be considered. Here it should be appreciated that the risk of ignition from spilled LNG can extend for some considerable distance and, therefore, ignition controls must extend beyond the immediate area and this may be both inside and outside the terminal boundary.

Clearly, it is important to remove all risks of ignition as far as it is practicable to do so. Procedures taken to limit the risk of spills, and minimise their scale, reduce the probability of gas cloud ignition. But even the marginal risks remaining can be unacceptable in a business where a first rate safety record is vital to sustain confidence. Further precautions are therefore adopted to limit ignition sources on the jetty and in its environs.

As mentioned in section 7.2.1, in some ports guard boats are used to patrol the offshore safety zones with a view to excluding other traffic. Often these craft are also fitted out for other emergency purposes and feature in contingency plans. Figure 2 below shows the general arrangement for one such craft.

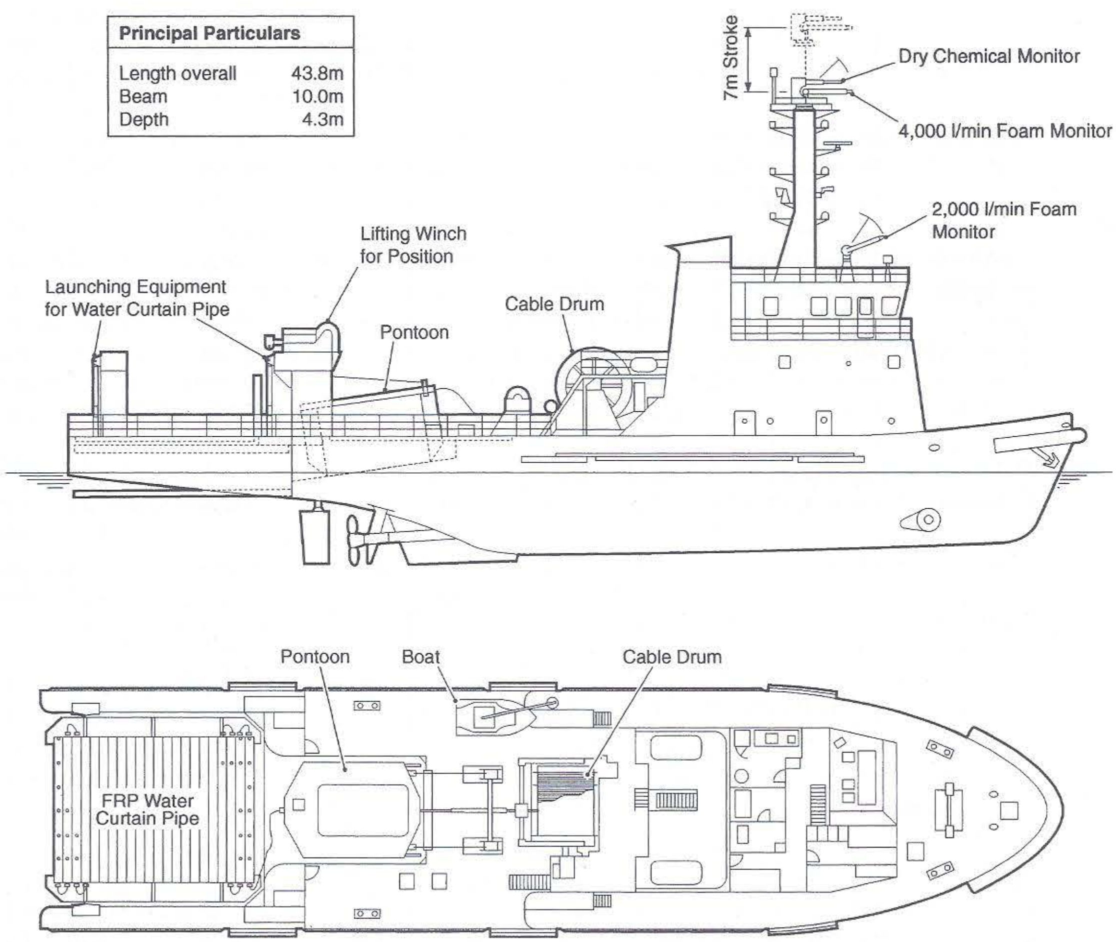

Figure 2: A Guard Boat Outfitted for Emergency Response
Details from Tokyo Electric Power Co. Inc. (see LNG 10, Conference Proceedings)

The area over which ignition-free zones should extend is determined by an analysis of the formation and dispersion characteristics of gas clouds resulting from a range of spill scenarios under a variety of weather conditions. The result provides the likelihood and possible extent of gas clouds in the vicinity of the jetty.

The range of a flammable gas cloud generated by a spill is principally dependant on spill rate and duration but inevitably some subjectivity must accompany the assessment of each spill scenario. Other factors such as climatic conditions, wind direction and speed are also of importance. In addition local topography such as harbour structures and the presence of the LNG carrier itself can have an effect.

Thus, determination of the minimum area from which all ignition sources must be excluded will vary from terminal to terminal and such determination should form part of the design considerations. Sometimes quite large zones, free from ignition sources, are considered desirable especially when terminal safety systems such as fire pumps could be engulfed within the gas cloud.

7.2.5 Specific Criteria - a Summary

In summary the essentials for a safe LNG berth are as follows:

Essential design for a safe LNG jetty

- find a location suitably distant from centres of population
- provide a safe position, removed from other traffic and wave action
- construct mooring points in a satisfactory array and of suitable strength
- use hard arms for cargo transfer
- interlink ship and shore ESD systems
- provide a two stage ERS system, linking ESD protocols with PERC operation
- fit hard arms with PERCs, together with quick acting valves
- fit wind speed and direction monitoring equipment
- install load monitoring equipment on mooring line quick release hooks
- determine maximum credible spill, gas cloud range, and ignition-free safety zones

Apart from the essential design factors listed above, the following terminal procedures should be in place.

Terminal procedures for the LNG carrier alongside

- set limits on the mooring system for wind speed, wave height, and current
- set wind limits for cargo stoppage, hard arm disconnection, and unberthing
- restrict the speed of large ships passing close to berthed LNG carriers
- control visitors and vehicles coming into jetty safety zones
- establish ignition-free offshore zones to stop entry by small craft
- disallow simultaneous LNG operations and ship movements at adjacent jetties
- have available local weather forecasts with suitable warning systems
- have pilots and tugs ready at short notice for emergency departure

Port planning should also ensure that advance procedures are available to control a ship's port entry. In this regard it is most important that each arrival is carefully agreed between the ship and terminal. In particular this should include up-to-the-minute information on berth availability, especially in times of bad-weather forecasts, when last minute changes in berth availability can be anticipated. To safeguard ships in transit from any last-minute change in status on berth availability a contingency plan should be available to include detail on suitable anchorages, lay-by areas or turning circles where the ship can wait or turn round to proceed back to the port entrance.

As a port moves into the operational phase critical revision of existing port procedures is recommended on a frequent basis. By this means, ship operators and terminal managers can be continually assured that cargo planning procedures remain valid, tugs numbers (and power) remain suitable and that matters of contingency planning remain up to date.

8 RISK MANAGEMENT IN THE PORT APPROACH

National authorities and LNG companies devote considerable resources to reduce any risk that an LNG terminal may present to the port environs. This is most apparent during design when special emphasis on the security of nearby population centres is obtained by applying Environmental Impact Assessments and application of references [6] and [8]. At this stage, the risks associated with an LNG carrier as it navigates through the port approach are also addressed and, to illustrate these matters, typical safety routines for the offshore areas are listed in the following paragraphs. Reference may also be made to publications from IAPH, PIANC, BSI and IALA on this subject and some of these standards are given in chapter 11.

8.1 PORT CONTROLS

Taken globally, the frequency of nautical accidents, such as strikings, collisions and groundings, to any class of ship are greater in port approaches and during berthing when compared to frequency rates at sea. For the whole class of gas carriers (LNG and LPG) such accidents account for over half the total reported and, when time factors are taken into account, this confirms that the opening statement also holds true in the gas trade. However, from historical records, it is good to report that serious incidents of this type are extremely rare for LNG carriers; indeed, only one such incident (a grounding) is known to have occurred at a receiving port, none at a loading port and none at all anywhere in the world since 1980.

This successful management of LNG ports can be explained only by the controls unique to the LNG business which have a significant risk reduction effect. At present these distinguishing features consist of:

- effective VTS (traffic management) and the use of escort craft
- adequate tug power to control LNG carriers, even in dead-ship conditions
- strict operating conditions
- regular ships in each trade, and
- high quality seagoing personnel

Some of these points are further explained below:

8.1.1 Vessel Traffic Systems (VTS)

Establishing safe conditions for the port transit of LNG carriers is always a matter of importance. This is usually a direct responsibility of the port authority. However, operational risk management on a day by day basis is a task shared between port authority, terminal owner and ship operator. In most cases there is agreement over the procedures required to assure low risk levels but, as a minimum, a good VTS system, as specified by the International Maritime Organization (Resolution A.578-14) for marine traffic management is recommended to prevent close encounters between LNG carriers and other ships.

Subordinate specifications concerning traffic management, such as the safe distances for other ships to pass LNG carriers, depend on the risks identified in particular situations. For example, in areas of high traffic density, the shore-based VTS may be supplemented by an escort craft (or guard boat) to attend the LNG carrier; in other situations, the VTS may suspend other traffic movements in the channel during the LNG carrier's approach. Whatever specific arrangements are made, they should aim to much limit collision risks caused by close encounters with other ships.

Other conditions for establishing safe operations in port are similar to those required for the harbour movements of any large ship, such as, adequate navigation marks and lights, limiting ship movements in poor visibility, and a high standard of pilotage service all of which contribute to minimising the risk of grounding.

The quality of pilotage service is particularly important. As part of terminal planning it is vital to secure not only consistent high quality in harbour pilotage operations but also to fix pilot boarding areas at a suitable distance offshore, beyond which the LNG carrier is not allowed to continue inwards without the pilot being on board. Many port authorities use navigational simulators for training their harbour pilots and, when used wisely, simulator courses can yield valuable results. Not least among the advantages of simulator training are the benefits which can be gained by learning how to build good bridge teamwork and an appreciation of Passage and Voyage Planning routines.

In another context, (see section 6.2) marine traffic management can also be important when the position of the jetty is taken into account. If large ships are allowed to pass close by, interactive effects can cause mooring line failure on the LNG carrier. Although such locations are not recommended, depending on the site chosen for the terminal, it may be necessary to limit the speed of passing ships and this may be achieved by VTS controls.

8.1.2 Tugs

Following the same weather which determines port design parameters, the operating limits for LNG carriers should also be specified in terms of wind speed and current drift. These parameters are then used to calculate the maximum wind forces acting on the largest LNG carrier using the port, and thence the number and power of the tugs needed for berthing manoeuvres is specified. There must always be sufficient tug assistance to control LNG carriers in the maximum permitted operating conditions and this should be specified assuming the ship's engines are not available. This method gives different results from one terminal to another. Accordingly, minimum tug power is not an absolute value. Nevertheless, it has been found that for LNG carriers of 135,000 m^3 capacity, acceptable standards are usually in the range of three or four tugs having a combined bollard pull between 120 to 140 tonnes. These tugs should be able to exert approximately half of this total power at each end of the ship. Given that four tugs are provided, in terms of tug propulsion, this suggests that each tug should have engines capable of a minimum of 3,000 horsepower, although this is dependant on propeller configuration.

8.1.3 Operating Conditions

When port design is being considered the aim should be to limit navigational risks involving LNG carriers within the port area. The extent of the system developed depends on factors such as:

- number and type of ships and other craft using the port
- port accident records
- navigational distances and difficulty through the port and jetty approach
- the maximum draft of the ships
- the nature of the sea-bed (rock, sand or mud)
- tidal conditions (tidal ranges and tidal currents)
- weather conditions (wind, waves, sea-ice and visibility)
- proximity of the terminal to populated areas and industrial sites

After studying such factors, port designers and port authorities can introduce LNG-related provisions appropriate to the local port. The operational procedures and equipments which follow from these considerations, and already adopted in many LNG ports, are summarised below.

8.1.4 Summary of LNG Port Procedures

Port procedural limits for weather

- establish weather limits for port closure
- draw up procedures to give advance weather warnings to ships
- restrict port manoeuvring of LNG carriers in strong winds
- restrict port manoeuvring of LNG carriers in reduced visibility
- establish safe anchorages at the port entrance and within the harbour

Port controls for approach channels

- provide suitable short range navigational aids for approach channels
- provide escape routes in cases where a ship is unable to berth
- establish port suitability for day and night transits
- set safe manoeuvring limits for, visibility, wind, current, and wave height
- relate channel widths to the beam of the largest ship
- relate turning circle diameters to the length of the largest ship
- set speed limits for channels to limit heavy groundings or penetrating collisions

Port controls for tugs and escort craft

- set safe weather limits for berthing
- provide tugs farther to seaward; beyond the normal 'assistance' area
- provide escort craft suited to the circumstances
- establish tug power as being sufficient to overcome maximum set wind conditions
- have pilots and tugs available at short notice for emergency departures

Procedures and systems regarding traffic control

- establish a VTS control to coordinate the movement of all craft within the port
- limit other traffic movements in the port while LNG carriers are in transit
- set a moving safety zone in approach channels ahead and astern of LNG carriers
- adopt Traffic Separation Schemes (TSS) in appropriate approach channels

In addition to these points other operational factors should be addressed. These can include instructing ships to carry appropriate charts and nautical publications and to implement Voyage Planning routines. Port authorities should also ensure that harbour pilots use the practice of Voyage Planning. However, being more in the realms of ship operation, these issues fall beyond the scope of this paper.

Study of the foregoing lists shows that only rarely are the criteria absolute, or conditions unchanging. Obviously water depth is critical, as are severe weather conditions, but in many other cases either the procedures, or the conditions they are set to control, have flexible application. Indeed, it is suggested in reference [14] that the principal value of listing the criteria is to identify the hazards with a view to setting operational procedures to control them. Similar reasoning is evident in reference [1], and its check list of risk reduction options is used as a basis for the Appendix to this paper. Hence, within many existing navigational controls, it is usual, as a consequence of human factors, for a low level of residual risk to remain. Under present industry guidelines, this is true even after the optimisation process for site selection is complete. Thus, in some existing ports this risk remains to be controlled on a day by day basis.

Of course, for new terminals, present day standards involving Environmental Impact Assessments, and similar procedures, should be even more effective in securing a low risk operation. However, within these systems, expert marine advice is necessary to ensure that, when a large gas release is considered, limited only by human elements, the consequences are controlled by other methods such as those discussed in chapters 9 and 10.

9 THE HUMAN ELEMENT

Accident reports show that effective risk management, whether in port or at sea, is often frustrated by an inability to completely obviate human error or uncharacteristic human behaviour. Indeed, the large majority of shipping casualties continue to occur as a result of the human element. But the relationship between operator error and risk assessment remains obscure; this is because human responses are difficult to predict and the process of human reaction is not fully understood.

For these reasons, risk management systems usually take the possibility of human error into account, attempting to control it by other means. Such methods can include alarms, ESD systems, engineered fail-to-safe equipment, equipment redundancy (back-up), and procedures. As appropriate, these devices include multiple cross-checking features. The positive contribution of all these measures to risk reduction is clear. However, casualty data shows (see sections 8.1 and 10.1), that even for LNG carriers, current techniques involving human controls are less than one-hundred per cent effective. Thus, when limiting the chance of a significant accident — to match a very low risk exposure — the range of industry standards covered in chapter 8 are found to be less than foolproof.

This paper suggests, therefore, that it is necessary in the port approach, to adopt a method of risk management which, as far as possible, discounts the contribution of human judgement. In particular, this chapter not only addresses the need to consider accidents where human judgement has proved helpful in limiting the consequences but also to consider the increased risk in some areas when human controls have failed — perhaps thus endangering the ship's cargo tank containment system.

Drawing on the discussion in chapter 10, the ship's speed which may damage the cargo containment system can be estimated. By this means, for parts of the port approach, speed controls can be established to limit the consequences of collisions, strikings and groundings. In the case of a ship grounding it is possible to assess whether the potential damage might cause cargo containment system rupture. This can be done by:

- reference to the quality of the sea-bed
- assessing the possible courses of the grounding ship
- estimating the ship's speed at the time, and
- applying the criteria given in references [17] and [18]

A similar list of criteria can be developed for collisions but the first item, as listed above, would be omitted and another added; vis, the angle of strike. In addition, references [19] to [26] should be studied.

This paper suggests, therefore, that each port should be investigated for the presence of the dangers which could cause critical impacts during the harbour transit of an LNG carrier and recommends that port designers, when assessing individual hazards, take the possibility of human error into account. This should be done to ensure a satisfactory safety margin is provided — that is, in the event of accident, an assurance ruling out cargo containment system rupture. It can be seen therefore that, when using this method, the following listing of existing safeguards are assumed to fail:

- operational procedures
- back up system warnings, and
- human controls

Evidently (see chapter 10) such high risk events are extremely rare in LNG shipping. Nevertheless, only after the above investigation has been completed can appropriate assurance be secured which protects a ship's cargo containment system against rupture. Because of the unquantifiable nature of the human element, this paper suggests that only by removal of all possibilities for containment system penetration can the correct level of port security be obtained.

10 GROUNDING AND COLLISION RISK

With respect to ship navigation, any hazard which may result in a large release of LNG can be identified by assessment of the energy necessary to penetrate the ship's inner and outer hulls. The double-hull arrangement provides LNG carriers' containment systems with protection to all but high impact. This means that, as part of port design there is every prospect for preventing a large gas release without introducing unrealistic port restrictions. However, and following from chapter 9, it should be seen that an important element to avoid, where possible, is any procedure over-dependant on human controls.

In this chapter, therefore, consideration is given to LNG carrier groundings and collisions with a view (through ship operation and port design) to reduce the risk of major gas releases. Clearly, once a terminal is in operation, knowledge that such accidents are virtually impossible, provides valuable input for future operations.

10.1 HULL DAMAGE - A HISTORICAL REVIEW

Analysis of SIGTTO and other casualty records give a reliable picture of the accident profile of the LNG shipping industry in the period between 1982 and 1996. However, because some categories of minor incident were considered unreportable, it is probable that the data is incomplete. Nevertheless, it is virtually certain that the data includes every incident, such as grounding and collision, having potential for damaging a ship's cargo containment system.

The data-base shows that the cargo handling and port-related accidents recorded in this period, and with the ships fully operational, numbered only ten. Of these:

- one occurred whilst manoeuvring in a port (propeller struck channel buoy)
- five involved ships breaking out from the jetty with the hard arms connected
- three involved mechanical failure, and
- one records a fire on the engine room switchboard

In none of these cases was the LNG carrier's cargo containment system put at risk.

For the period between 1962 and 1982 the data is less comprehensive, but still it is extremely unlikely that any significant incident, threatening an LNG carrier's cargo containment system, would have gone unreported. In this period there are only six accidents which might be categorised as posing a hazard to the ship's cargo containment system. Within this time frame there are five reported collisions and five reported groundings. One of the collisions involved an LNG carrier being struck whilst berthed, the others were outside port and none resulted in serious damage to the cargo containment system. Of the groundings only two (one in port and the other at sea) involved serious structural damage to the ship's bottom and in neither case was the cargo tank containment system penetrated.

The two serious grounding incidents demonstrate the capacity of LNG carriers to sustain bottom damage without experiencing rupture of the containment system.

Records show that there are no comparable data that would similarly demonstrate the resistance of an LNG carrier's side structures to collisions. Nevertheless, there are tools available for predicting such resistance, giving results which, when used with care, are able to establish the minimum energy required to put a cargo containment system at risk — see section 10.2.2.

So, although it has never happened over some three decades of LNG carriage, an important risk to be considered in port analysis is the possible release of cargo during groundings or collisions. Though open to interpretation, good estimates are available for the energy required to penetrate an LNG carrier's double hull so putting the ship's internal cargo tank containment system at risk. It is therefore possible to identify accident scenarios with potential for such damage and plan to remove them from port areas. Accordingly, when designing a port, the aim should be to limit the probability of high energy impacts on LNG carriers, such that damage to a ship's hull is minimised.

10.2 RISK OF STRUCTURAL DAMAGE TO LNG CARRIERS

10.2.1 General

The structure of LNG carriers, incorporating double bottom tanks and double sides, gives high resistance to the impact of grounding and collision. This is supported over many years of research (see references [17] to [26]), some of which is described in the following sections.

10.2.2 Collision Damage

One method [19], in which collision energy is assumed to be absorbed by the structures of both ships was, for many years, the accepted way for assessing collision resistance. Predictions using this method relied upon empirical resistance factors, mostly derived using data from actual impacts. More recent methods (see chapter 11), which include a better understanding of failure and collapse mechanisms, have led to more accurate predictions and these methods seem to be especially effective for low energy collisions; although the method first mentioned still gives acceptable results in high energy situations.

The results of such analyses are dependant on the impact angle (of the striking ship), the bow shape of the striking ship and the structure of the struck ship. Therefore conservative interpretations must be placed on such analyses, particularly if the results are intended to support the conclusions of a wider risk assessment.

Significant studies on the question of collision damage are included in the references. Based upon published methods, the following table lists examples of the resistance of a stationary 135,000 m^3 LNG carrier, expressed against the critical impact speed required to hole the outer hull but not to rupture the cargo tank containment system.

Hull Resistance for a 135,000 m^3 LNG Carrier	
Displacement of Colliding Ship (tonnes)	Critical Impact Speed (knots)
93,000	3.2
61,000	4.2
20,000	7.3

For the reasons indicated above, the results shown in the table are considered to be realistic and provide conservative estimates — so allowing a satisfactory margin for error.

10.2.3 Grounding Damage

Typical publications covering grounding damage are listed in the references — in some cases a reference may dwell on oil tanker topics, however, with respect to the double bottom depths, as present day oil tanker design is similar to that in LNG carriers, the references remain helpful. Indeed the references suggest that the similar structure in LNG carriers gives the same level of protection from low energy grounding and similar assurance in a significant proportion of high energy incidents.

Accurate prediction of damage in grounding incidents is difficult. But, given a smooth sea-bed of sand or mud, impact energy is usually spread over a large area of the ship's bottom and, with this cushioning effect, upward penetration is minimised. Rock bottoms cause more jagged penetrations with the impact being absorbed over a much smaller area.

10.2.4 Hazardous Penetration

As can be seen from the foregoing overview, analytical tools are available which can, with reasonable accuracy, predict damage to ship's hulls in collision and grounding situations. This means it is possible to set criteria for accident severity (in terms of ship's speed) below which rupture of the cargo containment system is virtually impossible.

It therefore becomes feasible to consider ways to analyse port approach channels so that any risk of cargo containment rupture can be removed and the remote possibility of an uncontrolled release of LNG reduced to non-credible proportions.

Hence, by removing individual risks in each port such as:

- rock outcrops or reefs
- underwater obstructions, and
- close encounters with other ships

from the main shipping channels and their immediate environs, port risks can be reduced to a level where a large release of LNG becomes too remote to imagine.

10.3 EXAMPLES

In this section practical application of the recommendations given in sections 10.1 and 10.2 is illustrated by simplified examples for a hypothetical port. The port in question is shown in Figure 3.

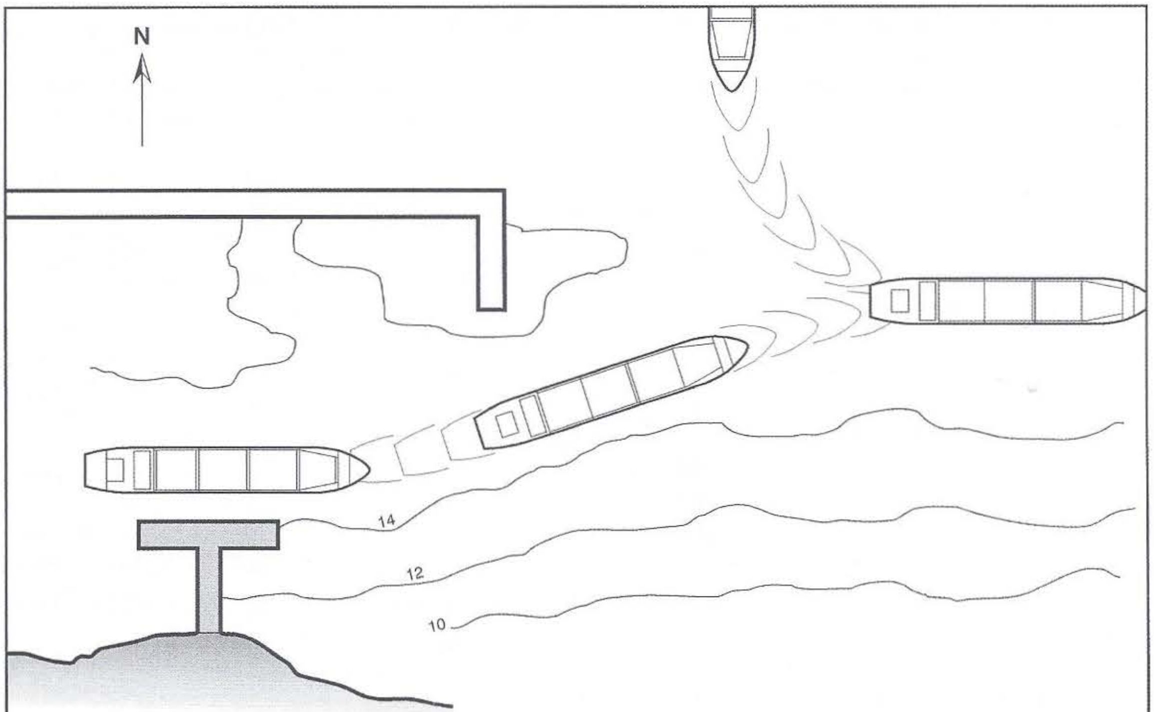

Figure 3: The port geography addressed in the examples

10.3.1 Striking a Fixed Structure - Example 1

Harbour entry is carried out in accordance with the manoeuvre illustrated in Figure 3. This involves moving stern-first through the port entrance under the control of tugs.

The following conditions are assumed to apply:

- Tug numbers, tug power, and operating conditions are specified for the port such that the LNG carrier is fully controlled by tugs alone, even in case of ship engine failure.
- Penetration of the ship's outer hull, through striking the corner of the harbour wall, is calculated to require a side-on speed of 5 knots. Furthermore, the calculations show that this damage will not extend to the cargo tank containment system. (For this scenario, the worst case condition occurs with impact on the ship's parallel body and with the transverse velocity at 90° to the point of impact).
- Misjudgment by those controlling the manoeuvre is assumed.
- At a point on the ship's track (from which impact on the corner of the harbour wall is possible) simultaneous failure of the ship's engines, and sufficient of the tugs for loss of control, is assumed. This is assessed as being possible once in 5 million operations.
- The most likely part of the ship to strike the wall is the ship's stern structure. Collision damage in this area cannot put the cargo containment system immediately at risk.

- The critical speed of 5 knots for a side-on striking cannot be achieved from any point in the manoeuvre since the ship's maximum drift speed in open sea conditions, in wind speeds of 30 knots, is calculated as just 4 knots. This wind produces conditions in which tugs cannot operate; and therefore, under such conditions, the port would be closed. In any case the wind does not contribute sufficient extra speed, to that already given by the tugs, for a 5 knot side-on speed to be achieved from the stern-first manoeuvre.

Solution

With the effects of harbour wall fendering discounted and the resistance of the cargo tank containment system ignored, the probabilities of sustaining cargo tank containment system penetration through striking the harbour wall are assessed as non-credible.

10.3.2 Grounding - Example 2

Assuming human error has occurred, the arriving LNG carrier overshoots the initial port-hand turn of the entry manoeuvre with excessive speed and, through technical failure or misjudgment, the tugs fail to stop the ship. As a result the carrier enters shallow water to the east of the jetty and grounds.

- It is assumed that the ship's last course before grounding can result in angles of impact from head-on (bow-on) to beam-on (side-on).
- Head-on grounding is assumed to have a higher speed than from other directions since any other angle of impact implies a change of course — hence speed loss.
- The sea-bed is free of obstructions and smooth, hence point penetrations are not possible. The slope of the sea-bed is two metres in every 100 metres over the ground.
- The maximum possible head-on grounding speed is assessed at 12 knots. Higher speeds are considered impossible because of shallow water effects, which slow the ship, and because the ship should have put its engines into manoeuvring mode (slower than full sea speed) well in advance. For this reason, grounding speeds for all other angles of impact must be less than 12 knots.
- Impact energy for a head-on grounding is mostly absorbed by structural damage forward of the cargo containment area, and the ship's forward speed is reduced to less than 6 knots (half the initial speed) before the ship's bottom under the cargo tanks takes the ground. The residual impact energy is then spread broadly through the bottom structure as the ship runs over a 2:100 gradient and this is calculated to be insufficient (with a smooth sea-bed) to achieve penetration of the cargo containment system.
- Groundings with the LNG carrier at any other angle to the shore, other than head-on, involve progressive combinations of speed reduction and structural deformation of the ship's bottom forward of the cargo tanks - until, with the beam-on grounding, the impact is taken wholly on the ship's side, but with a speed less than 6 knots.

Solution

Actual grounding incidents and theoretical calculations together suggest that rupture of the cargo containment system is non-credible in any of the cases.

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APPENDIX

LNG PORTS - RISK REDUCTION OPTIONS

General Requirements for LNG Carriers (Where figures are given they refer to LNG carriers of 135,000 m^3 capacity)	
1	**The Port**
1.1	**Port Analysis**
	Speed restrictions for LNG carriers should be appropriate to limit grounding and collision damage.
1.2	**Approach Channels and Turning Basins**
	Navigable depths (for most LNG carriers) should generally not be less than 13 metres below the level of chart datum.
	Under-keel clearances should be established in accordance with the sea-bed quality.
	Channel width should be about five times the beam of the ship (approximately 250 metres).
	Turning areas should have a minimum diameter of two to three times the ship's length (approximately 600 to 900 metres).
	Short approach channels are preferable to long inshore routes which carry more numerous hazards
	Traffic separation schemes should be established in approach routes covering many miles.
	Anchorages should be established at the port entrance and inshore, for the safe segregation of LNG carriers and to provided lay-by facilities in case, at the last moment, the berth proves unavailable.
1.3	**Navigational Aids**
	Buoys to mark the width of navigable channels should be placed at suitable intervals.
	Leading marks or lit beacons, to mark channel centrelines and to facilitate rounding channel bends, should be appropriately placed.
	Electronic navigational aids, to support navigation under adverse weather conditions, are needed in most ports.
	Lit navigational aids should be provided to allow ship movements at night.
1.4	**Port Services**
	Tugs should be made available and three to four are normally required giving 140 tonnes total bollard pull. (Tugs may be required to meet LNG carriers farther offshore).
	Mooring services are often required and these services should normally provide a minimum of two boats, each having at least 400 horsepower.
	Escort services comprising fast patrol craft, to clear approach channels, turning areas, jetty, etc. should be provided in busy port areas.
	Firefighting services comprising specially equipped craft, or, one or more suitably equipped tugs should be provided.

1.5	**Port Procedures**
	Traffic control or VTS systems should be strictly enforced to ensure safe harbour manoeuvring between the pilot boarding area and the jetty.
	Speed limits should be introduced in appropriate parts of the port approach, not only for the LNG carrier but also for other ships.
	Pilotage services should be required to provide pilots of high quality and experience. Pilot boarding areas should be at a suitable distance offshore.
	Ship movements by nearby ships, when the LNG carrier is pumping cargo, should be disallowed.
	Pilots and tugs should be immediately available in case the LNG carrier has to leave the jetty in an emergency.
1.6	**Port Operating Limits**
	Environmental limits for wind, waves, and visibility should be set for ship manoeuvres and these should ensure adequate safe margins are available under all operating conditions.
	Weather limits for port closure should be established.
1.7	**Weather Warnings**
	Forecasting for long range purposes should be provided to give warning of severe storms, such as typhoons and cyclones.
	Forecasting for short range purposes, such as those required for local storms and squalls, should be made available.
2	**The Jetty**
2.1	**Jetty Location**
	Jetty location should be remote from populated areas and should also be well removed from other marine traffic and any port activity which may cause a hazard.
	The maximum credible spill and its estimated gas-cloud range should be carefully established for the jetty area.
	River bends and narrow channels should not be considered as appropriate positions for LNG carrier jetties.
	Breakwaters should be constructed for jetty areas exposed to sea action, such as excessive waves and currents.
	Restrictions, such as low bridges, should not feature in the jetty approach.
	Ignition sources should be excluded within a predetermined radius from the jetty manifold.
2.2	**Jetty Layout**
	Mooring dolphin spacing - between the outermost dolphins - should not be less than the ship's length (approximately 290 metres).
	Mooring dolphins should be situated about 50 metres inshore from the berthing face.
	Mooring points should be suitably positioned, and have suitable strength, for the environmental conditions.
	Quick-release hooks should be provided at all mooring points.

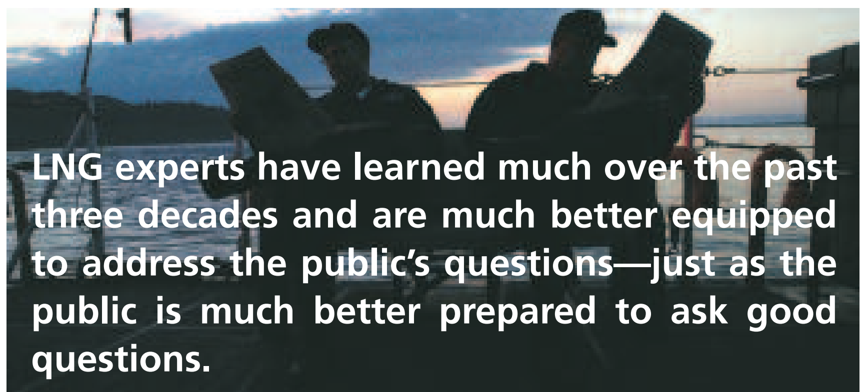
	Breasting dolphin spacing should be designed to ensure that the parallel body of the ship is properly supported.
	Fendering for the dolphins, and for the berth face, should be to a suitable standard.
2.3	**Jetty Equipment**
	Pipelines and pumps etc should be designed to provide a rapid port turn-round.
	Emergency Release Systems at the hard arms should be fitted in accordance with industry specifications. The ERS should be suited to both ship and shore by interlinking and a PERC should be fitted to each hard arm for emergency stoppage and quick release purposes.
	Emergency shut-down valves should be fitted to both ship and shore pipelines and should form part of the ERS system.
	Powered emergency release couplings (PERCs) with flanking quick-acting valves should be fitted to the hard arm as part of the ERS system.
	Plugs both on ship and shore to carry all ESD and communication signals should be standardised.
	Surge pressure control should be provided in LNG pipelines.
	Communications equipment (telephone, hot-line and radios) should be provided for ship/shore use.
	Load monitors, to show the mooring force in each mooring line, should be fitted to quick release hooks.
	Gangways should be provided to give safe emergency access to or from the ship.
2.4	**Basic Firefighting Facilities**
	Water curtain pumps and pipelines should be provided.
	Fixed Dry Powder systems should be provided.
	Gas detection monitors should be fitted at strategic locations.
	Fireproof material should be used for the construction of hard arms (no aluminium).
2.5	**Jetty Procedures**
	On shore jetty safety zones should be effectively policed while the ship is alongside thus providing control over visitors and vehicles.
	Offshore safety zones should be effectively policed by a guard boat to limit the approach of small craft.
	Passing ships, close to the jetty, should have their speed controlled by the harbour VTS system.
	Communications procedures should be well established and tested.
	Contingency plans should be available in written form.
	Operating procedures should be available in written form.
	A Port Information/Regulation Booklet should be provided for passing operational advice to the ship.

LNG and Public Safety Issues

Summarizing current knowledge about potential worst-case consequences of LNG spills onto water.

by Jerry Havens
Professor, Chemical Engineering, University of Arkansas

In 1976 Coast Guard Admirals were being called to Capitol Hill to answer the question: If 25,000 m^3 of liquefied natural gas (LNG) were spilled on water without ignition, how far might a flammable cloud travel before it would not pose a hazard? As technical advisor to the Office of Merchant Marine Safety in the Coast Guard's Bulk Hazardous Cargo Division, I was assigned to provide an answer on the LNG vapor cloud issue within a couple of weeks. Although no longer with the Coast Guard, I am still working on the problem 30 years later.



Past Lessons

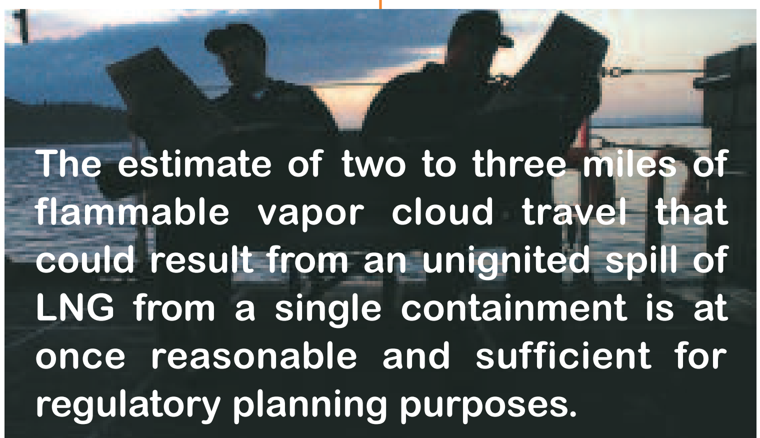
The tragic events of September 11, 2001, changed everything. Watching the World Trade Towers fall sharply focused my research of LNG spills on water. It is understood now that the towers fell because the insulation was knocked off the steel, which could then not withstand the extreme fire exposure. The lesson from this is to understand the consequences of such events, not only in planning for decisions that are within our control, but in planning for events over which we may have little or no control.

LNG experts have learned much over the past three decades and are much better equipped to address the public's questions—just as the public is much better prepared to ask good questions. For space constraints this discussion sidesteps many important issues in the LNG debate; however, it summarizes what is currently known about potential worst-case consequences for public safety of LNG spills onto water.

The description of current LNG knowledge is aided by reference to reports prepared in 2004 by the ABS Shipping Group for the Federal Energy Regulatory Commission[1] and by the Sandia National Laboratory for the Department of Energy.[2] These two reports, which appear to be largely accepted by all of the regulatory agencies involved, emphasize for their analyses one scenario of the consequences of LNG marine spills—spillage onto water of 12,500 m^3 of LNG, which is representative of approximately one half of a single tank on a typical LNG ship. While the Sandia report does provide some consideration of multiple-tank spills, it suggests that such occurrences would not involve more than three tanks at one time. The choice of spillage of only half a tank appears to be the result of the report's consideration of the extreme implausibility of the rapid spillage of the entire tank as an initial result of a terrorist attack. However, limiting discussion to the initial results of a terrorist attack is not necessarily sufficient.

LNG Vapor Cloud Dispersion

My year-long look at the LNG vapor dispersion issue for the Coast Guard produced a report[3] in 1978 that reviewed several predictions by leading authorities of the vapor cloud extent, following spillage of 25,000 m^3 LNG onto water. Those estimates ranged from 0.75 mile to a little over 50 miles. The range was narrowed by showing the errors in reasoning underlying the lowest and highest estimates, but the uncertainty range could not be tightened closer than three to 10 miles.



The estimates, which range between approximately two and three miles, presented in the Sandia and ABS Group reports are endorsable. Note, though, that these estimates are for the spillage of 12,500 m^3 of LNG, half the amount considered in the Coast Guard report produced in 1978. Nonetheless, the estimate of two to three miles of flammable vapor cloud travel that could result from an unignited spill of LNG from a single containment is at once reasonable and sufficient for regulatory planning purposes. Indeed, given the uncertainties involved, the point of diminishing returns has been reached on this scenario for vapor dispersion from a 12,500 m^3 LNG spill on water.

Thermal Radiation from LNG Pool Fires

For thermal radiation from pool fires, the findings of the ABS Group and Sandia reports are also endorsable. Both reports appear to provide estimates of approximately one mile as the distance from a pool fire on a 12,500 m^3 spill on water to which unprotected persons could receive second-degree burns in 30 seconds (based on a thermal flux criterion of 5 KW/m^2). Although this estimate is reasonably representative of the best available estimates of the distance to which the public could be exposed (to this damage criterion), the endorsement is qualified as follows.

First, the use of a thermal flux criterion that would result in second-degree burns in 30 seconds is not necessarily appropriate to ensure public safety, as such exposure essentially ensures that serious burns will occur at that distance to persons who cannot gain shelter within 30 seconds. Aside from questions about the ability of even the most able to gain shelter in such a short time, questions are also raised about the safety of those less able. Lower thermal flux criteria (~1.5 KW/m^2) are prescribed in other national and international regulations designed to provide safe separation distances for the public from fires. Since such lower thermal flux level criteria could increase the distances prescribed in the ABS Group and Sandia reports by as much as one and a half to two times, this end point criteria for ensuring public safety from LNG fires should be reconsidered, especially if the goal is to provide for public safety.

Second, the mathematical modeling methods in the reports that predict the various levels of thermal radiation intensity from a massive LNG pool fire are not on as firm scientific ground as are the methods for predicting vapor cloud dispersion. The vapor cloud question has been more extensively studied to provide data for the models' verification. The physical basis for extrapolation from small-scale experimental data is better understood for vapor dispersion than are the methods in present predictions of thermal radiation extent from pool fires. Sandia and others are considering the need for further large-scale LNG fire testing. Such tests should be conducted with appropriate scientific planning and for the purpose of obtaining experimental data that could be used to verify mathematical modeling methods; this additional testing is advised to provide a better understanding of large LNG fires on water.

However, the Sandia report states that cascading events, resulting either from brittle fracture of structural steel on the ship or failure of the insulation that results in LNG vaporization at rates exceeding the capability of the relief valves, cannot be ruled out. Foamed plastic insulation, widely used on LNG carriers, would be highly susceptible to failure by melting or decomposition. It is a cardinal safety rule that the pressure limits on tanks carrying flammable or reactive materials should not be exceeded, as such excess portends catastrophic rupture of the containment. While the Sandia report concludes that such cascading events would be very unlikely to involve more than three of the five tanks on a typical LNG carrier, the report's optimism in this regard is unexplained. Once cascading failures begin, what would stop the process from resulting in the total loss of all LNG aboard the carrier? More research is required.

Other Hazards

Other hazards associated with spilling LNG onto water include oxygen deprivation, cold-burns, rapid phase transitions, and explosions in confined spaces, as well as the potential for unconfined vapor cloud explosions (UVCEs) if the LNG contains significant heavies. As the hazards of oxygen deprivation and cryogenic burns are not expected to affect the public, they will not be considered further here.

Explosions in confined spaces, either combustion events or events of rapid phase transition, may have the potential for causing secondary damage that could lead to further spillage of LNG. Unconfined vapor cloud explosions cannot be dismissed if the cargo contains significant amounts—perhaps greater than 12 to 18 percent, based on Coast Guard-sponsored tests at China Lake in the 1980s—of gas components heavier than methane. Enrichment in higher boiling point components of LNG remaining on the water can lead to vapor cloud concentrations that pose a UCVE hazard, even if the concentration of liquid initially spilled does not. LNG contact with ship structural steel, rapid phase transitions, and gas explosions in confined spaces on the ship are not expected to pose hazards to the public, except as they may relate to the ship's vulnerability to further damage following the cryogenic cargo spillage onto ship structures, with or without ignition.

Vulnerability Issues

Coast Guard Navigation and Vessel Inspection Circular No. 05-05, "Guidance on Assessing the Suitability of a Waterway for Liquefied Natural Gas (LNG) Marine Traffic," incorporates requirements for a vulnerability assessment that identifies the exposures that might be exploited to ensure the success of an attempted terrorist attack.[4] Two types of vulnerabilities are considered: system and asset. System vulnerabilities consider the ability of the terrorist to successfully launch an attack; asset vulnerabilities consider the physical properties of the target that may influence the likelihood of success of a terrorist attack.

Worst Case?

The hazards of brittle fracture, rapid phase transitions, and explosions in confined ship spaces, as well as cascading events that may result from the extreme fire exposure a ship would experience if a nominal 12,500 m^3 spill on water around the ship was ignited, will require careful consideration. The definition of the worst case event that could be realized as a result of a terrorist attack is likely to hinge on the assessment of the asset vulnerabilities that is required to be considered in NVIC 05-05. This is largely where our unfinished work remains.

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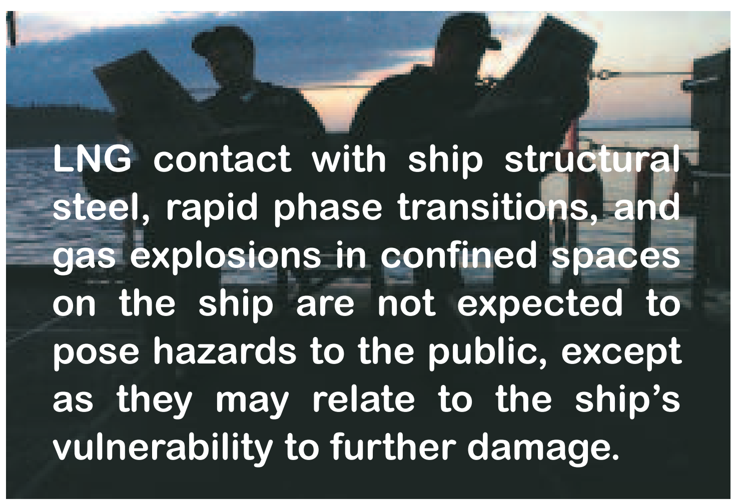
About the author: *Jerry Havens is a chemical engineering professor at the University of Arkansas. He has three decades of experience researching LNG spills onto water.*



UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL OCEAN SERVICE
OFFICE OF OCEAN AND COASTAL RESOURCE MANAGEMENT
Washington, D.C. 20235

DEC 15 1986

Mr. James F. Ross
Director
Department of Land Conservation
and Development
1175 Court Street, N.E.
Salem, OR 97310-0590

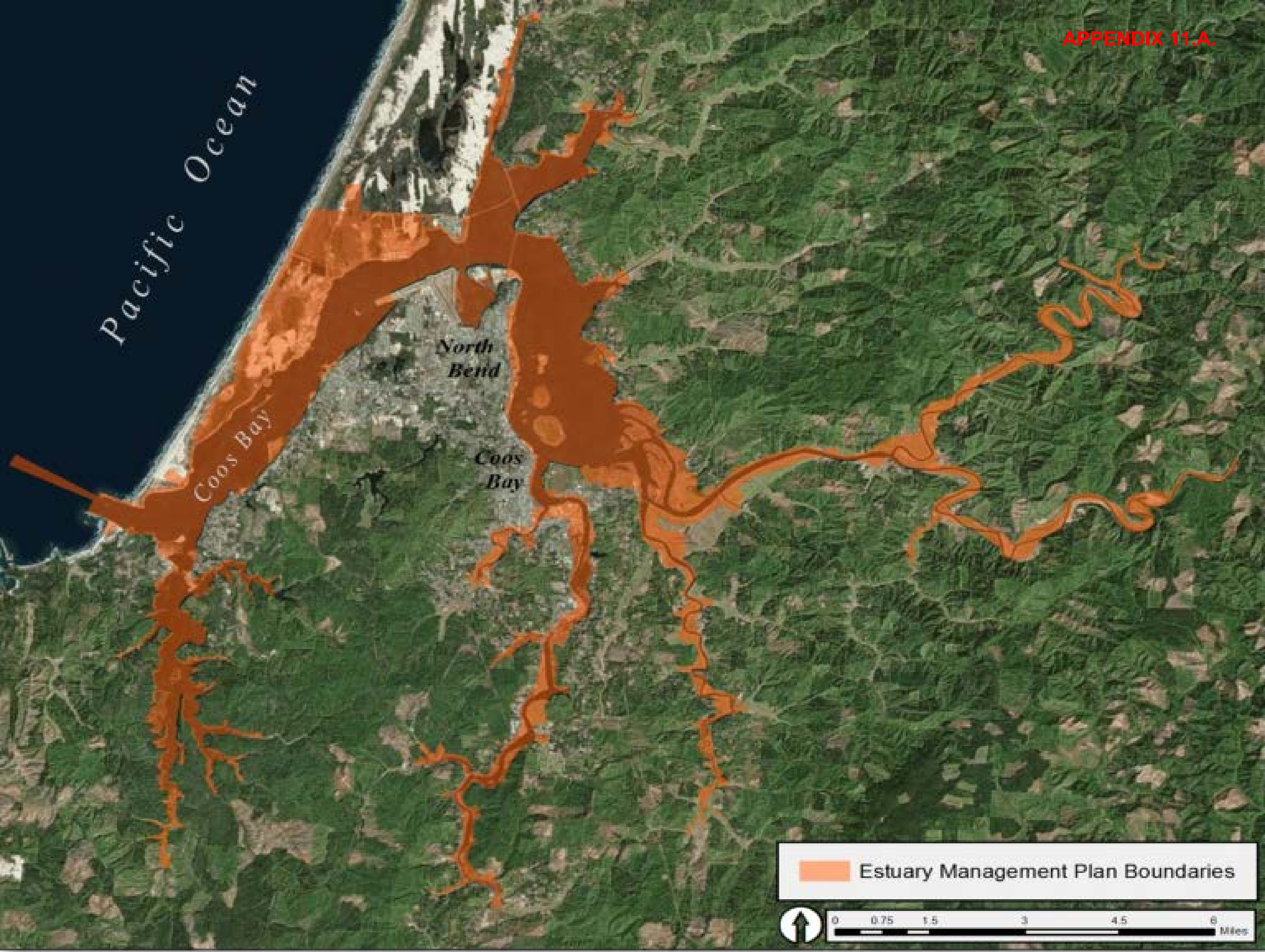
Dear Mr. Ross:

On November 20, 1986, we received your request to incorporate changes to Oregon Revised Statutes 197, 215, and 227 and to add Oregon Administrative Rule Chapter 660, Divisions 1-6, 8, 9, 11, 14, 16-19, 30, 31, and 40 into the Oregon Coastal Management Program (OCMP). We concur with your finding that these statutory changes and administrative rules constitute routine program implementation, and approve their incorporation into the OCMP pursuant to 15 CFR 923.84. Federal consistency will apply when you publish notice of our approval.

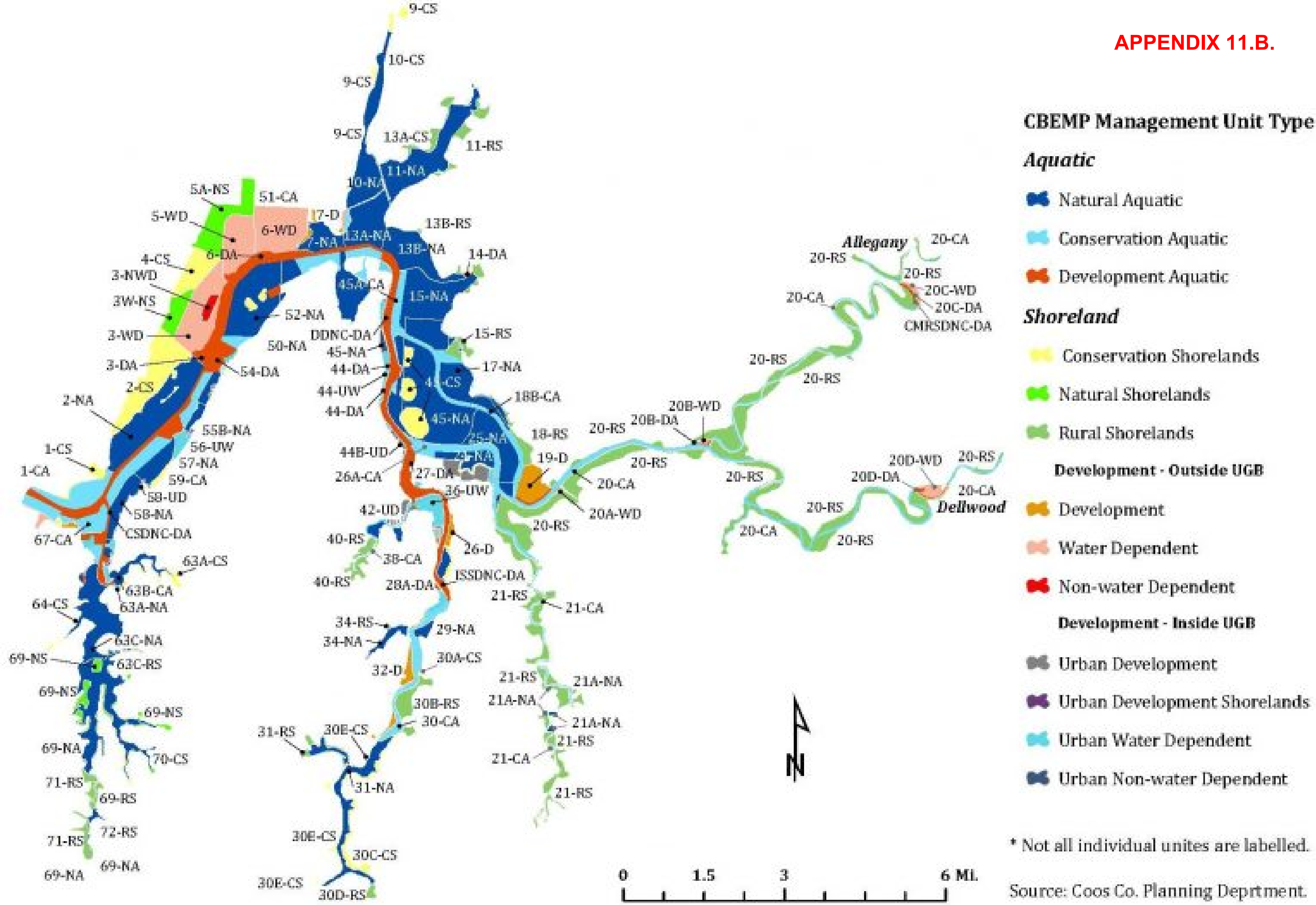
Sincerely,

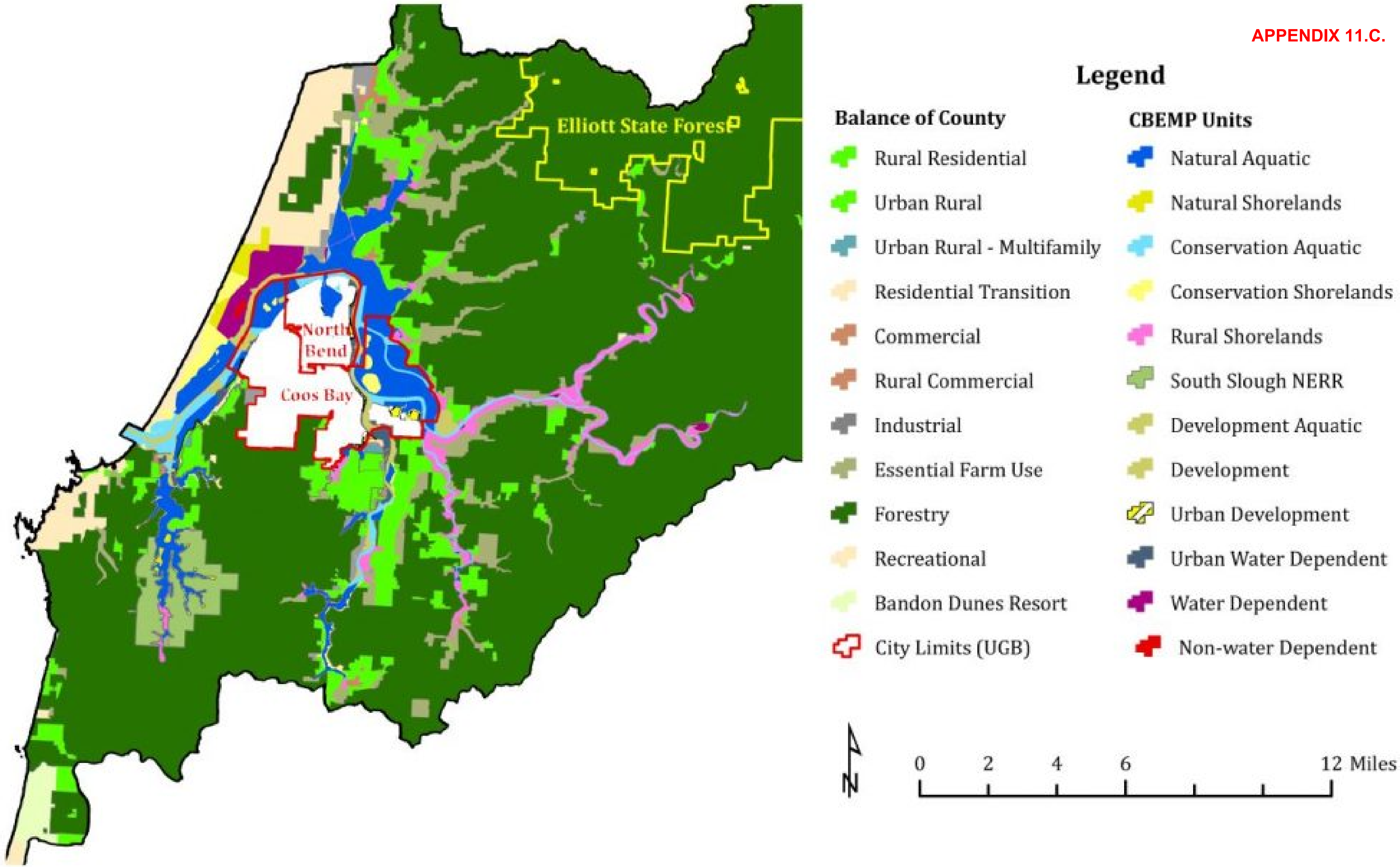
Peter L. Tweedt
Director

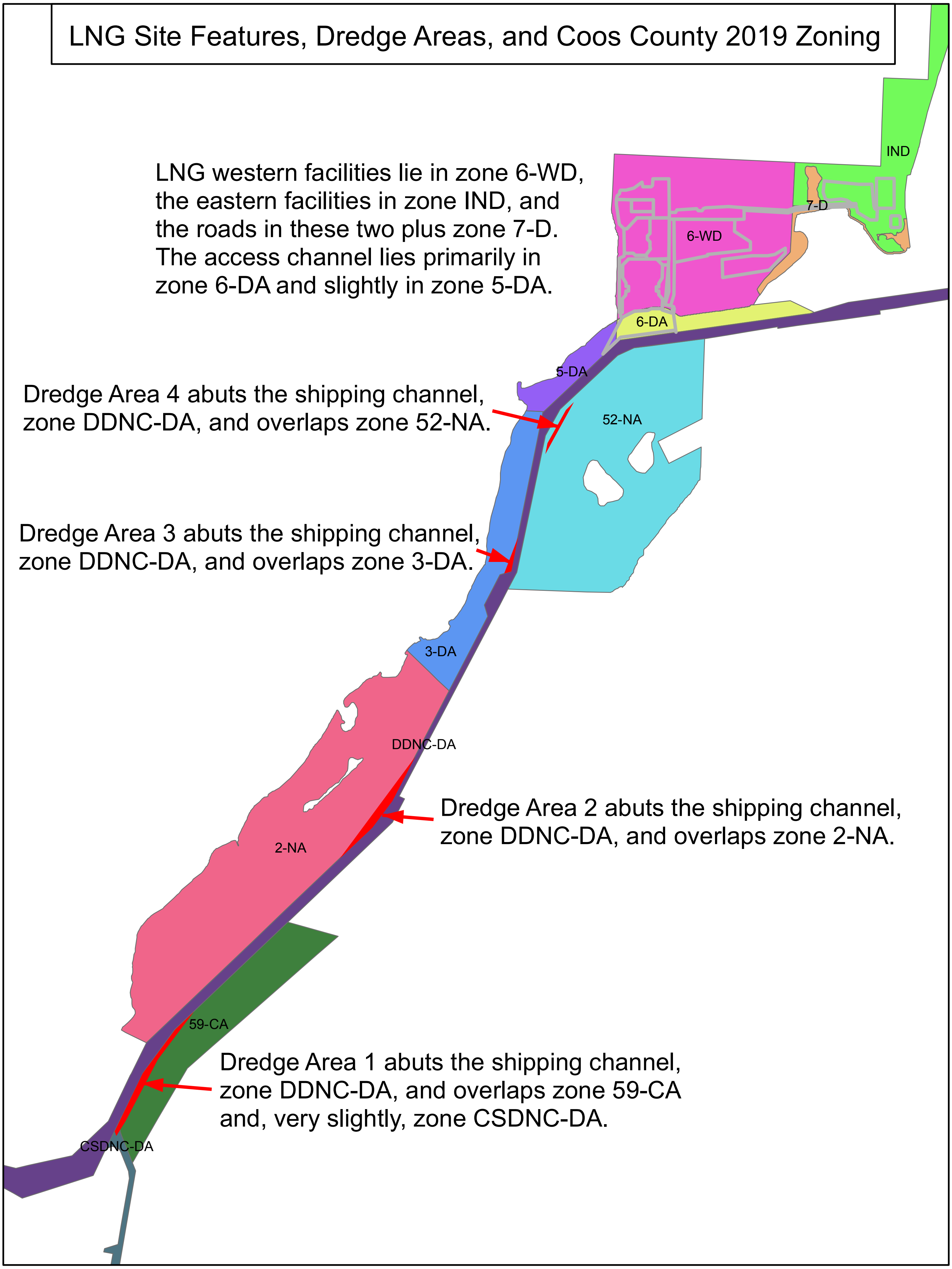
APPENDIX 11.A.



APPENDIX 11.B.

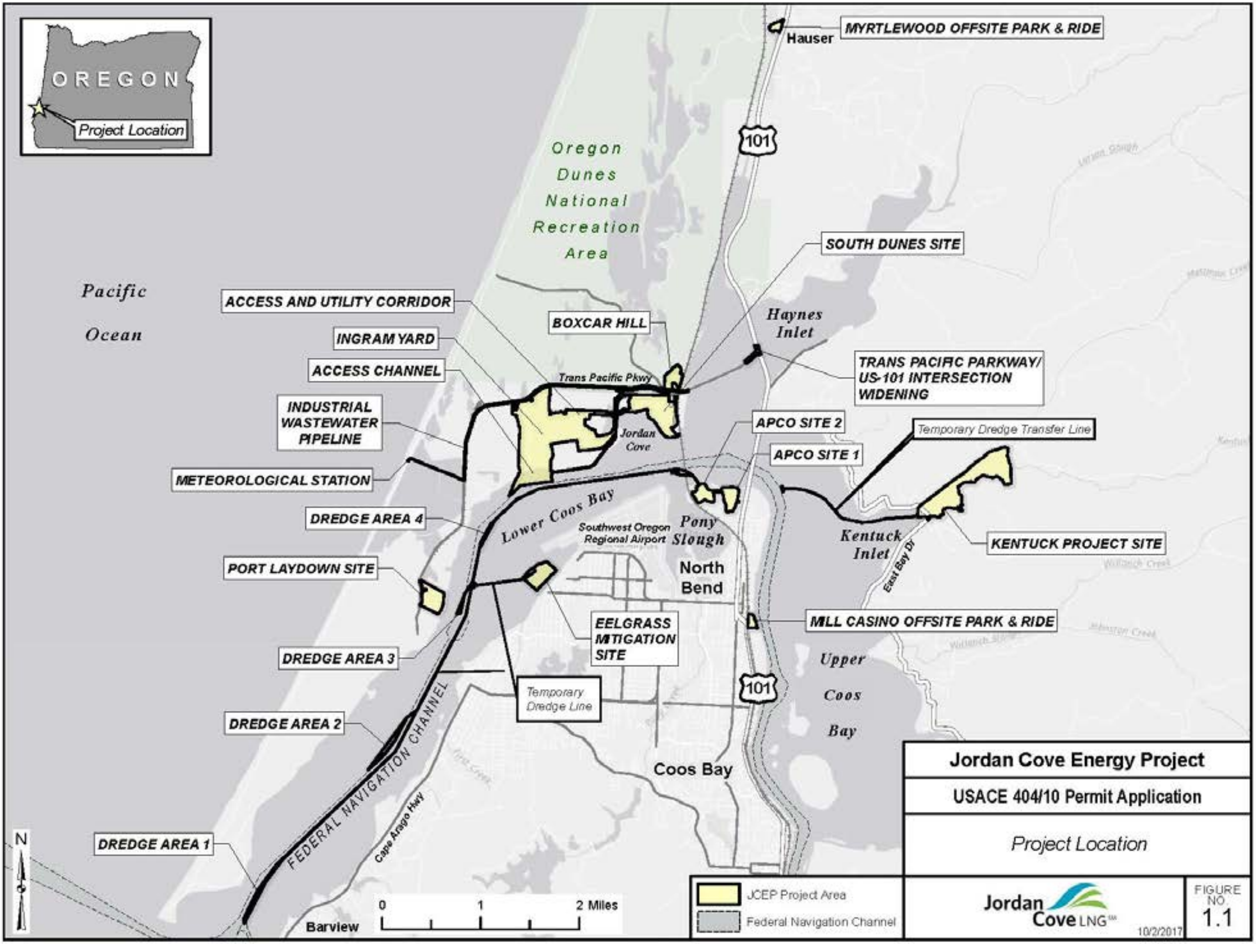



Elliott State Forest
North Bend
Coos Bay
Legend
Balance of County
Rural Residential
Urban Rural
Urban Rural - Multifamily
Residential Transition
Commercial
Rural Commercial
Industrial
Essential Farm Use
Forestry
Recreational
Bandon Dunes Resort
City Limits (UGB)
CBEMP Units
Natural Aquatic
Natural Shorelands
Conservation Aquatic
Conservation Shorelands
Rural Shorelands
South Slough NERR
Development Aquatic
Development
Urban Development
Urban Water Dependent
Water Dependent
Non-water Dependent
N
0
2
4
6
12 Miles


LNG Site Features, Dredge Areas, and Coos County 2019 Zoning
LNG western facilities lie in zone 6-WD, the eastern facilities in zone IND, and the roads in these two plus zone 7-D. The access channel lies primarily in zone 6-DA and slightly in zone 5-DA.
Dredge Area 4 abuts the shipping channel, zone DDNC-DA, and overlaps zone 52-NA.
Dredge Area 3 abuts the shipping channel, zone DDNC-DA, and overlaps zone 3-DA.
Dredge Area 2 abuts the shipping channel, zone DDNC-DA, and overlaps zone 2-NA.
Dredge Area 1 abuts the shipping channel, zone DDNC-DA, and overlaps zone 59-CA and, very slightly, zone CSDNC-DA.
IND
7-D
6-WD
6-DA
5-DA
52-NA
3-DA
DDNC-DA
2-NA
59-CA
CSDNC-DA

APPENDIX 11.E.

APPENDIX 11.F.



Jordan Cove LNG - Estuarine Habitats

APPENDIX 11.G.

Estuary Habitats

Classes based on the Coastal & Marine Ecological Classification Standard (CMECS)

- 2.2 - Faunal Bed
  - 2.2.1 - Attached Fauna
  - 2.2.2 - Soft Sediment Fauna
- 2.5 - Aquatic Bed
  - 2.5.1 - Benthic Macroalgae
  - 2.5.2 - Aquatic Vascular Vegetation
- 2.6 - Emergent Wetland
  - 2.6.1 - Emergent Tidal Marsh
- 2.7 - Scrub-Shrub Wetland
  - 2.7.1 - Tidal Scrub-Shrub Wetland
- 2.8 - Forested Wetland
  - 2.8.1 - Tidal Forest / Woodland

Coos Bay Estuary Plan Units

Estuary and surrounding Zones

Natural Management Units

- 10-NA
- 7-NA
- 52-NA
- 13A-NA

Jordan Cove LNG Facilities

Site Elements

Feature

- Slip
- Access Channel

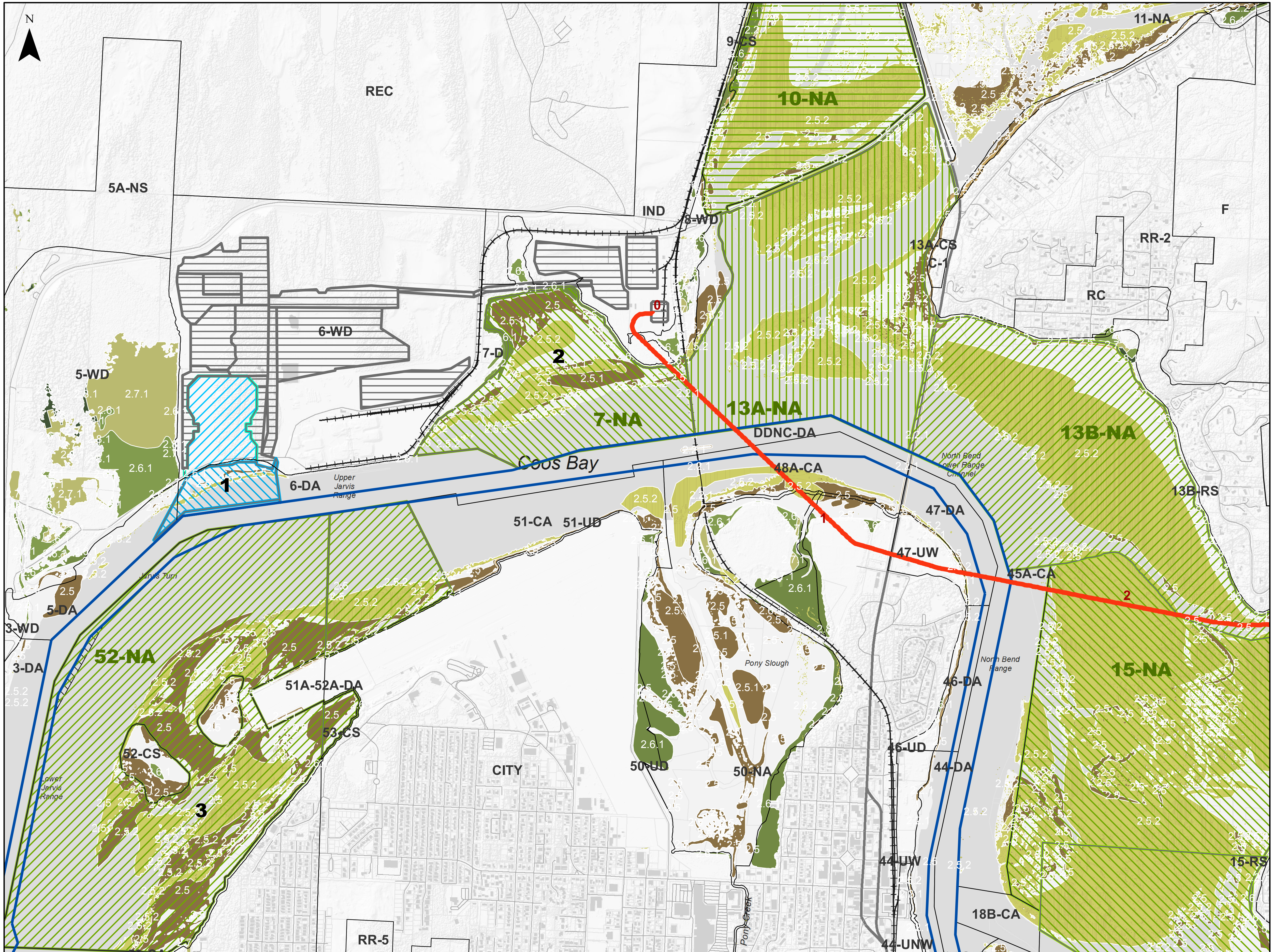
0 0.2 0.4 0.8 Miles

OCMP DLCD

Oregon Coastal Management Program, Department of Land Conservation & Development

Jordan Cove LNG - Estuarine Habitats

APPENDIX 11.H.



Estuarine Habitats

Classes based on the Coastal & Marine Ecological Classification Standard (CMECS)

- 2.2 - Faunal Bed
  - 2.2.1 - Attached Fauna
  - 2.2.2 - Soft Sediment Fauna
- 2.5 - Aquatic Bed
  - 2.5.1 - Benthic Macroalgae
  - 2.5.2 - Aquatic Vascular Vegetation
- 2.6 - Emergent Wetland
  - 2.6.1 - Emergent Tidal Marsh
- 2.7 - Scrub-Shrub Wetland
  - 2.7.1 - Tidal Scrub-Shrub Wetland
- 2.8 - Forested Wetland
  - 2.8.1 - Tidal Forest / Woodland

Coos Bay Estuary Plan Units

Estuary and surrounding Zones

Natural Management Units

- 15-NA
- 13B-NA
- 10-NA
- 7-NA
- 52-NA
- 13A-NA

Jordan Cove LNG Facilities

- Other Site Elements
- Slip
- Access Channel
- Pipeline
- Channel

Notes

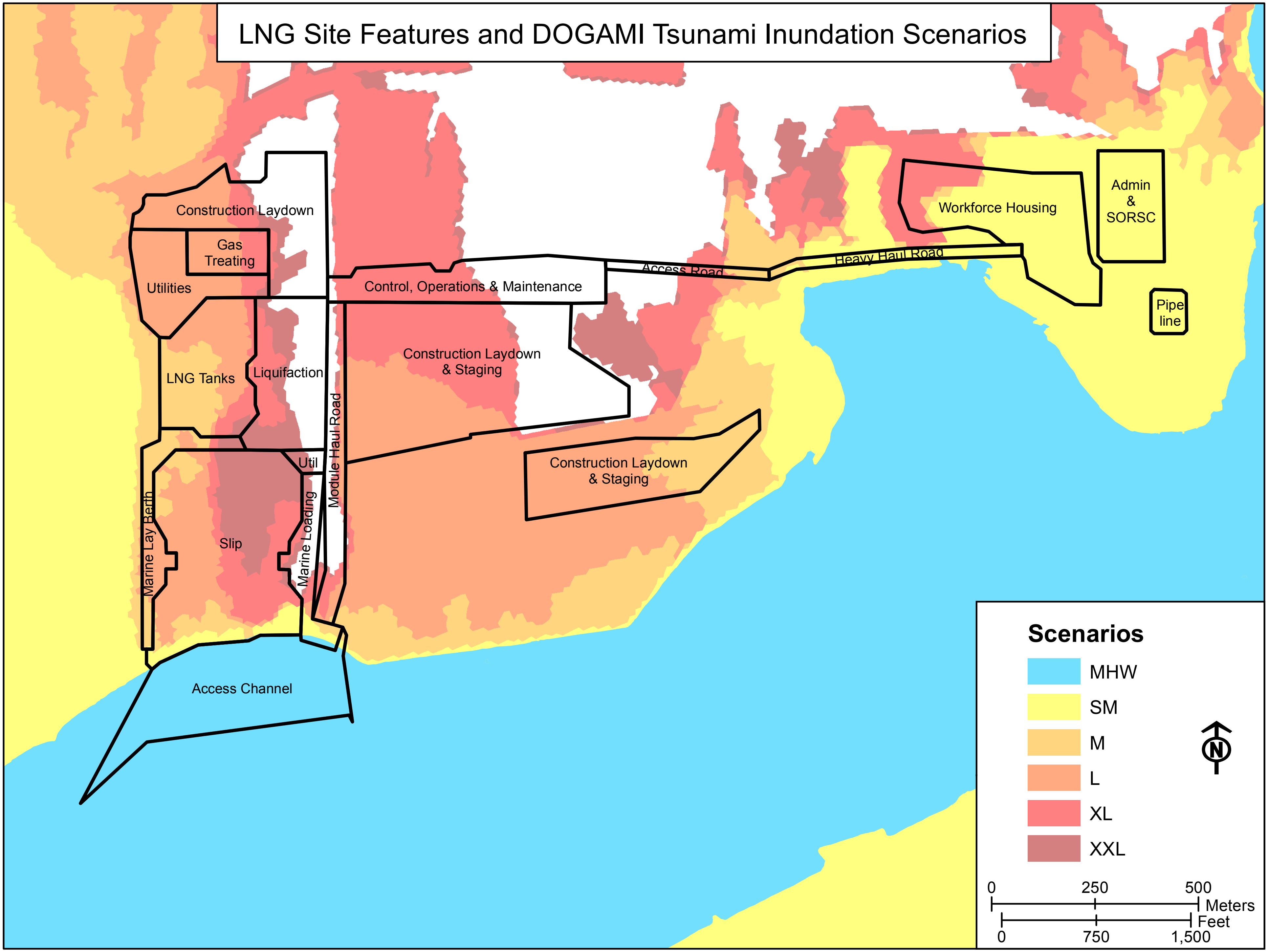
1 Existing eelgrass bed to be impacted
2 Salvage eelgrass bed to be created
3 Mitigation eelgrass bed to be created

0 0.2 0.4 0.8 Miles

OCMP DLCD

Oregon Coastal Management Program,
Department of Land Conservation & Development

APPENDIX 11.I.



APPENDIX 12.A

Code	Management Type	Area (ac.)
	Aquatic Units	
NA	Natural	8,928
CA	Conservation	2,700
DA	Development	1,639
	Aquatic Unit Totals	**13,267**
	Shoreland Units	
NS	Natural	762
CS	Conservation	1,737
RS	Rural Shorelands	4,037
	Sub-total	6,536
Development – Outside UGB		
D	Development	384
WD	Water Dependent	1,528
NWD	Non-water Dependent	52
	Sub-total	1,964
Development – Inside UGB or Urban Unincorporated Communities (UUC)		
UD & UDS	Urban Development	257
UW	Urban Water- dependent	514
UNW	Urban, Non-water	30
	Sub-total	801
	Shoreland Unit Totals	**9,301**

Uses that maintain the integrity of the estuarine ecosystem

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Water-dependent uses requiring estuarine location

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Water-related uses which do not degrade or reduce the natural estuarine resources and values

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Nondependent, nonrelated uses which do not alter, reduce or degrade estuarine resources and values

Source: DLCD. 2010.