Annex 2 **Letter from Natural Resources Canada to the Agency, March 15, 2016**

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March 15, 2016

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Re: Response to the Canadian Environmental Assessment Agency's March 2, 2016 Request for Advice on comments from the Lax Kw'alaams and Tsimshian Environmental Stewardship Authority for the Pacific Northwest LNG Project submitted in December, 2015

The attached submission represents Natural Resources Canada's (NRCan) continued efforts in support of a scientifically rigorous review process for the Pacific Northwest LNG Project focused on assessing the potential effects of the marine structures on hydrodynamics and sediment deposition, including potential impacts on Flora Bank. This submission also responds to the Canadian Environmental Assessment Agency's (CEAA) March 2, 2016 request for advice to inform the federal assessment and finalize the EA Report and proposed federal enforceable conditions. Specifically, CEAA requested whether NRCan has updates to our January 2016 advice (found on CEAA's public registry: http://www.ceaa.gc.ca/050/document-eng.cfm?document=104462) arising from consideration of the December 2015 submissions of the Lax Kw'alaams and the Tsimshian Environmental Stewardship Authority (TESA). CEAA also shared with us for information the March 2016 comments from the Lax Kw'alaams on the draft EA Report and proposed federal conditions.

NRCan is required under the *Canadian Environmental Assessment Act 2012* to provide specialist or expert information or knowledge to CEAA who is the Responsible Authority for the designated project. NRCan staff involved in the technical review have expertise in marine and coastal geology, sedimentology, sediment transport and marine geohazards.

NRCan's extensive involvement since December 2014 is witnessed through our participation in technical meetings with the Proponent, Aboriginal groups, and federal experts (most recently on March 4), as well as through our review of the various PNW LNG studies supporting the modeling work. As a result of several separate technical reviews by NRCan and Fisheries and Oceans Canada (DFO) scientists, the proponent's work evolved from the original 2D modelling study to a far more advanced and comprehensive 3D study, allowing for a better understanding of the potential effects of marine structures on site hydrodynamics, sediment transport and fish and fish habitat, including on Flora Bank.

NRCan's Review:

As part of their March 2 request for advice, CEAA asked NRCan and DFO to consider a number of questions related to the issues raised by the Lax Kw'alaams and TESA in their December 2015 submissions. NRCan's responses to the questions are found hereafter. NRCan's detailed review of materials in support of our responses to the questions can be found in Annex 1.

NRCan's Responses to CEAA's March 2 questions on the December 2015 submissions of the Lax Kw'alaams and TESA:

CEAA question #1: Concerns raised by McLaren and Davies regarding the inability of the model to explain observable sand grain sizes and bedforms on Flora Bank, as well as concerns regarding the accuracy of current speeds

NRCan response:

NRCan agrees with the opinions expressed by Dr. McLaren and Dr. Davies on behalf of the Lax Kw'alaams and TESA that the dominance of medium sand and occurrence of sand waves on Flora Bank are indicative of moderate to high energy conditions. The aerial photographs taken at low tide on Flora Bank and presented in McLaren's Reports (2015, 2016) provide new information on the occurrence of these sand waves, which are also referenced in the March 2016 Lax Kw'alaams submission to CEAA. NRCan is of the view that these photographs support the interpretation that the Bank hosts coarse sediments and that significant wave and tidal processes must be acting on the Bank.

NRCan also suggests that the characterization of the Bank as "low energy" is misleading when discussing sediment transport. As NRCan has commented in our review of the November 2015 3D Modeling Update Report, the Proponent predicted tidal currents up to 30-40 cm/s (pages K16 to K24) and storm currents up to 0.8 – 1 m/s (Fig. 5-3), which are sufficient to cause sediment transport and likely the development of sand waves. However, the Proponent also provides information to show that there would typically be dissipation of wave and current energy across the Bank and that sediment transport over much of the Bank would occur relatively infrequently due to this energy dissipation and periods of low tidal currents and very shallow water or exposure at low tide. Thus the Bank surface might in truth be characterized as high energy some of the time and low energy for the rest of the time. This understanding helps reconcile the views of the various experts who have commented and provided analysis on these issues (McLaren - Lax Kw'alaams December 2015 submission, Davies - TESA December 2015 submission and the Proponent's numerical modellers).

Similarly, the numerical model results are not completely inconsistent with the observation of bedforms on Flora Bank. The estimated velocity range for the formation of sand waves in medium to very coarse sand is 0.4 – 1.0 m/s (see Amos and King, 1984 and Ashley, 1990). The numerical model predicted storm-induced currents up to 1 m/s over Flora Bank at the peak of the 50-year storm (Fig. 5-3 on p. 57). Thus the model simulates conditions under which such bedforms could develop. However such conditions occur infrequently under the present simulations. NRCan notes that a detailed field examination of these bedforms has not been reported to date. In NRCan's view, such a study would permit more detailed analysis of the nature of sediment transport processes (e.g. asymmetry and migration of sand waves, the relative importance of tidal currents and waves in sediment transport and maintenance of Flora Bank). In addition, NRCan suggests that the proposed draft federal condition, based on our January 2016 advice to CEAA, to improve calibration of the numerical models will likely improve correspondence between model predictions and observations on grain size and bedforms

There is contrary information about the accuracy of model predictions of currents over Flora Bank. The Proponent's November 2015 Modeling Update Report shows that the model predicts tidal currents up to 30-40 cm/s for selected points on Flora Bank (Figs. K-14 to K-22). Comparison between model prediction and the Acoustic Doppler Current Profiler (ADCP) current data over Flora Bank collected in February 2015 by the Proponent shows that the measured currents range from 20 to 40 cm/s while the maximum of the model predicted currents is up to 20 cm/s. This would suggest that the model may under-predict tidal currents by 50%. If the model should predict tidal currents up to 40 cm/s, the magnitude and duration of sediment transport will increase. However, easterly transport during flood and westerly transport during ebb both will increase. In NRCan's view, the changes to the net transport would likely be small. This would suggest that the main conclusion that the construction of the marine structures will not cause significant loss of sand from the Flora Bank will not likely be changed.

CEAA question #2: Concerns regarding effects of the proposed Project infrastructure (construction and operations) on Flora Bank's stability

NRCan Response:

NRCan conducted a review of Dr.McLaren's (2015, 2016) Sediment Trend Analysis (STA) and the subsequent McLaren review of the Proponent's November 2015 Modeling Update Report. The STA analysis focusses on issues related to the origins of Flora Bank and the potential of adverse effects on the stability of Flora Bank from proposed developments.

In NRCan's view, the STA results (McLaren, 2015) are not quantitative in terms of actual rates of transport or in terms of any time scale, but they do provide an averaged general pattern of overall sediment movement in the area. NRCan agrees with the conclusions of the STA analysis that the sediments of Flora Bank are likely derived from in situ reworking of underlying glacial deposits and have not been transported onto the bank from surrounding channels.

However, in terms of Flora Bank stability, NRCan considers McLaren's conclusion of the "Great Escape" to be a hypothetical concept. McLaren suggests that the structure and/or berthed LNG carriers, will sufficiently reduce wave and tidal current energy to break the metaphorical "wall of energy" that holds the sand on Flora Bank in place. The hypothesis is based on an assertion that the net effects of the processes must be equal on both the NW and SE sides of the Bank in order to maintain its stability. This concept of a bi-directional equilibrium is somewhat simplified but implies that there must be a long term equilibrium in net sediment transport that retains sediment on the Bank. For Flora Bank's equilibrium to become unstable there would need to be a significant change of the net sediment transport direction so that sediment transport would diverge away from the Bank or net transport in one direction would be significantly increased or decreased. NRCan believes that this is not an inevitable consequence of a reduction in wave and/or tidal current energy. If the equilibrium is relatively stable, it would be possible for the energy to be reduced and for the net sediment transport to still remain approximately balanced. If the equilibrium is unstable, loss of sediment through sediment transport off the Bank would be a possibility. Results from the Proponent's November 2015 Modeling Update Report suggest that the equilibrium on Flora Bank is relative stable. Maps of the net transport flux for the 28 day freshet simulation for tide-dominant situation (Fig. 6-12) show that the magnitude and patterns of net transport with the marine structures did not change substantially from that of the existing conditions. The morphological changes for the 1-year simulation including all natural processes (Fig. 6-21 and Table 6-5) demonstrate insignificant changes in the seabed erosion/deposition patterns and a slight decrease in the net loss of sediment after the construction of the marine structures.

The Proponent's Delft-3D numerical model could be used to test the stability of the equilibrium by examining the threshold at which a reversal of net sediment transport direction would occur (if at all) and compare this to the expected change in processes due to the project. It might also provide some constraints on the rates of transport involved and on the feasibility of mitigation or adaptive management.

NRCan also reviewed the Lax Kw'alaams December 2015 review of the Proponent's November 2015 3D Modeling Update Report by Ian Townend who commented on long-term morphological changes resulting from Extreme Storms. Townend notes that even though the Proponent has done an enormous amount of additional modeling, it does not contribute in any substantive way to our understanding of the geomorphological stability of Flora Bank.

Townend observes that there has been a lot of additional work done on extreme storms by the Proponent and he points out that the work is useful as it now covers all directions of potential exposure (SSE, SW, W, and NW). Townend highlights that the modelling has been undertaken for a sustained event lasting 11 days, and such an event can be considered a hypothetical extreme (return periods of >1,000 years) and could be argued to be a (very) conservative estimate of impact. As such, Townend concludes that the results are fairly meaningless in terms of the actual impact within the context of long-term morphological change.

As recommended previously by NRCan, the erosion and depositional changes for extreme storms could be added to the morphological changes from the 1-year time series model runs to assess the possible maximum erosional and depositional changes. In this sense the results of the extreme storm modelling are useful. NRCan agrees with Townend that the Proponent could improve the analysis in this area by integrating the results of extreme storms with time series modelling of various durations to demonstrate how extreme storms impact the predictions of long-term morphological changes on Flora Bank.

CEAA question #3: How the presence of one or two LNG carriers at the marine berths could materially affect the model predictions of sediment movement on and off of Flora Bank

NRCan response:

In the December 2015 TESA submission, Dr. Davies and Dr. Isaacson recommended that further exploration of the possible effects of berthed vessels on waves and wind to verify whether this would have an impact on the morphology of Flora Bank.

In NRCan's view, qualitatively, the berthing of LNG ships could change (either increase or decrease) the local currents and reduce waves in the immediate areas around the ships. However, it is outside of the NRCan expertise to quantify these changes. NRCan notes that CEAA has proposed a draft federal condition (6.2) to consider the impact of two berthed LNG vessels in future modeling efforts prior to the start of in-water construction activities. If additional modeling efforts undertaken by the Proponent show significant effects to regional predictions of waves and currents, NRCan has the expertise to review the potential local and regional changes to sediment transport and morphology in the project area. It is also NRCan's understanding that the Proponent has discussed this issue with TESA and has commenced some preliminary analysis through a conceptual examination of ships at berth in the high resolution (MORPHO) model. The results of this analysis would be important for CEAA's consideration.

CEAA question #4: Concerns raised regarding the exclusion of the rock outcrops from the modelling efforts

NRCan Response:

In the December 2015 TESA submission, Dr.Davies observes the presence of rock outcrops at the southwest corner of Flora Bank and close to the ship berthing area and suggests the exclusion of these rock outcrops in the model may lead to incorrect assessment of hydrodynamics and sediment stability near the berthing area and may have affected the accuracy in the model's reproduction of physical processes over Flora Bank.

In NRCan's view, these features are very small compared to the modelled region. The rock outcrops may have some local influence on the wave, current and sediment transport processes but in NRCan's view, should not significantly affect the broad regional predictions for the entire Flora Bank area. If additional modeling efforts undertaken by the Proponent show significant effects to regional predictions of waves and currents, NRCan has the expertise to review the potential local and regional changes to sediment transport and morphology in the project area.

Conclusion:

NRCan's review points to the need for convergence between the McLaren hypothesis and the numerical model results to confidently predict the potential effects caused by the project marine structures. NRCan believes that both tools have contributions to make to the evaluation of project effects and that such a convergence would be possible particularly with additional collection of wave, current and suspended sediment data on Flora Bank leading to improved model calibration. This is consistent with our January 2016 advice to CEAA where we recommended collection of additional field data on Flora Bank, completion of modeling efforts using Flora Bank data for model calibration, and monitoring of morphological changes on Flora Bank to verify EA predictions. NRCan notes, that a number of draft CEAA conditions are aligned with this advice. In addition, NRCan notes that TESA has proposed conditions to CEAA that aligns well with NRCan's January 2016 advice (as presented by TESA during the March 4, 2016 meeting with Aboriginal groups and federal representatives). TESA's proposed condition would require the Proponent to conduct additional modeling using new field data collected on Flora Bank , and ensure using best available technology to monitor "real world response" to the project. The condition would require the Proponent to provide the results of future modeling to CEAA, DFO, NRCan and Aboriginal groups.

NRCan officials would like to acknowledge the ongoing efforts put forth in this review by federal scientists from Fisheries and Oceans Canada (DFO) and NRCan; Aboriginal groups and their technical representatives, CEAA staff and PNW LNG and their consultants.

Regards, Jessica

Original signed by

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Annex 1: NRCan's review of comments from the Lax Kw'alaams and Tsimshian Environmental Stewardship Authority for the Pacific Northwest LNG Project submitted in December, 2015

Part 1: NRCan comments related to the stability, wave and surficial characteristics of Flora Bank

For part 1 of NRCan's submission, NRCan reviewed: 1) the December 15, 2015 report by PGL Consultants to the Tsimshian Environmental Stewardship Authority (TESA); 2) the December 3, 2015 report by Patrick McLaren, SedTrend Analysis Limited, for the Lax Kw'alaams Band and the Skeena Fisheries Commission; 3) the January 2016 scientific article published by McLaren in Journal of Coastal Research.

SUMMARY OF REPORTS

1) December 15 report by PGL Consultants to the Tsimshian Environmental Stewardship Authority (TESA):

The report from PGL Environment Consultants (2015) was developed in consultation with experts in coastal engineering and defines some issues related to the stability of Flora Bank and, in particular, in respect to the findings within the Sediment Trend Analysis undertaken by Dr. P. McLaren (2015). The key points raised in the PGL report are:

1. Sand wave or subaqueous dunes occur on Flora Bank and align with the key tidal flow patterns and do not represent drainage features.
2. The coarse well-sorted clean sand and sand waves that occur on Flora Bank suggest that current velocities must be over 30 cm/s regularly, otherwise finer sediments would be present.
3. The sediment transport patterns predicted from Flora Bank by the 3D model do not agree with the apparently stable geometry of the bank as it exists today. Dr. M. Davies argues that, if this balance of sediment transport is not correctly reproduced in the model, then the model will be unable to predict the effects of changes to this balance that occur when the marine terminal facilities are constructed. If the present balance is not properly understood, then we are not yet able to properly understand the effects of changes to that balance.
4. The sedimentary bedforms clearly seen on Flora Bank suggest a dynamic sediment environment with flow conditions generally well in excess of the sediment transport threshold. Evidence suggests that Flora Bank has been stable over the past century without any obvious gain or loss in size. For this to be the case, the back and forth movements of sediments caused by waves and/or tidal currents, must be balanced.

The report concludes that when contradictions around various lines of evidence occur they are generally resolved through collection of real-world data that can be used to verify and calibrate the model. The report by Dr. Davies notes that while some real-world data was used to calibrate the model, this data was recorded in channels adjacent to Flora Bank rather than on Flora Bank itself. Best practices for impact assessment suggest that further work should be done to increase confidence in the predictions of impact.

2) Dec 3 2015 report by Patrick McLaren, SedTrend Analysis Limited for the Lax Kw'alaams Band and the Skeena Fisheries Commission entitled "An assessment of the "Supplemental Report for 3D Modelling Update" prepared by Hatch for PNWLNG, November 10, 2015".

This report provides further arguments on the results and proposed implications of the STA analysis. Key points include:

1. The surface of Flora Bank contains the coarsest and most well-sorted sand found throughout the whole of the Prince Rupert marine and coastal region. Its grain-size distribution is unique in that all sizes smaller than 3.0 phi (0.125 mm) are essentially absent. If sand has not been transported onto Flora Bank, it must have formed in situ or be a remnant from a pre-existing environment.
2. Virtually the entire surface of Flora Bank is covered with sand waves. Although no detailed analyses have been made, rough measurements from vertical mosaics show the wave lengths in each of these fields to be extremely regular. The considerable literature on sand wave formation shows that, for the range of grain sizes on Flora Bank, currents must be from 2 to 6 times larger than the 30 cm/sec currents, that is the threshold for the movement of Flora Bank.
3. Neither the STA nor the modeling have resolved the paradoxical nature of Flora Bank; namely, if the energy of the processes are so low that they cannot move the coarse sand off the bank, how do the sediments remain the coarsest and best sorted of sandy sediment found throughout the entire Prince Rupert area?
4. From the STA it was concluded that high energy process events must not only be responsible for maintaining the coarse and well-sorted sediment, but they are also instrumental in creating the barrier necessary to keep the sand on the bank rather than being lost to the offshore waters.

The report does conclude that as a kinematic model, the STA is unable to analyze the specific nature of processes responsible for sediment transport.

3) January 2016 scientific article published in the Journal of Coastal Research (McLaren 2016).

In this article, McLaren reprises the information presented in his original January 3 2015 report for the Lax Kw'alaams (A Sediment Trend Analysis (STA®) of Prince Rupert Harbour and its Surrounding Waters) and in report 2) above. The peer-reviewed paper includes sections on the origin and dynamics of Flora Bank and predicted fate of Flora Bank based on STA results.

The author provides a theoretical concept of how sediment processes may change if facilities are built adjacent to the bank, but provides no data to support or refute the concept. The key prediction in this paper based on this concept is that "in order for Flora Bank sand to remain in place, the net effect of the processes (i.e. the energy produced by the combined action of tidal, river, wave, and wind-driven currents) must be equal on both the NW and SE sides of the bank. If this were not so, the sand would be unable to remain and Flora Bank, as it is seen today, would not exist. For this reason, it is believed that a reduction of energy along any portion of the perimeter of the bank caused by the pilings obstructing the currents (regardless of which process or combination of processes are responsible for generating the currents) will result in an inability for the sand to continue being held in place".

Part 1 - NRCAN REVIEW COMMENTS:

These review comments supplement comments previously submitted to CEAA by NRCan in February 2015.

1. The STA results (McLaren, 2015) are not quantitative in terms of actual rates of transport or in terms of any time scale, but they do provide an averaged general pattern of overall sediment movement in the area. NRCan agrees with the conclusions of the STA analysis that the sediments of Flora Bank are likely derived from in situ reworking of underlying glacial deposits and have not been transported onto the bank from surrounding channels. Aerial photographs taken at low tide on Flora Bank and presented in reports 2) and 3) provide new information on the occurrence of sand waves. NRCan agrees that these photographs support the interpretation that the bank hosts coarse sediments and that significant wave and tidal processes must be acting on the bank. We note that a detailed field examination of these bedforms has not been reported to date. Such a study would permit more detailed analysis of the nature of sediment transport processes (e.g. whether tidal currents, waves or both combined play a role in sediment transport and maintenance of Flora Bank).

2. NRCan considers the "Great Escape" to be a hypothetical concept. McLaren suggests that the structure and/or berthed LNG carriers, will sufficiently reduce wave and tidal current energy to break the metaphorical "wall of energy" that holds the sand on Flora Bank in place. The hypothesis is based on an assertion that the net effects of the processes must be equal on both the NW and SE sides of the bank in order to maintain stability of the bank. This concept of a bi-directional equilibrium is somewhat simplified but implies that there must be a long term equilibrium in net sediment transport that retains sediment on the bank. For the bank equilibrium to become unstable there would need to be a significant change of the net sediment transport direction so that sediment transport would diverge away from the bank or net transport in one direction would be significantly increased or decreased. NRCan believes that this is not an inevitable consequence of a reduction in wave and/or tidal current energy. If the equilibrium is relatively stable, it would be possible for the energy to be reduced and for the net sediment transport to remain approximately balanced. If the equilibrium is unstable, loss of sediment through sediment transport off the bank would be a possibility. The Delft-3D numerical model could be used to test the stability of the equilibrium by examining the threshold at which a reversal of net sediment transport direction would occur (if at all) and compare this to the expected change in processes due to the project. It might also provide some constraints on the rates of transport involved and on the feasibility of mitigation or adaptive management.

3. The above comments and those provided by the experts in the three reports point to the need for convergence between the McLaren hypothesis and the numerical model results.

NRCan believes that both tools have contributions to make to the evaluation of project effects and that such a convergence would be possible particularly with ongoing wave and current data collection on Flora Bank leading to improved model calibration. The following comments attempt to indicate two areas of convergence.

- With regard to concerns raised by McLaren and Davies regarding the inability of the model to explain observable sand grain sizes and bedforms on Flora Bank, some of the disagreement about whether the bank surface is a low or high energy environment may be more semantic than real. NRCan agrees that the Proponent report is incorrect to suggest that the STA results support the finding that the Flora bank is a low energy environment. They do not. We would also suggest that the characterization of the bank as "low energy" is misleading when discussing sediment transport. As NRCan has commented, in our review of the November 2015 report, the Proponent report predicts tidal currents up to 30-40 cm/s (pages K16 to K24) and storm currents up to 0.8 – 1 m/s (Fig. 5-3), which are sufficient to cause sediment transport. However, the Proponent also provides information to show that there would typically be dissipation of wave and current energy across the bank and that sediment transport over much of the bank would occur relatively infrequently due to this energy dissipation combined with periods of very shallow water or exposure at low tide. Thus the bank surface might in truth be characterized as high energy some of the time and low energy for the rest of the time. This understanding helps reconcile the views of McLaren, Davies and the numerical modellers.

- Similarly, the numerical model results are not completely inconsistent with the observation of bedforms on Flora Bank. The estimated velocity range for the formation of sand waves in medium to very coarse sand is 0.4 – 1.0 m/s (see Amos and King, 1984 and Ashley, 1990). The numerical model predicted storm-induced currents up to 1 m/s over Flora Bank at the peak of the 50-year storm (Fig. 5-3 on p. 57). Thus the model simulates conditions under which such bedforms could develop. However such conditions occur infrequently under the present simulations as explained above. NRCan suggests that the proposed CEAA condition to improve calibration of the numerical model will likely improve correspondence between model predictions and observations on grain size and bedforms.

References

Amos, C.L., and King, E.L. 1984. Bedforms of the Canadian eastern seaboard: A comparison with global occurrences. Marine Geology, 57, 167-208.

Ashley, G.M., 1990. Classification of large-scale subaqueous bedforms: a new look at an old problem. Journal of Sedimentary Petrology,60, 160–172.

McLaren, P., 2015. A Sediment Trend Analysis (STA®) of Prince Rupert Harbour and its surrounding waters. Report Prepared For the Lax Kw'alaams Band, 32 p.

McLaren, P., 2015. An Assessment of the "Supplemental Report for 3D Modelling Update" Prepared by Hatch for PNW LNG, November 10, 2015. Prepared for the Lax Kw'alaams Band and the Skeena Fisheries Commission in support of CEAA's request for updated advice from Aboriginal groups. 10p.

McLaren, P. 2016. The environmental implications of sediment transport in the waters of Prince Rupert, British Columbia, Canada: A comparison between Kinematic and Dynamic approaches. Journal of Coastal Research, in press.

Part 2: NRCan comments related to the review by third parties of the Proponent's November 2015 3D Modeling Update Report.

For Part 2, NRCan reviewed the following documents: 1. An Assessment of the "Supplemental Report for 3D Modelling Update" (McLaren Report, Dec 3, 2015) 2. Expert Review – Pacific Northwest LNG Supplemental Modelling Report, PGL Environmental Consultants, Dec. 15, 2015 (PGL Report) 3. Coastal Science & Engineering Applications Review of Supplemental Modelling Report (Townend Report, Dec 17, 2015)

1. **Review of "An assessment of the "Supplemental Report for 3D Modelling Update" prepared by Hatch for PNWLNG, November 10, 2015". (McLaren Report, Dec 3, 2015)**

This report provides further arguments on the results and proposed implications of the STA analysis. Key points include:

1. Medium sand grain size and energy level on Flora Bank:
One of the main objections of the McLaren report is that the STA is a kinematic model and is unable to analyze the specific nature of processes responsible for sediment transport, and for this reason the Proponent's November 10 report was incorrect to suggest that the STA results support the low energy findings of the dynamic model.

While NRCan agrees with the McLaren Report that the Proponent report should not cite the STA results to support the low energy finding, this will not significantly change the overall conclusions by NRCan as the Proponent's Report provided adequate information to support their key conclusion points (p. xii of the November 2015 Modeling Update Report). The report shows evidence of gradual dissipation of waves for the 50-year storm and the gradual dissipation of waves and tidal currents during the modelled October 2012 storm. Tidal currents for the freshet period demonstrate the low to moderate energy for tide-dominant conditions. The wave and storm-induced currents for the 50-year storm presented in the report demonstrate high energy during storms. The sediment transport for the freshet period under tide dominant conditions and the analysis of sediment transport frequency show episodic sediment transport. The report also presents low levels of net transport evidenced for the 50-year storm, for the freshet period and for the natural storm of October 2012. As NRCan has commented in our review of the Proponent's November 2015 Report, it is likely inappropriate that the Proponent classifies the conditions on Flora Bank as "low energy" as the Proponent actually predicts tidal currents up to 30-40 cm/s and storm currents up to 0.8 – 1 m/s over Flora Bank.

2. The second key point of the McLaren report was that the presence of sand waves on Flora Bank indicates high energy and that the patterns of sand wave fields suggest that the east side is influenced by strong ebb currents while the west side is strongly wave affected.

If the large-scale features are sand waves, then the statement of currents must be 2 to 6 times larger than the 30 cm/sec currents for the occurrence of the sand waves was essentially correct. However, the upper limit of 1.8 m/s may be too high because the estimated velocity range for the formation of sand waves in medium to very coarse sand should be 0.4 – 1.0 m/s (e.g. Amos and King, 1984; Ashley, 1990). The performance of the flow model on Flora Bank could not be evaluated at the time the November 2015 report was reviewed due to the lack of measured current data over Flora Bank. However, the flow model was shown to adequately predict tidal currents up to 1.2 m/s in the Porpoise Channel and that the model also predicted storm-induced currents up to 1 m/s over Flora Bank at the peak of the 50-year storm. It is thus appropriate to suggest that Flora Bank could be episodically under moderate and high energy. In theory the sand waves could be developed under the strong storm-induced currents. NRCan is not aware of any analysis of the asymmetry and/or net migration direction of the sand waves. Without the information of the asymmetry and/or net migration of the sand waves, it is premature to conclude that sand waves on the east side of Flora Bank are influenced by strong ebb currents while those on the west side are strongly wave affected. Therefore it is not realistic to expect that the Proponent could use the numerical model results to determine whether the transport regimes on the east and west sides of the bank are respectively dominated by ebb currents and waves.

3. The Conclusion re-emphasizes two key concerns, (1) Both the kinematic approach of the STA and the observations of sand waves demand that the current velocities occurring over the bank must be stronger and more frequent than the values determined by the model; and (2) Unless the model can provide a better understanding of how the processes are actually interacting to hold the sand in place, including an assessment of how the tidal vs. wave dominance affect the sand transport regimes on each side of the bank, the risk of losing the sand from Flora Bank appears to be far greater than the "no harmful effects" conclusion purported by the model.

NRCan assessment indicates that although the model prediction of currents has not been calibrated with measured data over Flora Bank, the model actually predicted tidal currents up to 30-40 cm/s which agree with the ADCP data over Flora Bank which was collected by the Proponent and recently shown in the TESA presentation during the March 4 meeting. The model also predicted storm-induced currents up to 1 m/s (Fig. 5-3) during extreme storms. Thus it is not unrealistic to suggest that the model could predict currents greater than 30 cm/s on Flora Bank.

Although the November 2015 report did not specifically address the issue how the processes are interacting to hold the sand in place over Flora Bank, NRCan's opinion is that some results presented in the Report could potentially be used to qualitatively address this issue. The net transport during the modelled freshet period dominated by tidal processes is to the northwest. The net transport is to the southeast during the 50-year storm that approaches from the west. It is thus feasible that these opposing net transport directions could strike a balance so that the amount of net transport to the southeast due to storms approaching from the west could be approximately equal to the amount of net transport to the northwest due to tidal currents over the long term so that the sand will be held in place on the Flora Bank. For the bank equilibrium to become unstable there would need to be a significant change of the net sediment transport direction so that sediment transport would diverge away from the bank or net transport in one direction would be significantly increased or decreased. Results from the Proponent's November 2015 Report do not suggest this is the case. Maps of the net transport flux for the 28 day freshet simulation for tide-dominant situation show that the magnitude and patterns of net transport with the marine structures did not change substantially from that of the existing conditions. The morphological changes for the 1-year simulation including all natural processes demonstrate insignificant changes in the seabed erosion and deposition patterns and that the net loss of sediment was slightly reduced after the construction of the marine structures. All these suggest that the proposed structures will not significantly alter the net transport conditions on Flora Bank and that the risk of significant loss of sand from Flora Bank is low.

References:

Amos, C.L., King, E.L., 1984. Bedforms of the Canadian eastern seaboard: A comparison with global occurrences. Mar. Geol. 57, 167–208.

Ashley, G., 1990. Classification of large-scale subaqueous bedforms: a new look at an old problem. J. Sediment. Petrol. 60, 160–172.

2. Review of December 2015 report by PGL Consultants to the Tsimshian Environmental Stewardship Authority (TESA):

The report from PGL Environment Consultants (2015) was developed in consultation with experts (e.g. Isaacson, Davies) in coastal engineering and defines some issues related to the stability of Flora Bank and, in particular, in respect to the findings within the Sediment Trend Analysis undertaken by Dr. P. McLaren (2015). The key points raised in the PGL report are:

1. The Delft3d model is a good tool for predicting effects associated with the Project and current data measured over Flora Bank could have been used to better calibrate the model prediction.

   NRCan agrees with these comments. Although measured wave and current data in areas around the Flora Bank were used to adequately calibrate the models, NRCan repeatedly commented in previous submissions that field data of waves, currents, and sediment transport collected over the Flora Bank would help to better calibrate the models.

2. Dr. Davies' findings indicate that the earlier 2-D model appears to indicate currents stronger than the threshold of sediment motion and thus suggests active sediment transport occurs over Flora Bank.

   NRCan's view is that this is not an issue as the 3-D model used in the November 2015 Report did predict low to moderate sediment transport under tide-dominant conditions.

3. Dr. Davies noted the presence of rock outcrops at the southwest corner of Flora Bank and suggested the exclusion of these rock outcrops in the model likely affected the accuracies in the model's reproduction of physical processes over Flora Bank.

   NRCan's opinion is that these features are very small relative to the modelled region and any effects will be local and thus should not significantly affect the broad regional predictions over the entire Flora Bank.

4. Dr. Davies' findings indicate the construction of the proposed structures will result in reduction of sediment transport by 20 to 40%; and given that the model likely under-predicts sediment transport, the actual effects of the Project may be even larger.

NRCan's opinion on this is that the Proponent's reports demonstrate that the project will reduce both the erosion and accretion volumes from the existing conditions which should enhance the stability of the Flora Bank. The more important values are the net volume changes over the bank. Table 6-5 for the 1-year simulation shows that the Flora Bank is losing 28000 m^3 sediments per year under the existing conditions while that value decreases to 25000 m^3 after the project construction. Therefore the construction of the proposed structures slightly reduces the net loss of sands and hence improves the stability of the Flora Bank.

5. The Proponent's report shows a consistent pattern of sediment moving from the western edge of Flora Bank toward the center of the bank. None of the simulations showed a reverse scenario where material moves from the centre of the Bank to the western edge of the Bank. As a result, sediment transport patterns from the model do not agree with the apparently stable geometry of the bank as it exists today. Dr. Davies suspects that this is because the tidal currents predicted by the Delft3D model are too small to move the sand on Flora Bank. This may lead to the opinion that if this balance of sediment transport is not correctly reproduced in the model, then the model will be unable to predict the effects to this balance by the changes that could occur due to the proposed structures.

   NRCan would like to highlight that the strongest storms in the project area come from the southeast and these storms would produce the reverse scenario where sediments will be transported from southeastern and central parts of the bank and be deposited on the northwestern part of the bank. This reversed pattern is demonstrated in the modelled seabed changes for the 20-year storm approaching from 170 degrees and for the 50-year storm approaching from 170 degrees (Appendix H of the November 2015 Report).

   Some results presented in the proponent's report are contrary to the notion that the tidal currents predicted by the Delft3D model are too small to move the sand on Flora Bank. For example, the model predicts tidal currents up to 30-40 cm/s for selected points on Flora Bank and episodic sand transport for these points. Also low to moderate total transport and net transport to the northwest were predicted for the freshet period under tide-dominant conditions.

   Recently ADCP current data along transects on Flora Bank collected on September 21, 2013 and on February22, 2015 became available and the data were compared with model predictions. The data collected in September 2013 show current speeds ranging from 5-30 cm/s. These are slightly lower or comparable with the model predicted tidal currents on Flora Bank. The February 2015 ADCP data show measured currents range from 20 to 40 cm/s while the model predicted maximum currents are up to 20 cm/s.. It is thus likely that the model under-predicted tidal currents by 50% based on this single ADCP transect data. If the model would predict tidal currents up to 40 cm/s, the magnitude and duration of sediment transport will increase. However, the reversal of flood and ebb flow direction means that easterly transport during flood and westerly transport during ebb both will increase. In NRCan's view, the changes to the net transport thus will be small.

   Thus the above point would suggest that the main conclusion that the marine structure will not cause significant loss of sand from the Flora Bank will not likely be changed.

3. NRCan Comments on Coastal Science & Engineering Applications Review of Supplemental Modelling Report (Townend Report, Dec 17, 2015)

Summarized below are the key points raised by Townend in his assessment of the Proponent's report entitled "*Pacific Northwest LNG, 3D modelling Update, Supplemental Modelling Report, 16/9/15, Rev C*"

1. Townend commented that the report does not contribute significant new knowledge to our understanding of the geomorphological stability of Flora Bank.

Townend noted that it is unclear just what is being reported regarding the long-term morphological changes. The Townend report questioned that the September 2015 report does not add to the understanding of the morphology of Flora Bank already provided by the May 2015 modelling report since it does not relate the new modelling to the previous modelling.

NRCan's review suggests that the following differences from the May 2015 report add to the understanding of the geomorphological stability of Flora Bank:

- May 2015 report used the weekly base method while the September, 2015 and November 10, 2015 reports used hourly time series wind and wave data. This improved methodology ensured that the models adequately simulate the real physical processes and the maximum magnitude of the tides and storms.
- Erosion and deposition volume changes were presented for several key modelled cases. These include the 50-year extreme storm (Sections 5.1 and 6.1), 3 month of stormy period (sections 5.3.4.1 and 6.1.4.1), 4 month of calm period (sections 5.3.4.1and 6.1.4.2), and 1 year time series simulation (sections 5.3.4.3 and 6.1.4.3).
- The time series and maximum values of sediment-transport related parameters such as suspended sediment concentration, sediment transport flux and net sediment transport flux, are needed to substantiate the predictions of long-term morphological changes. The May report was not consistent in presenting these types of results for key modelled cases. The November report consistently presented this information for several modelling cases: (i) the 50-year extreme storm (Sections 5.1 and 6.1), (ii) the freshet simulations (sections 5.2 and 6.1.3), and (iii) the total-load transport flux and net transport flux for the Oct 2012 natural storm (Appendix H) and impact on total suspended solids for the 3-month stormy period (Appendix H).

2. Extreme storms and relevance of results to long-term morphological changes:

The Townend report states that there has also been a lot of additional work done on extreme storms (Appendix G). This is useful as the work now covers all directions of potential exposure (SSE, SW, W, and NW). However the modelling has been undertaken for a sustained event lasting 11 days, although the logic behind this selection is not made clear. Such an event can be considered a hypothetical extreme (return periods of >1,000 years) and so could be argued to be a (very) conservative estimate of impact. As such, the results are fairly meaningless in terms of the actual impact within the context of long-term morphological change.

NRCan believes that erosion and depositional changes for extreme storms could be added to the morphological changes from the 1-year time series model runs to assess the possible maximum erosional and depositional changes. In this sense the results of the extreme storm modelling are not meaningless. NRCan agrees with the Townend report that the Proponents could do a better job to integrate the results of extreme storms with time series modelling of various durations to demonstrate how extreme storms impact the predictions of long-term morphological changes on Flora Bank.

3. Different results of sediment mobility calculations:

The Townend report states that the work presented in Chapter 3 making use of Sedtrans05 would be more useful than the sediment mobility analysis results presented in Appendix K. Mr. Townend ran the same model using some “representative” conditions. The Townend report suggests that their results presented in the Appendix provide a rather different picture to the one suggested by Table 3-1 of the Proponent’s 2015 September report. The 2015 September report suggests that there is only a short period of transport (around 20% of the time) regardless of grain size. In contrast, the results in Appendix A of the Townend report suggest that a sediment grain size of 0.35mm is transported much more frequently.

In NRCan’s view, the methods used in the September 2015 report and the Townend report were different and thus the results would be different. The Proponent’s September 2015 Report compared the instantaneous currents through tidal cycles, which vary from zero to peak speeds of ~30 cm/s in a flood-ebb tidal cycle (~12 hours), with the threshold velocity for medium sand (median grain size 0.35 mm) to assess the frequency and magnitude of total transport over the 28-day freshet simulation (Fig. 3-22 and Table 3-1). The Proponent’s results suggest that transport only occurs near the peaks of flood and ebb when tidal currents are the strongest. The Townend report, however, used constant peak tidal currents of 20 or 30 cm/s to compare with the threshold velocity. Therefore the Appendix A of the Townend report shows much higher frequency of sediment transport. NRCan’s opinion is that the results and approach of the Proponent’s September 2015 Report are more realistic. The Townend report was correct in stating that the fine sediment should be far more likely to be transported than the coarser fraction.