APPENDIX 52A LETTER FROM TETRA TECH EBA – JULY 7, 2015

TETRA TECH EBA

OQM | Organizational Quality Management Program

July 7, 2015

ISSUED FOR REVIEW
FILE: 704-V13203022
Via Email: Bikramjit_Kanjilal@transmountain.com

Trans Mountain Pipeline ULC
2844 Bainbridge Avenue
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Attention: Mr. Bikramjit Kanjilal

Dear Mr. Kanjilal,

Subject: Hearing Order OH-001-2014
Trans Mountain Pipeline ULC (Trans Mountain)
Application for the Trans Mountain Expansion Project (Project)
Name of Intervenor: David M. Farmer
Response by Trans Mountain

Dear Mr. Kanjilal,

The Intervenor, Dr. Farmer, is concerned that Trans Mountain has not adequately addressed the hydrodynamics in the Boundary Pass/Haro Strait region, especially the potential for subduction of floating oil in the presence of tidal fronts. Tetra Tech EBA Inc. (Tetra Tech) believes that the work presented in the Application has addressed the hydrodynamics adequately, as outlined below. For clarity, Trans Mountain's response is divided into the same section headings as the Intervenor's submission.

1.0 INTRODUCTION

Observations and opinions expressed by the Intervenor in this section will be addressed in the following sections, where they are described in more detail by the Intervenor.

2.0 TIDAL FRONTS IN BOUNDARY PASS AND HARO STRAIT

This section is concerned with a front that forms during flood tides at the eastern end of Boundary Pass where it joins onto the southern Strait of Georgia. The Intervenor notes that this front is attached to the shallow sill extending eastward from the eastern end of Saturna Island, as shown in Figure 1 of the Intervenor's Submission. The discussion in the Evidence is based largely on a paper by Baschek, Farmer and Garrett (2006), provided as an Appendix to the Intervenor's Evidence.

With respect to Figure 2 of the Evidence, there is the appearance of the lighter grey-shaded water sitting in place as a solid body, with the flooding tide plunging underneath it. It understood that this sketch is based on observational data shown in Figure 5 of the Appendix (shown below), where one does indeed note that the strong flooding water are generally attached to the bottom on the lee side of the sill, and a deep, fast current characterizes the bottom 50-m or so of the water column. Currents above 100-m depth are much slower, and in fact, there is a large depth range over which they flow upstream, in an ebb direction. Currents in the top 40-m generally maintain a flood direction.

The authors of the Appendix, for instance in the Abstract, postulate that this frontal circulation feature is responsible for large amounts of mixing. It is difficult to square this with Figure 2 from the Appendix (shown below), which shows the oxygen distribution in a longitudinal section through the Salish Sea. A tongue of oxygen-rich water is evident northward (to the right of) Boundary Pass, at a depth of about 100 m, as if the surface waters

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coming from Boundary Pass were bodily entrained into a mid-depth flow. Oxygen levels in this tongue of water are similar to surface oxygen levels in Boundary Pass, indicating that little mixing of these waters occurs as they enter the Strait of Georgia, since such mixing would change oxygen levels. The Appendix also reports that the amount of air entrained at the front could only increase the oxygen content of the water containing bubbles by 4.6 × 10^{-3} mL/L, or less than about 1/1000th of the oxygen level in the mid-depth tongue shown in Figure 2 of the Appendix with a value of about 5 mL/L. From these considerations, one can infer that the mechanism to transfer air bubbles generated at the water surface by wave breaking into the descending flow in Figure 5 is weak, and the appearance of the tongue is simply related to advection of surface waters in Boundary Pass, including the descent along the northern side of the sill as the flood tide enters the Strait of Georgia.

Furthermore, if one examines Figure 6 of Appendix A (shown below), one notes that in the top panel, showing the along-strait current, that there is no reversal of flow at the surface, in agreement with Figure 5. So, while some water may move downward, some carries onward at the surface. This observation argues against the concept of a conveyor belt-like system that carries all surface water down to depths of 50-100 m, as Figure 2 of the Evidence implies.

The three figures below (Figures 2, 5 and 6) are extracted from the Evidence's Appendix A.

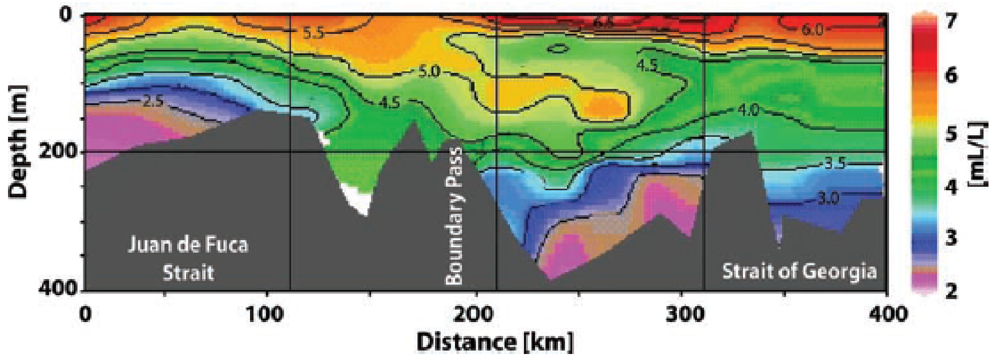

Figure 2. Oxygen section along the Fraser Estuary in July 2000 (D. Masson, IOS, Sidney, Canada). The Pacific Ocean is to the left, the Strait of Georgia to the right, and the sill at Boundary Pass at $x = 180$ km.

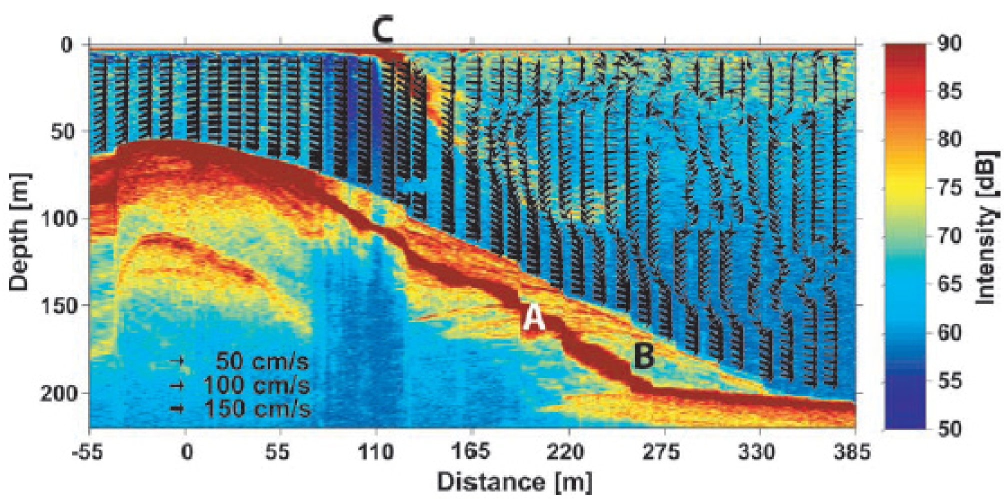

Figure 5. Flow over the sill at Boundary Pass during strong forcing on September 29, 2000. The colors show the acoustic backscatter intensity measured with an echo sounder and the black arrows indicate the current speed perpendicular to the sill crest. The aspect ratio is 1:1.

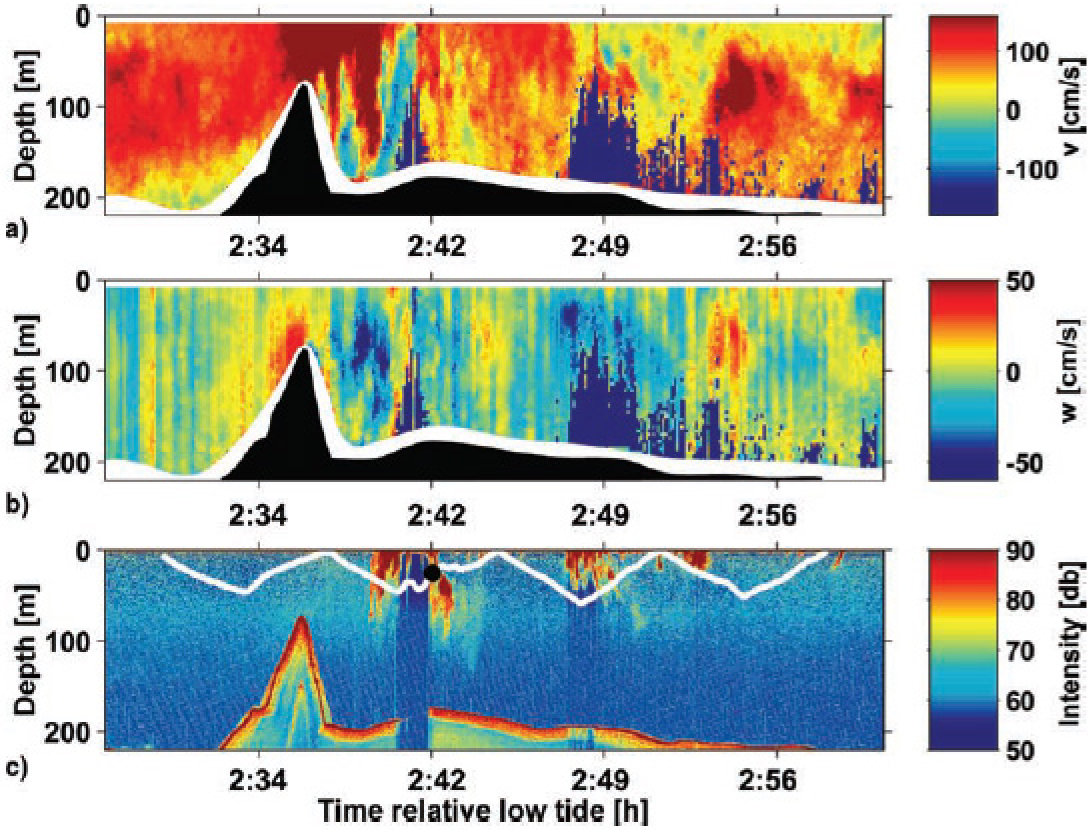

Figure 6. Transect over the sill at Boundary Pass during extreme forcing measured with an ADCP, an echo sounder, and a towed Acoustical Resonator on September 29, 2000. (a) Along-strait current; (b) vertical current; (c) acoustic backscatter intensity. The path of the resonator is shown by the white line and the location of the bubble measurements in Figure 17 by the black dot.

3.0 TIDAL FRONTS IN HARO STRAIT - TURN PONT

This front was discussed in several responses to IRs from Dr. Farmer (Filing ID A3Y2K4). It is Tetra Tech EBA's opinion that subduction flow is in fact water that flows from the southern side of Stuart Island and then joins into the main ebbing flow in Boundary Pass and Haro Strait by descending below the main flow. The water flowing around the south side of Stuart Island would not be expected to have oil slicks floating on it, since any oil that would be lost from a ship travelling through Boundary Pass and Haro Strait would primarily follow the navigation route, as shown in the stochastic simulations in the Application. In the event that oil does enter this south Stuart Island flow during and ebb tide, similar considerations as for the Patos Island front apply: the rate at which oil is withdrawn from the surface into a subducting flow is very small.

4.0 WILL FRONTS SUBDUCT OIL AND IF SO, WHAT WILL HAPPEN TO IT?

The intervenor's discussion of Figure 2 assumes that breaking waves are present, forming air bubbles which would be carried downward in the subducting current. Figure 3a of the Evidence shows breaking waves in the Stuart Island tidal front. These are not particularly large waves, and one wonders if they have sufficient energy to break the oil slick into droplets, and then inject these droplets into the water column to a sufficient depth where they are caught in the subducting flow. A calculation was done, using the same equations as are in the oil spill model SPILLCALC (based on Delvigne and Sweeney, 1988), of the amount of oil that would be broken into droplets, and hence available for the subducting process. The rate of oil entrainment in the water column was computed based on the wave energy dissipation rate, which is primarily a function of the wave height, the wave period and the wind speed. Based on Figure 3a of the Evidence, waves were assumed to be 0.3 m high. A wind speed that would generate such waves was estimated from classical coastal engineering procedures (Bretschneider, 1970), and was found to be 3.5 m/s, with a period of 2.9 s. The area over which breaking waves would be generated by the subduction process was estimate to be 5 m wide, and 1,000 m long. Based on these parameters, the amount of oil that would be injected into the water column by the wave breaking process over a three-hour period, taken to be the part of the tide when flood velocities were strong enough to generate subduction, was of the order of 17 L.

One could also estimate, admittedly crudely, a characteristic horizontal flux of oil spreading out and moving away from a spill. Assuming a thickness of 10 microns (very thin), the same 1000 m width of the front, a velocity of 2 m/s and duration of three hours, one obtains a volume of oil flowing horizontally across the frontal zone of 108,000 L. The amount subducted, 17 L, is thus 0.2% of the inflowing oil. If the thickness of the slick were greater, the percentage subducted would be proportionately smaller.

There is a factor of about 1,000 between oil on the surface and oil entrained. The same factor was reported in the Evidence Appendix where the increase in oxygen concentration due to the tidal front was about 1,000 times lower than the background oxygen level. In summary, should the conditions be favorable to the tidal front formation and strength, only a small portion of the oil (about 0.2%) could be entrained.

Oil that is subducted follows two pathways: first, it gives up some significant fraction of its soluble components: this is what happed during the Horizon blowout in the Gulf of Mexico: oil that arrived at the surface was impoverished with respect to soluble fractions. Secondly, the oil will have a rising tendency, and will rise to the surface due to its buoyancy. Indeed, the Gainford experiment and Environment Canada's report agreed on the fact that dilbit didn't sink in saline waters, representative of the marine environment. If subducted at the Patos Island front, it will likely surface in the southern Strait of Georgia. If subducted at the Stuart Island front, it will likely surface in southern Haro Strait. However, the amount of oil that is subducted, and hence resurfaces, is extremely small compared to the volumes involved in a spill, so would likely not be of significant concern.

5.0 LIMITATIONS OF THE SPILL MODEL

The Intervenor outlines some limitations, in his view, of the circulation model used to provide currents for the spill model. These concerns were raised, and dealt with adequately we believe, in responses to various IR's from Dr. Farmer.

The Intervenor's main concern appears to be that a hydrostatic (i.e., vertical accelerations of the water column are ignored) model was used, rather than a non-hydrostatic model:

> *"The hydrostatic model that Trans Mountain used cannot simulate the role of tidal front in subducting and dispersing spilled oil" (p.7 line 23 of Intervener's Evidence).*

All commercial and most research models suitable for studies of water bodies such as the Salish sea are hydrostatic: ROMS (Shchepetkin and McWilliams, 2005), Delft 3D (Deltares 2015), Telemac (Galland et al., 1991), POM (Blumberg and Mellor, 1987), NEMO (Madec, 2014), Hycom (Bleck and Boudra, 1981). FVCOM (Chen et al., 2006) has a non-hydrostatic option, but it is only available to government researchers and universities. The current world class oil transport system studies being funded by the Federal Government have led to the development of hydrodynamic and oil spill models at various institutions. To the best of our knowledge, all are hydrostatic.

If one were to prioritize modelling activity, a higher spatial resolution is more important for revealing fronts and is also the first step to implementing a non-hydrostatic model. Even the 1-km resolution H3D model used for the Application produced significant vertical velocities at the Patos Island sill, upwards on the southern side and downwards on the north side during a flood tide, but the velocities are too small to match the values reported in the Evidence. If a finer grid were used, the area of strong upward and downward flows would be confined to a smaller region, where the bottom slope is significant, and the vertical velocities would presumably increase to levels reported in the Evidence.

6.0 SUMMARY

The Intervener, Dr. Farmer, provides an interesting oceanographic discussion concerning the presence of tidal fronts and their potential impact on oil spills. While the presence of these tidal fronts has been proven under specific conditions, the associated rate of entrainment of air or oil, if present, is apparently negligible. Proof is shown in the Appendix of the Intervener's Evidence where the increase in dissolved oxygen in deeper layers due to tidal front entrainment is only about 0.1% of the background oxygen level.

Furthermore, it should be remembered that, under specific conditions, only a portion of the surface water is being entrained in deeper depth, the other portion staying on the surface. Should a small portion of the oil (0.1%) be entrained, its buoyancy would lead to resurfacing at a later stage. The TMEP Application incorporated the study of oil in the water column due to submergence or sinking and this behaviour, specifically the concentration of soluble oil constituents, was part of the Ecological Risk Assessment. A slight temporary increase of oil in the water column due to frontal subduction would not affect these results.

7.0 LIMITATIONS OF REPORT

This report and its contents are intended for the sole use of Trans Mountain Pipeline ULC and their agents. Tetra Tech EBA Inc. (Tetra Tech EBA) does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than Trans Mountain Pipeline ULC, or for any Project other than the proposed development at the subject site. Any such unauthorized use of this report is at the sole risk of the user. Tetra Tech EBA's General Conditions are provided in Appendix A of this letter report.

8.0 CLOSURE

We trust this report meets your present requirements. If you have any questions or comments, please contact the undersigned.

Respectfully submitted,
Tetra Tech EBA Inc.

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APPENDIX A

TETRA TECH EBA'S GENERAL CONDITIONS