


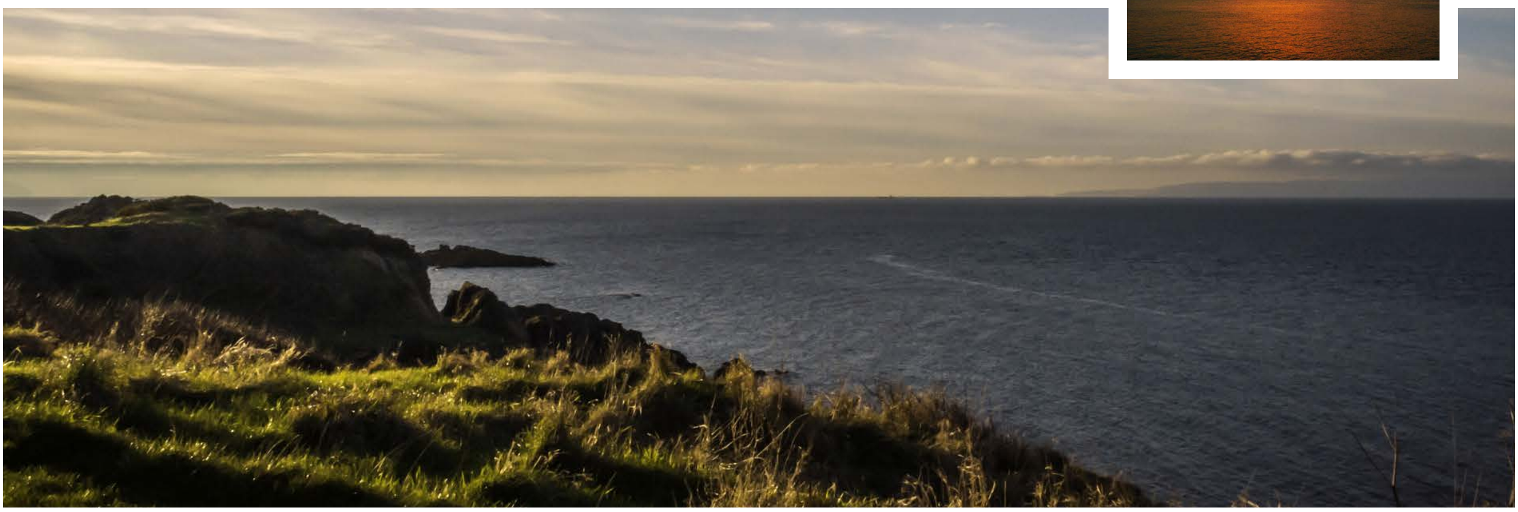

Environmental Protection Authority

Technical Review of Oil Spill Modelling

Tamarind Taranaki Ltd. Application EEZ100016

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Review of EEZ100016 Oil Spill Modelling

Prepared for
Environmental Protection Authority

Prepared by

Coffey Services (NZ) Limited

131 Wrights Road, Addington
Christchurch 8140 New Zealand
t: 64 3 374 9600

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Acronyms

ADCP – Acoustic Doppler Current Profiler – An instrument used for measuring ocean currents
ASA – Applied Science Associates, now RPS ASA

APASA – Asia-Pacific offices of ASA

CFSR – Climate Forecast System Reanalysis

HYCOM – Hybrid Coordinate Ocean Model.

IOA – Index of Agreement. A statistical measure of model skill.

MDO – Marine Diesel Oil

MTBE – Methyl *tert*-butyl ether

RPS – RPS Group Plc.

STB – Stock Tank Barrels – A barrel of oil at surface conditions.

1. Introduction

Coffey Services (NZ) Limited, a Tetra Tech Company, (Coffey) was engaged by the New Zealand Environmental Protection Authority to conduct a technical review of the oil spill modelling reports in Tamarind Taranaki Limited's application for marine consent and marine discharge consent, EEZ100016.

1.1. Qualifications and experience

1.1.1. Justin Rogers

I have a Bachelor of Arts in Earth and Environmental Science from Wesleyan University and a Master of Science in Oceanography from the University of Rhode Island. I have been working for Tetra Tech since 2008 applying hydrodynamic models to engineering and scientific projects. In 2016, I transferred to Coffey's office in Christchurch. I have expert knowledge of coastal oceanography, limnology, and sediment transport modelling, with a focus on pollutant fate and transport.

Specific projects relevant to this review include:

- Modelling of oil spills off the British Columbia coast using Tetra Tech's spill tracking model and public domain coastline type and meteorological data.
- Developing hydrodynamic models in support of complete oil transport and weathering study for potential oil spills in the St. Lawrence River, Canada.
- Developing hydrodynamic models in support of complete oil transport and weathering study for potential oil spills in the Salish Sea, including the Lower Fraser River, Vancouver, Canada.
- Applied stochastic hydrodynamic models, field judgement, and risk analysis to identify potential areas of risk to the public from sewer overflows at multiple locations.

I confirm that I have read the Expert Witness Code of Conduct. I have complied with the Code of Conduct in preparing this report. This report is within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed in this report.

1.1.2. Aurelien Hospital

I have a Master of Marine Engineering from the Institute of Engineering Sciences of Toulon and the Var, and a second Master of Physical Oceanography from the University of Toulon and the Var. I have been working for Tetra Tech since 2008, focusing on numerical modelling to support environmental studies and engineering design. I have expert knowledge of oceanography, oil spill transport and weathering and more generally pollutant tracking.

Specific projects relevant to this review include:

- Modelling the fate and behaviour of diluted bitumen spills off the British Columbia's coast and in the Fraser River estuarine system, using Tetra Tech's spill tracking model.
- Modelling the fate and behaviour of spills of light, medium and heavy crude oil in the Bay of Fundy and in the St Lawrence River, Canada, using Tetra Tech's spill tracking model.
- Participating in stakeholder engagement as technical expert in support of an area risk assessment of ship-source oil spills in Northern British Columbia, Canada.
- Modelling the fate and behaviour of spills ranging from volatile to heavy oils in Northern British Columbia, Canada.

- Providing technical support following an MTBE spill in Galveston Bay, Houston, USA.

I confirm that I have read the Expert Witness Code of Conduct. I have complied with the Code of Conduct in preparing this report. This report is within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed in this report.

1.1.3. Dr. James Stronach

I have a Ph.D. in Physical Oceanography from the University of British Columbia. I have been working for Tetra Tech since 2006, and have been working for similar companies since 1979. The focus of my work has been the use and improvement of numerical hydrodynamic models to inform marine operations, including navigation, search and rescue, oil spill behaviour, dispersion of contaminants such as sewage and mine tailings and engineering design.

Specific projects relevant to this review include:

- Modelling the fate and behaviour of diluted bitumen spills off the British Columbia's coast and in the Fraser River estuarine system, using Tetra Tech's spill tracking model.
- Modelling the fate and behaviour of spills of light, medium and heavy crude oil in the Bay of Fundy and in the St Lawrence River, Canada, using Tetra Tech's spill tracking model.
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2. Documents reviewed

The following documents in Tamarind Taranaki Limited's applications for marine consent and marine discharge consent were reviewed.

- ERM - Impact Assessment, Sections 7.1 and 7.2.
- RPS APASA 2018. Report titled 'Tamarind Resources – Tui Field Oil Spill Modelling' (21 March 2018).
- RPS APASA 2018b. Report titled 'Tamarind Resources – Tui Field 110-Day Oil Spill Modelling' (21 March 2018).

The two RPS APASA Tamarind reports were delivered together as Annex F of the application. The spill modelling reports are similar except for the duration considered, and are discussed together.

Note that in this review, 'Table 1' refers to a table in this report. 'RPS Table 1' refers to a table in the Tamarind Resources – Tui Field Oil Spill Modelling report (RPS report), which covers a marine diesel oil spill and a 45-day well blowout scenario. References to the 110-day report, which covers a longer well blowout scenario, have been made explicitly. References to other reports are also made explicitly, and where relevant, the 'RPS report' is referred to as the 'RPS APASA Tamarind report' to avoid confusion.

3. Technical comments on oil spill modelling

The technical review has focused on the tools used by RPS for the study, the inputs to the model, as well as the results. Where possible, cross-checking with other models, literature or reports was conducted to assess the suitability of the results.

A risk matrix with two axes is used to focus the review on the severity of an information deficit or technical deficiency (y-axis), and the potential impact of the issue on decision making (x-axis).

A deficiency is ranked low, medium or high in severity based on the reviewers' experience and comparison of the report's technical content with international best practices. An information deficit is ranked on the same axis, when there is not enough information to determine whether there is or is not a deficiency.

The potential impact on decision-making ranks low, medium or high to the degree that the issue could materially affect the results of the study. In the context of this study, decision-making is affected by the accuracy and results of the stochastic modelling, including shoreline oiling, sub-surface exposure, and areal extent affected by a potential spill.

3.1. Project descriptions, oil types and scenarios

In general, the choices of oil spill model, input data sources, and spill location are appropriate, as described in RPS Sections 1, 2, 6 and 7.

Modelled scenarios include a 200 m^3 release of marine diesel oil (MDO) via a support ship collision, a 45-day (56,721 m^3) release of Tui Crude via well blowout, and a 110-day (104,068 m^3) release of Tui Crude via well blowout.

The season modelled includes the months of March and April, which are proposed for drilling, and one month on either side. Adding adjacent months to increase the period of record of available winds and currents is reasonable, but considering the length of the blow-out scenarios range from 1.5 to nearly 4 months, presumably a spill could continue into June or even July. It is not clear how many months were used in the stochastic modelling. The periods of record of data sources are reviewed in Section 3.4 below.

The MDO spill scenario is well justified in the Impact Assessment.

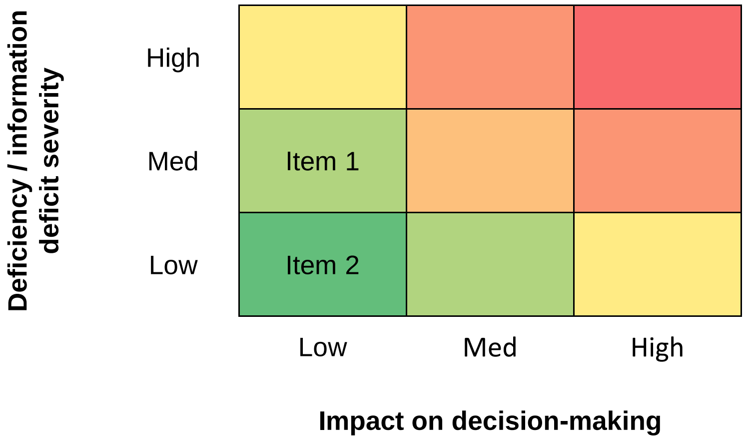
Modelling assumes that during a blowout, the well would initially produce 19,803 bbl/day, or about nine times the current oil production rate. The initial release rate is approximately half of that referenced in Navigatus Consulting (2015) for Deepwater Taranaki, a nearby but distinctly different reservoir to the proposed well. The reasoning behind the choice of release rate is not discussed or referenced in the oil spill modelling report. The reduction in flow rate over time appears realistic compared with Navigatus Consulting (2015). The Impact Assessment refers to, but does not reference or describe, the reservoir modelling to justify the release rate.

Oil concentration is discussed in many units in RPS Section 6: g/m^2, litres per km^2, m^3/km^2, and g/m^2 again. Use of these different units makes it difficult to compare between RPS Figure 14 and RPS Table 7, for example. The approach of designating specific low, moderate and high concentration thresholds is good, but the supporting photographs and oil appearance codes should be aligned somehow with these choices, in consistent units.

3.1.1. Risk matrix

Coffey notes two main items of concern with respect to RPS Sections 1, 2 and 6. These concerns are placed in Risk Matrix 3.1 that considers the degree of deficiency or information deficit, and the potential impact on decision making.

- Item 1: Release rate. A reference should be provided for the blow-out release rate and decline in rate over time. The release rate is a key input for the entire study. The impact on decision-making is deemed low because a suitable reference likely exists and supports the rate used.
- Item 2: Units. Oil concentration units should be consistent, or related, in the introductory tables and images. The impact on decision making is low because context on oil appearance and concentration can be found in literature.



Risk Matrix 3.1 – Oil Types, Scenarios and Initial Release

3.2. Current models and inputs

An oil spill model requires long-term, realistic records of currents across the region of interest, and these data are described in RPS Section 3. The currents of interest occur on two timescales. Tidal currents are the well-understood ebb and flow of water as the coastal ocean responds to the phases of moon and sun. In New Zealand they are dominated by the lunar semidiurnal tide, which rises and falls every 12 hours and 25 minutes. Currents that are **not** strictly tidal in nature can be driven by winds, regional oceanographic patterns, supply of freshwater (estuarine circulation) and other forcings. These non-tidal flows can be called regional, ocean, subtidal, and/or residual currents, although there are distinctions between these terms. In this review, regional and residual are used interchangeably.

In the RPS APASA Tamarind report, regional currents were obtained from the HYCOM model, which has approximately 8.25 km resolution with an output frequency of once per day. Tidal currents were generated by RPS' HYDROMAP model. The currents were then combined in an unspecified manner.

3.2.1. HYDROMAP

The HYDROMAP model was used to simulate tidal currents, a component of oil transport. The validation provided shows tidal elevations at nine locations around New Zealand. The Index of Agreement (IOA), sometimes termed as model skill, is an appropriate statistic for validation, but a higher agreement would be expected from a well-calibrated tidal model, with 1.0 being a perfect agreement. The IOA values average 0.94 in this comparison (RPS Table 2). Similar tables in modelling studies RPS APASA (2014) and RPS APASA (2017) have much better agreements, with IOA values around 0.99.

The lower model skill in the current RPS report does not have a clear explanation. If different months, again comparing with those presented in RPS APASA (2014 and 2017) have such variable model skill, how well does the model perform over the five-year period modelled? The report should provide the tide height validation statistics for the months used in the study.

It is impossible to determine whether the modelled tide heights are either consistently overestimated or underestimated since there is a typographical error in RPS Figures 6-8 where the figure legend states that the predicted tide is blue, and observed is red, but the figure caption states the opposite.

A model’s skill in reproducing tide heights does not necessarily translate into skill reproducing currents, which are more difficult to match. No validation of tidal currents is provided for HYDROMAP. It is understood that offshore current data is difficult to collect, but NIWA (2012) provides a useful degree of detail in a nearby, albeit shallower, area that is within the stochastic spill envelope.

3.2.2. HYCOM

One year of HYCOM model results were obtained for the study area. As ten years of combined currents were used, the HYCOM regional currents must have been reused many times with different tidal currents and wind fields superimposed (discussed in Section 3.4.1). The transport of oil due to tidal currents is important in estuaries and complex near-shore geometry, but lessens in importance as the distance from shore and time scale increases. The dominant drivers of open-ocean oil transport are the residual, or non-tidal currents and the wind, which are physically related.

Coffey has obtained the HYCOM currents from the year 2012 and reviewed current roses and basic monthly statistics, summarized in Table 1 (HYCOM 2018).

Typical current directions appeared somewhat different from the current roses in RPS Figure 10, because of the combined presentation of currents. There are two ways of averaging vector quantities such as winds and currents, shown in Table 1 above. One method (average current speed) averages the absolute magnitude, or speed of the current regardless of direction. The speeds can be zero or positive numbers. Another method (vector averaged mean currents) averages each vector component of the velocity time series separately. The average current speeds in RPS Table 3 do not specify the form of averaging and combine the results from two models in a way that does not differentiate between residual and tidal currents.

While it is not unreasonable to rely on HYCOM, checking the residual currents against local New Zealand shelf data would strengthen the report. If no current validation data was available it should be stated in the report.

Table 1: HYCOM Currents, 2012, Near Amokura Well Site – monthly means

Month	Mean E-W (u) current (m/s)	Mean N-S (v) current (m/s)	Vector-Averaged Mean Currents (m/s)	Average Current Speed (m/s)	Maximum of the Magnitude (m/s)
Jan	0.14	0.07	0.15	0.28	0.76
Feb	0.02	-0.03	0.04	0.19	0.40
Mar	-0.05	-0.01	0.05	0.28	1.13
Apr	0.01	0.01	0.01	0.20	0.51
May	0.04	0.02	0.04	0.21	0.54
Jun	0.09	0.04	0.10	0.25	0.56
Jul	-0.03	-0.05	0.05	0.20	0.75
Aug	0.01	0.00	0.01	0.14	0.41
Sep	0.10	-0.03	0.10	0.28	0.62
Oct	0.18	0.09	0.20	0.32	0.67
Nov	0.09	0.08	0.12	0.26	0.44
Dec	0.13	-0.01	0.13	0.25	0.49
Net	0.06	0.01	0.08	0.24	0.61

3.2.3. Combined currents

The RPS APASA Tamarind report does not make clear exactly how the tidal and regional currents were combined. A nearby data report provides some insight on the relevance of each component of the combined currents.

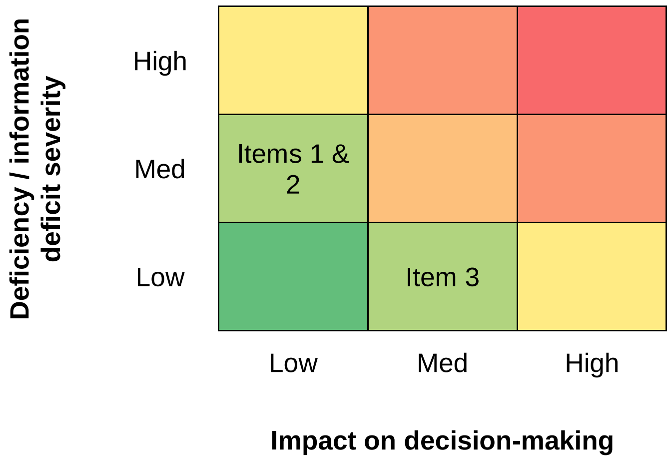
NIWA (2012) presents progressive vector diagrams from long-term Acoustic Doppler Current Profiler (ADCP) deployments approximately 100 km southwest of the well site, within the area of the stochastic envelope. The NIWA report presents a number of progressive vector diagrams, which summarize the time series of observed currents at one point by showing the path of an imaginary particle subject to those currents. The tidal currents, while larger in magnitude than the residual currents, average to near zero over time, so the path of a particle is dominated by the residual currents, with only small 'wiggles' from the tide. The path of an individual particle in SIMAP likely has a similar pattern. The multiple years of modelled tidal currents are potentially less important to the results than the four months of HYCOM results. Little new information is obtained from multiple years of tidal-only modelling.

It cannot be determined from the current roses whether they represent long-term directions of transport or are overwhelmed by the tidal currents, since residual and tidal currents have been combined. Discussion of the tidal excursion at the well site and representative sites throughout the stochastic envelope would better describe the currents.

3.2.4. Risk matrix

Three items of concern with RPS Section 3 are placed in Risk Matrix 3.2 for this section.

- Item 1: Validation. Validation of the tidal elevations were less skilled than expected, and compared to other RPS reporting. Is there month-to-month variability in model skill? The impact on decision-making is low because tidal currents are less relevant on the temporal and spatial scales of interest.
- Item 2: Labelling. The tidal elevation graphs have conflicting labels, making the direction of error unknown. The impact on decision-making is low, as in Item 1.
- Item 3: Averaging and Combinations. The presentation of currents does not split out the tidal and non-tidal magnitudes, and the method of averaging is not specified, making the average currents appear to disagree with the trajectory maps and reducing the usefulness of the current roses. The impact on decision-making is medium because the summary of input data is oversimplified to the point where it does not seem to agree with the results, reducing confidence in both.



Risk Matrix 3.2 – Currents

3.3. Wind models and inputs

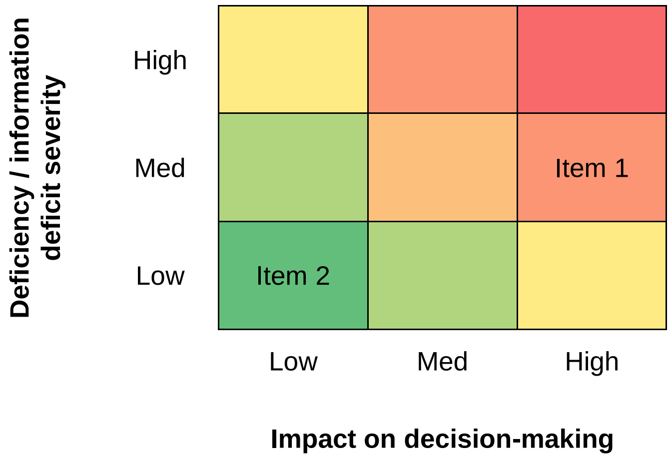
Wind is a major factor in the movement of surface oil slicks, and the wind inputs to oil spill modelling are described in RPS Section 4. The CFSR wind hindcast model is appropriate, and reasonable validations thereof can be found in the literature. The method by which 10 years of wind data is combined with the 4 months of HYCOM results and 5 years of HYDROMAP results is poorly described, and is a source of uncertainty. HYCOM residual surface currents are expected to be strongly wind-driven, as in the NIWA (2012) observations. As the winds used for the stochastic modelling are decoupled from the HYCOM currents, there is a considerable loss of realism. Winds and currents would at times be opposed in direction, effectively cancelling out transport. Repetitive random combinations of an unphysical situation do not improve the result.

As discussed in the HYCOM section above, it is reasonable to use these wind data but some sort of validation in New Zealand offshore waters would strengthen the report.

3.3.1. Risk matrix

Two items of concern are placed in Risk Matrix 3.3 for this section.

- Item 1 – Decoupling. Decoupling of winds and residual currents (HYCOM currents) in time reduces the physical relationship between wind and current to random, un-correlated time series, which could under-predict the travel distance of oil, or produce unrealistic trajectories. The impact on decision making is high because a potential systematic under-prediction of travel distance would reduce the area of predicted effect and reduce the accuracy of each trajectory.
- Item 2 – Averaging. The method of averaging is unspecified, making the summary of winds less useful for checking the trajectory results. The impact on decision-making is low because winds are steadier than tidal currents, reducing the uncertainty in input data presentation.



Risk Matrix 3.3 – Winds

3.4. Stochastic methods

3.4.1. Model settings

For comparison purpose, the same company, RPS ASA, conducted similar spill modelling in the North Atlantic in 2014 (RPS ASA 2014a) in support of the Shelburne Basin Exploration Drilling Program. Blowout and surface spills were simulated. Ocean conditions as well as depth of discharge are different. Nonetheless, the method stays the same and can be used here for comparison.

The minimum thickness for tracking considered in the RPS APASA Tamarind report was a 0.5 µm for oil on surface (RPS Section 6.2.1). That is, once a part of the slick became less than 0.5 µm, that part of the slick was omitted from the results. This thickness is still significant. Based on RPS APASA Tamarind Table 6, the omission of any thickness less than 0.5 µm means that the RPS APASA Tamarind report did not consider a sheen on surface for exposure calculation. The RPS ASA (2014a) report considered 0.04 µm for cut-off in surface oil thickness, with the rationale that this would be the minimum thickness to determine impact on socioeconomic resources.

Similarly, the minimum concentration of oil on the shoreline for tracking was set to 10 g/m^2 in the RPS APASA Tamarind modelling, whereas a minimum concentration of 1 g/m^2 was considered in RPS ASA report (2014a). A minimum concentration of 1 g/m^2 would trigger shoreline clean-up on amenity beaches, however the 10 g/m^2 would be a conservative number for impact on shoreline habitat. In other words, the 1 g/m^2 represents a threshold for socioeconomic impact, whereas the 10 g/m^2 represents the threshold for ecological impact.

The RPS APASA Tamarind report conducted modelling of 100 spills. This appears to be on the low side to representatively cover a 4-month x 10-year period. For comparison, the RPS ASA (2014a) modelling conducted 40 runs per month for a sub-surface spill stochastic simulation. It is possible that 100 spills is adequate for the blow-out scenarios due to the length of each event. However, 100 spills seems low for the ship spill, and the report does not demonstrate that the stochastic results stabilised with 100 spills; that is, it does not demonstrate that another 10, 20, or 50 simulations would not materially change the stochastic results.

The items described above have been summarised in Table 2 below. A column was also added for the Greenpeace Oil Spill Modelling report (Dumpark, 2013) for comparison purposes.

Table 2: Comparison of RPS APASA Tamarind Model settings with other similar studies

Item	Tamarind RPS APASA 2018 Report	Shelburne Basin RPS ASA 2014a Report	Greenpeace Spill Modelling 2013 Report
Number of Stochastic Spills	Every 12 days on average: 100 (over 10 years * 4 months)	Every 18 hours on average: 40/month over 12 months	Every 3.5 days in average: 1,000 over 10 years
Minimum Oil Concentration on the Shoreline	10 g/m^2	1 g/m^2	1 g/m^2
Minimum Oil Thickness on Water Surface	0.5 µm	0.04 µm	0.01 µm
Threshold Value for Dissolved Aromatics Concentrations in Water Column	6 ppb (for a 96-hour LC_{50})	1 ppb	unknown
Model Used to Simulate Sub-Surface Spill	SIMAP	OILMAP Deep (calculate droplet size and plume behaviour) SIMAP (used OILMAP Deep results as inputs)	GNOME Model (NOAA) with HYCOM currents

3.4.2. Periods of record

Ten years of wind data were used, which provides a wide variety of potential meteorological conditions to support the stochastic modelling.

Five years of tidal currents were generated, which is more than sufficient to cover the variability in tidal heights and currents, and in fact provides little new information.

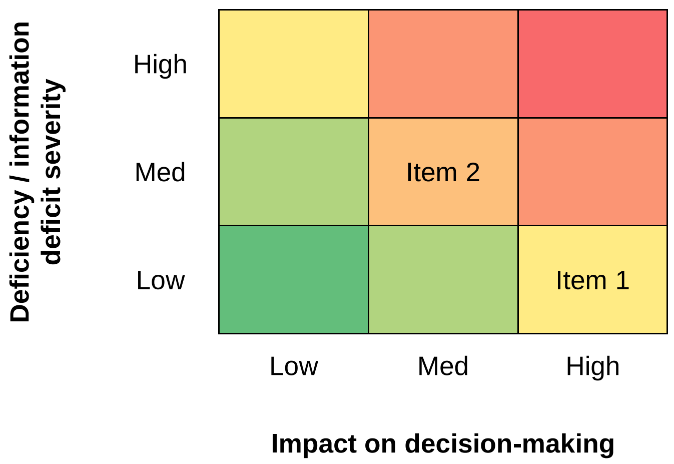
Only one year of regional currents was used, obtained from the HYCOM model. The report states in multiple locations that the modelled period is February to May, or four months. It is not clear whether spills that started near the end of the four-month window continued into subsequent months, or looped back to February. Regardless, it is clear that only a portion of one year of HYCOM currents were used and reused throughout the ten-year simulation period. As noted previously in this report, it is highly likely that combining winds and ocean currents in the manner used by RPS would result in unphysical situations.

If the four HYCOM months, repeated and looped, were not representative of the range of possible ocean conditions then the number of stochastic simulations is of limited use. Inter-annual variability in ocean currents is neither discussed nor represented in the stochastic results. The report does not explain why the many years of publicly available HYCOM results were not suitable, or used, in the modelling.

3.4.3. Risk matrix

Two items of concern are placed in Risk Matrix 3.4 for this section.

- Item 1: Thresholds. The potential discrepancy of using a higher threshold to assess exposure and produce maps of oil presence can have a significant impact. Other similar studies considered a threshold ten times lower, which could significantly change the amount of oil reported to reach the shore, as well as the exposure on the surface and in the water column. The impact on decision-making is high because of the potential for ‘hiding’ results with thresholds, and the discrepancy with similar studies.
- Item 2: Periods of Record. The period of record for HYCOM is not sufficient to ensure a wide range of residual currents are available. The review cannot determine whether these four months of currents are statistically representative of the long-term variability in ocean currents. The impact on decision-making is medium because the area of effect could not just be under-predicted, as in Section 3.3, but in a different direction if ocean current patterns change from year to year.



Risk Matrix 3.4 – Stochastics

3.5. Oil trajectories

The average currents and winds in RPS Tables 3 and 4 suggest a greater travel distance than shown in the trajectory maps. RPS Figure 25 shows approximately 10 days of travel time to New Plymouth, approximately 85 km northeast of the well site. This implies a net residual current and wind summing to about 0.1 m/s to produce the fastest travel time.

Using an average current from RPS Table 3 of 0.23 m/s and an average wind from RPS Table 4 of 16 knots (8.2 m/s) with a windage of 2% (reducing the travel speed to 0.16 m/s) allows an estimate of the distance travelled, on average, in ten days. If the wind and current are aligned, a surface slick could travel 360 km. If the wind and current were offset by 90 degrees, the travel distance would be 260 km. Alternatively, the travel time to reach the shore would be three to four days.

The reviewers are confident that the SIMAP model can correctly ingest wind and current data and compute trajectories, but the provided tables and wind roses do not allow a good understanding of the time scales involved. The method of vector averaging is likely the issue with the above calculation, which was raised as a concern in Section 3.2 and is not repeated here.

It should be repeated that there is a lack of clarity of which environmental conditions were used for the stochastic modelling.

No risk matrix was produced for this section, as the concerns (wind and current data) have been discussed in Section 3.2.

3.6. Oil weathering

This section focuses on the weathering, i.e. physical and chemical degradation of the oil, and is mainly concerned with RPS report Section 7 and onward.

3.6.1. Mass balance

The mass balance for the 200 m^3 MDO surface release is not indicated. The RPS report does indicate that no shoreline was contacted, nonetheless a mass balance summarising the amount of oil that evaporated, dissolved, or decayed is necessary to understand the fate of the discharged oil. The omission of mass balances is a serious flaw in the report.

Regarding the well blowout stochastic modelling, only a partial mass balance (amount reaching shoreline) was provided. Again, this information is important for the reader to fully understand the behaviour of the spilled oil.

RPS Figure 17 is useful for illustration, but note that it is not realistic to have a sustained 15 knot wind for 20 days. In reality, the wind will calm down, and oil will resurface following its vertical dispersion in the water column. Hence RPS Figure 17 should not be used to assess representative weathering nor mass balance.

The selection of a decay coefficient such that the exposure falls to 1% of an initial concentration over 1 week, seems possibly optimistic about the decay process and is reviewed in more detail in Section 3.6.2 Depuration.

3.6.2. Depuration

The mechanism of depuration refers to "*the rate of removal due to the ability of the organism to expel or metabolise hydrocarbons*" (RPS, 2018). The depuration rate was set to reduce to 1% of the initial concentration over one week, assuming no additional exposure would occur. One concern in this assumption is the lack of information on the selection of this value. It is also unclear if this depuration process includes biodegradation. The depuration process depends on factors, such as the type of organism ingesting the oil, and, for biodegradation, the presence, or not, of bacteria at the spill site, the environmental conditions favourable to the development of the bacterial population, etc. While there are no clear guidelines, the reason of this important parameter choice should be explained. As shown on RPS Figure 15, the effect of depuration is extremely significant. Should the depuration rate be lower, oil concentrations in the water column would be higher.

Based on RPS Figures 16 and 17, the decay field only applies to the dispersed oil, i.e. oil in the water column. Note that one would expect some decaying through dissolution and biodegradation occurring at the surface also.

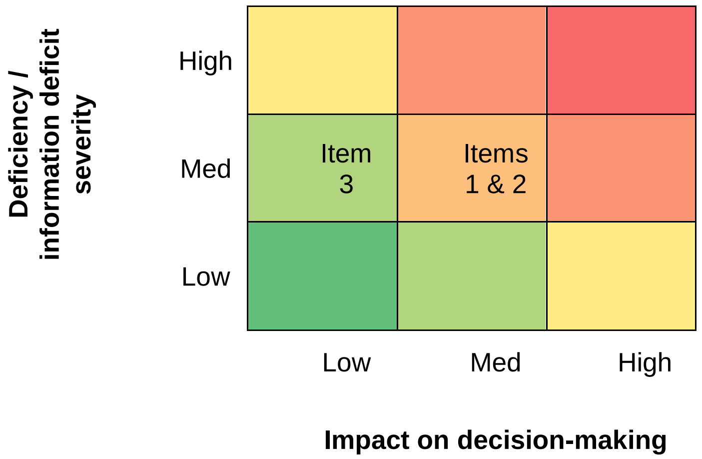
3.6.3. Emulsification process

For the Tui crude, one can expect emulsification to occur due to its 29% residual content. The emulsification will result in greater viscosity and a reduction in evaporation, hence potentially a longer time period with the presence of oil on the surface. However, there is no mention of the formation of such emulsion in the RPS report. It should be indicated if this mechanism was taken into account or simply dismissed.

3.6.4. Risk matrix

Three items of concern are placed in Risk Matrix 3.6 for this section.

- Item 1: Mass Balance. If a summary of the mass balance at the end of the simulations specifically explaining the fate of the persistent fraction were to be provided, this addition would reduce the severity of deficiency. The impact on decision-making is medium because a mass balance allows a clear summary of the final fate of spilled oil, and its behaviour over time. Omission, or a partial mass balance, leaves questions on the final fate of spilled oil un-answered that are easily provided by the model used.
- Item 2: Depuration. A clear explanation on the value of the depuration parameter, with adequate literature/past experience, is required to reduce the severity of the deficiency. If this parameter value is properly supported, then the impact on decision making would also be reduced. Currently, the impact of decision-making is medium, because the impact of the depuration factor on the results is significant. Should this depuration factor be different, say exposure values be brought down to 1% of initial concentration over one month instead of a one week period as in the RPS report, exposure results may be above the considered threshold.
- Item 3: Emulsification. There is no indication in the RPS report that emulsification was taken into account. If it were, a larger amount of oil would potentially be travelling on the surface, since evaporation would be reduced. Indication on the incorporation, or not, of this mechanism in the modelling would reduce the severity of deficiency. The impact on decision-making is low, because this mechanism, and potential slightly longer persistence of oil on water surface, would not change the overall trajectory maps.



Risk Matrix 3.6 – Oil weathering

3.7. Shoreline contact results

3.7.1. Shoreline retention

The shoreline loading appears as a mass per area – this means the shoreline must have a slope over which an area is determined, which is unspecified. A sandy shoreline is assumed and considered as the worst case, although that may not be the worst case. A shoreline with unrealistically high oil retention would trap oil at first contact instead of allowing it to spread further or refloat, which may, in fact, be worse. It cannot be discerned from the RPS report whether shoreline segments reached their holding capacity.

3.7.2. Amount of oil stranded on shore

Maps in the RPS report show that no marine diesel reached the shore. While volatile, this product contains 5% of heavier residual hydrocarbons, which will not evaporate nor degrade rapidly, and would have the ability to reach the shore. This statement is a supposition, but it is likely the marine diesel did reach the shore, albeit in quantities less than the 10 g/m^2 threshold used in the model. If a lower threshold were used, such as 1 g/m^2, oil might have been tracked to the shore in the model.

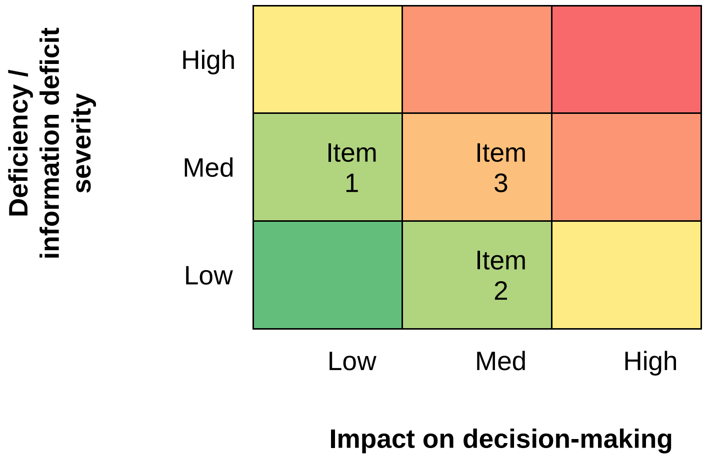
In the well blow-out scenarios, 29% of the crude is classed as 'persistent' in RPS Table 12. In RPS Table 15, the 45-day spill results in a maximum shoreline volume of 706 m^3 out of 56,721 m^3 spilled, or 1.2%. For the 110-day spill, the maximum volume ashore was 778 m^3 out of 104,068 m^3 released, or 0.75%. The amount reaching the shoreline appears to be much less than the fraction of crude classed as persistent, further supporting the need for a mass balance summary.

The RPS Table 15 volumes do not seem comparable to the peak shoreline loads presented by receptor in RPS Table 17 of each study. Summing the mean shoreline volumes in RPS Table 17 exceeds the volume in RPS Table 15, though it is not clear if the receptors' volumes should be summed due to the nature of stochastic results. It is clear that the peak volumes in RPS (110-day) Table 17 are higher than the peak volume in RPS 110-day Table 12, suggesting that the results have been filtered by use of the 10 g/m^2 threshold.

3.7.3. Risk matrix

Three items of concern are placed in Risk Matrix 3.7 for this section.

- Item 1: Shoreline Retention. The maximum potential shoreline oil retention should be stated. The impact on decision-making is low, since the spill source is quite away from the shoreline and oil was indicated to contact the shore in limited amounts.
- Item 2: Amount of Oil Stranded on Shore – MDO. The fate of any residual fraction should be stated, even if it is below a shoreline threshold. The impact on decision-making is medium for the same reasons as Section 3.6 Item 1 – Mass Balances.
- Item 3: Amount of Oil Stranded on Shore – 45-Day and 110-Day mass balances. The quantities stranded on the shore appear low, and the results would be better supported by a mass balance as discussed in Section 3.6. The impact on decision-making is medium for the same reasons as Section 3.6 Item 1 – Mass Balances.



Risk Matrix 3.7 – Shoreline contact

3.8. Water column exposure results

3.8.1. Environmental dataset

The RPS report only presents and describes surface currents. No indication was given regarding the magnitude or direction of currents used for the sub-surface spill. It is unclear if surface currents were applied to the oil in the water column or if a different current dataset from HYCOM was used at various water depths for sub-surface oil.

3.8.2. Model used to simulate water column exposure

No information is provided on how the oil reaches the surface during the assumed blowout, or whether there is significant subsurface travel or dissolution during the period of time that the spill is acting as a plume. The RPS report currently appears to assume it surfaces quickly.

To simulate the fate of the discharged oil in sub-surface areas, one key parameter is the ability to simulate the behaviour of the jet and plume once discharged. This jet/plume is characterised by the droplet size. The OILMAP Deep model calculates this process and then passes on the results as inputs in the SIMAP model. While the RPS ASA (2014a) North Atlantic, RPS APASA (2014) Maui Condensate, and Metocean (2014) reports used this, or similar approaches, considered as industry standard, the RPS ASA Tamarind report did not use the OILMAP Deep, and instead only used the SIMAP model.

Reviewing whether this choice is appropriate was not possible given the information in the RPS report. Initial release starts at ~20,000 bbl/day, or 37 L/s. The diameter of the pipe or orifice from which the oil escapes is not indicated, making impossible the calculation of the exit velocity. If this exit velocity is significant, i.e. a jet forming, then the use of SIMAP directly is inadequate and RPS should have used OILMAP Deep first to simulate this jet behaviour before using SIMAP.

Since the method by which the well blowout reaches the surface is not specified, SIMAP determines dissolved concentrations only as released from surface slicks. There would be a 45-day / 110-day continuous exposure in between the blow-out well and the surface, and presumably entrainment and dissolution processes. While this would occur over a relatively small area, the continuous nature ensures high temporal exposure in the area of the initial plume.

3.8.3. Droplet behaviour following release from sub-surface

The depth of the Tui Crude Oil release is at 122.5 m. Recent work has been conducted by the New Jersey Institute of Technology (USA) in collaboration with the CSIRO (Australia) in order to develop the VDROP model to simulate deep sea blowout. When hindcasting the Deepwater Horizon event, the largest oil droplet size was assumed to be 10 mm (Zhao et al., 2014a). Also, lab experiments with diluted bitumen (a heavier product compared to Tui Crude) show size ranging from 0.1 mm to 0.5 mm (Zhao et al., 2014b). Figure 1 shows experimental oil droplet diameter during a sub-surface release.

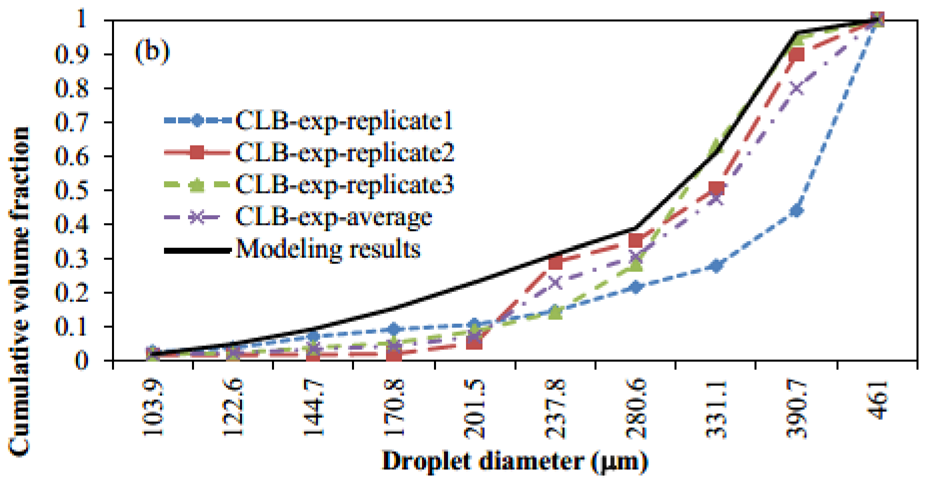


Figure 1: Experimental oil droplet diameter during sub-surface release (from Zhao et al, 2014)

These droplet diameters have also been confirmed by RPS ASA in their Shelburne 2014 report, with droplet size varying between 1.5 mm and 10 mm. Figure 2 below shows a figure from the Shelburne RPS ASA (2014) report. As shown, the free rise velocity of a droplet would have a maximum speed of 20 m/hour.

If one were to consider the larger rising velocity, i.e. 20 m/hour, the oil droplet would still require at least 6 hours to reach the surface of the ocean. Aromatic hydrocarbons such as benzene, which are most likely present in the oil, will partially dissolve during this migration towards the surface. While it could be true that no exposure above threshold was found below 30 metres depth in the water column (paragraph 1 of Section 10.1.2 –In-Water Exposure of the RPS Report describing the potential exposure from dissolved aromatics from entrained oil in water column), a graph is needed to support this statement, i.e. the vertical profile of dissolved hydrocarbons should be produced. Entrained hydrocarbons are usually in the surface layer, however aromatics would also dissolve into the water column during the rising process of the oil. Further, the selection of a 30-m layer to display results needs to be explained. For example, does it correspond to the depth of the surface mixed layer?

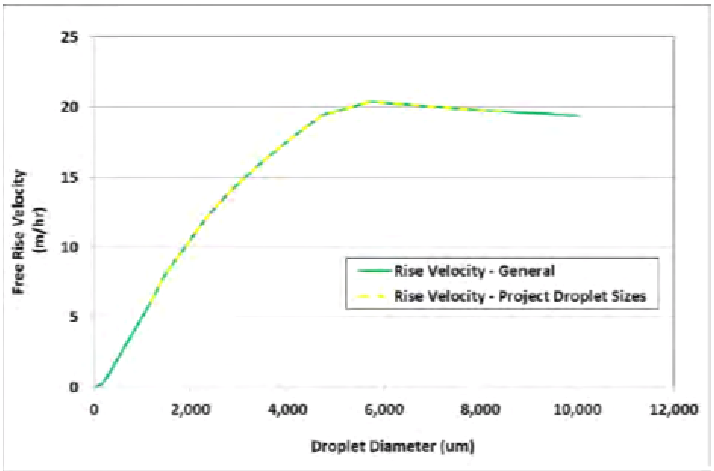


Figure 10. Free rise velocity as a function of droplet size for the project oil for both the predicted size range of the two sites as well as an extended range for general reference.

Figure 2: Rising velocity of oil droplet (RPS ASA, 2014)

Moreover, it appears that the dissolved fractions in the RPS APASA Tamarind report are generated by mixing downward from the surface slick. The relative magnitude of dissolution and dispersion from the ascending plume also needs to be quantified.

3.8.4. Threshold used to assess water column exposure

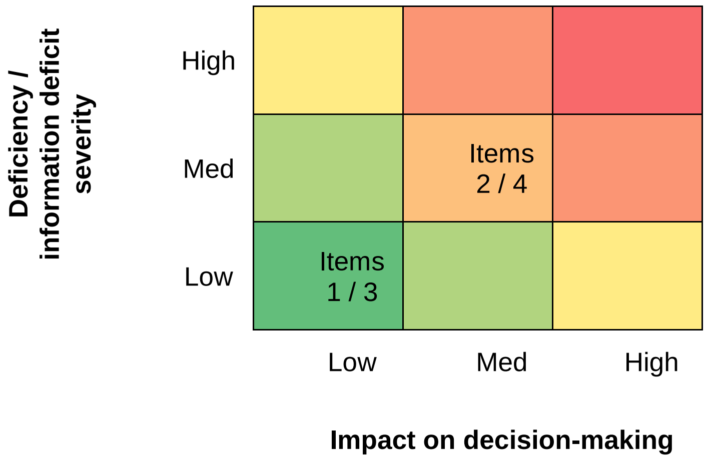
Looking at the threshold for concentrations of dissolved aromatics in the water column, the RPS APASA Tamarind report used a 6 ppb for a 96-hour LC50, whereas the RPS ASA 2014 report considered 1 ppb. Note however that the RPS ASA 2014 report did not indicate if this 1 ppb corresponds to the 96-hour LC_{50}. If a lower threshold were to be used, one might see exposure at deeper depths in the water column.

In addition, for dispersed oil, the RPS APASA Tamarind report calculated the *Predicted No Effect Concentration* (PNEC) LC_{50} following ANZECC/USEPA/European Chemicals Agency guidelines through “*applying a factor of 100 to PNEC values”*. While this approach may be adequate, it does appear too convenient, and a bit confusing. The report should indicate how universal this scaling factor process is.

3.8.5. Risk matrix

Three items of concern are placed in Risk Matrix 3.8 for this section.

- Item 1: Environmental Dataset. Indication of the data used for the advection of sub-surface oil would remove this item as being an item of concern.
- Item 2: Model Used to Simulate Water Column Exposure. The lack of a near-field or plume model, such as OILMAP Deep, means that no subsurface dissolution or entrainment from the 45- or 110-day blowout event was simulated. The impact on decision-making is medium because this omission potentially underestimates the water column exposure in the vicinity of the blowout.
- Item 3: Droplet Behaviour Following Release from Sub-Surface. This item on decision-impact is low, since the potential impact on dissolution was factored in Item 2 above.
- Item 4: Threshold used to Assess Water Column Exposure. A more restrictive threshold, similar to other studies, could result in different exposure results, particularly deeper in the water column. The impact on decision-making is medium because of the potential for ‘hiding’ results by use of thresholds, as in Section 3.4 Item 1.



Risk Matrix 3.8 – Water column exposure

3.9. Editorial / typographical / spelling

The following editorial issues were noted in the RPS report:

- Throughout: leeching should be leaching.
- STB units should be spelled out in glossary.
- Figure 4 – spelling of ‘hydrodynamic.’

4. Technical comments on impact assessment

The Impact Assessment (ERM 2018) summarised results from the 200 m^3 support vessel marine diesel spill modelling in Section 7.1 and the 45-day well blow-out scenario in Section 7.2. The results of the marine diesel spill are well summarised in the Impact Assessment and no new concerns are raised.

In Section 7.2, the Impact Assessment states that reservoir pressure is well known from past and current operations, but as in the RPS spill modelling report an appropriate memo is not referenced.

Two worst-case blow-out scenarios are discussed and modelled, with the 45-day scenario described as the worst feasible. In this scenario, an undamaged drilling rig is assumed to be able to drill a relief well. Another scenario, a 110-day blow-out is where the drill rig is damaged and travel time for a new rig is added to the blow-out duration. This scenario is considered an “absolute worst case” and is not considered feasible: the 110-day blow-out scenario is not discussed further.

The reasoning behind this probability classification is unclear. Blowouts are very rare events, however situations where well control is lost are often due to damage or fire aboard the drilling vessel or platform. Some description of how often blow-out scenarios leave the rig unable to drill a relief well should be provided to frame the scenario. As this deficiency is related to, but potentially beyond the scope of reviewing the oil spill modelling reports, no risk matrix is warranted.

5. Summary of key items

While the various sections of this report summarise the findings through risk matrices, the most important items are reiterated in this section. These key items were selected based on either the deficiency or impact on decision making being high, or both metrics being of medium severity.

I. The omission of mass balances is an important deficiency in the RPS report, since it limits the understanding of the overall fate and behaviour of the oil (Section 3.6 Item 1 and Section 3.7 Item 3). Issues related to mass balances include clear explanation on the value of the depuration parameter (Section 3.6 Item 2) and uncertainty regarding the quantity of oil on shore (Section 3.7 Item 1).

II. The advection of the surface oil slick is driven by the winds, surface currents and horizontal diffusion. Two main issues are related to this environmental dataset:

   a. The period of record for HYCOM (current data) is not sufficient to ensure a wide range of residual currents are available. The review cannot determine whether these four months of currents are statistically representative of the long-term variability (Section 3.4 Item 2).

   b. With the stochastic approach described in the report, the decoupling of winds and residual currents (HYCOM currents) in time reduces the physical relationship between wind and current to random, un-correlated time series, which could under-predict the travel distance of oil, or produce unrealistic trajectories. Winds and currents would at times be opposed in direction, effectively cancelling out transport. Repetitive random combinations of an unphysical situation do not improve the result (Section 3.3 Item 1).

III. The lack of a near-field or plume model, such as OILMAP Deep, means that no subsurface dissolution or entrainment from the 45- or 110-day blowout event was simulated, reducing the confidence in the water column exposure results (Section 3.8 Item 2).

IV. The last key item of concern is related to the choice of the thresholds to determine the exposure and probability of oil presence on water surface, shoreline and in the water column. This choice can have a significant impact on the results. Other similar studies have considered a threshold ten times lower for oil on water or on the shoreline, for example. Exposure calculation as well as the reported statistics related to shore oiling can be vastly different (Section 3.4 Item 1 and Section 3.8 Item 4).

6. Closure

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

Respectfully submitted,

Coffey, a Tetra Tech Company

Prepared by:

Justin Rogers, MSc.
Oceanographer
Direct Line: +64 3-336-5441.
Justin.Rogers@coffey.com

Prepared by:

Aurelien Hospital, M.Eng., M.Sc
Team Lead – Oceanography & Limnology
Direct Line: +1 (778) 945-5747
Aurelien.Hospital@tetratech.com

Reviewed by

Jim Stronach, Ph.D., P.Eng.
Principal Technical Specialist
Direct Line: +1 778.945.5849
Jim.Stronach@tetratech.com

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