Oil spill modelling

Background

NOPSEMA has identified a need to provide clarification for titleholders regarding the application and interpretation of oil spill modelling presented in environment plans. This is required to promote good practice and ensure that the community is better informed about the purpose and interpretation of oil spill modelling and to ensure the outputs of oil spill modelling are meaningful.

The following consolidates NOPSEMA advice to better equip all stakeholders with background knowledge of oil spill modelling including key input parameters, modelling methods and presentation of results beyond the existing high level information provided in the Oil spill modelling at a glance fact sheet. Oil spill modelling is a valuable tool for risk evaluation and response planning, but it is technically complex and can be easily misinterpreted or misunderstood, particularly where varied approaches are taken.

This advice primarily relates to the application of stochastic modelling to support risk evaluations, but also has application to the use of deterministic modelling in response planning.

What is needed?

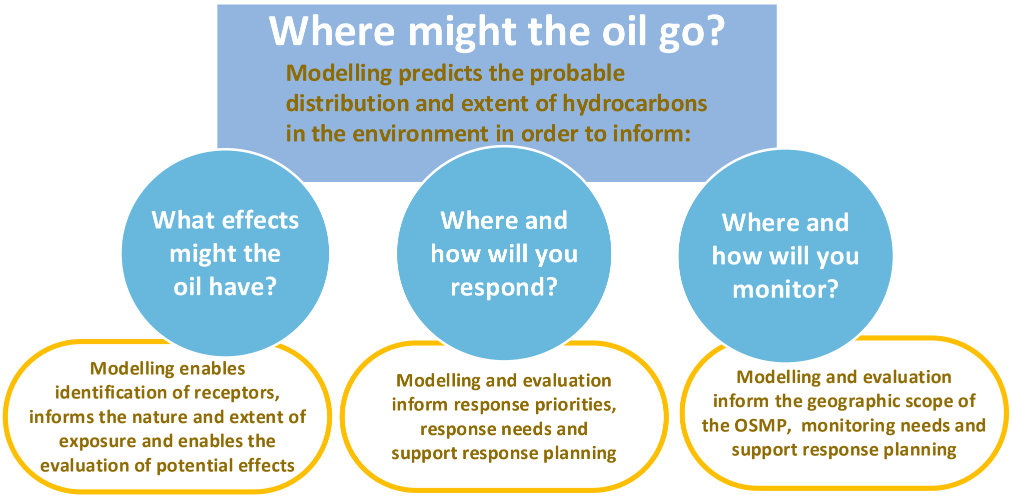
A consistent and robust approach to oil spill modelling and presentation of modelling outputs is needed to provide realistic and meaningful evaluation of oil spill risk and to effectively communicate outcomes.

A basic foundation for meaningful oil spill modelling is the selection of appropriate oil exposure values. These values are set to interpret the modelling undertaken and inform subsequent risk evaluation and environmental management actions.

The exposure values applied in oil spill modelling must be relevant to inform:

- the identification of receptors in the environment (e.g. social, economic and cultural features) that may be exposed to oil under varying conditions in the event of a spill
- the identification of species and/or their habitats to address required statutory management arrangements
- the evaluation of the full range of spill consequences from lower order water quality and aesthetic consequences, through to physical and toxicological consequences
- a basis on which to prepare for oil spill response and meaningful and useful environmental monitoring programs.

Figure 1: The purposes of oil spill modelling



Principles for selection of oil spill modelling exposure values

Noting the importance of setting appropriate oil exposure values, NOPSEMA provides the following advice.

Defining the environment that may be exposed

- Oil spill modelling should identify the full range of environmental receptors that might be contacted by surface and subsurface hydrocarbons in the highly unlikely event of a worst case oil spill. This should include, the timeframes within which contact may occur, and the probability of contact under an appropriate variety of environmental and oceanographic conditions (e.g. different seasons).
- Oil spill exposure values, and/or probabilities of exposure, should not be used to constrain the extent of predicted oil contact derived from oil spill modelling as this has the effect of excluding potentially-affected receptors.
- In general, NOPSEMA is of the view that the low thresholds should be used to define the environment that may be affected (EMBA). NOPSEMA acknowledges that these low thresholds may not be ecologically significant but should be used as a predictive tool to set the outer boundaries of the EMBA. This can/should then inform the protected matters search.

Exposure values

- A range of exposure values should be applied in modelling to approximate the spatial extent and variability of the receiving environment's contact with oil.
- These exposure values should be selected and justified taking into consideration the values and sensitivity of the environment. It is up to the applicant/titleholder to justify the thresholds being used for surface, entrained and dissolved hydrocarbons. This justification should be supported by scientific evidence where possible. In the absence of robust scientific evidence, conservative thresholds should be selected to account for this scientific uncertainty.
- Exposure values selected should broadly reflect the range of consequences that could occur at various contact exposures and are also commonly applied to inform and justify decision-making about appropriate oil spill response options and capability.
- Zones representing different intensities and probabilities of exposure (e.g. low, moderate and high exposure zones) can assist to ensure uncertainty in consequences are accounted for.
- Exposure values selected should be appropriate for predicting oil contact at appropriate concentrations to inform the key purposes of modelling, including:
  - identification of the environment that may be exposed to oil contamination
  - areas that may require monitoring of water quality
  - evaluation of consequences associated with an oil spill; and
  - oil spill response planning.
- Exposure values selected should be applicable to relevant environmental compartments, such as water surface, water column and shoreline.

Evaluation of effects/consequence

- There are known limitations and uncertainties noted in the scientific literature regarding consequences of exposure to hydrocarbons, which should be acknowledged in the risk evaluation. For example, the toxic effects of dissolved hydrocarbons on selected marine species are relatively-well understood, in comparison to the level of understanding about how entrained oil droplets affect the environment. Further, emerging research utilising a range of approaches continues to identify sublethal effects of dissolved hydrocarbons at low concentrations. A precautionary approach should be applied in the absence of certainty in relation to potential effects of hydrocarbons in the marine environment, consistent with the principles of ecologically sustainable development.

- Exposure values should be relevant to informing evaluations of potential socio-economic consequences (e.g. tainting effects) and environmental consequences (e.g. toxic effects)
- Various exposure values should be applied to interpret modelling to inform an evaluation of potential consequence to receptors that might be contacted by oil at these exposure values. This should include suitable discussion of contemporary scientific literature and/or oil-specific scientific investigations into the effects of hydrocarbon exposure on relevant receptors. This discussion should consider the pathway and duration of exposure.
- In the preparation of an EP, the level of content and effort to evaluate effects should be scaled according to the predicted exposure levels and contact probabilities. For example, receptors of low sensitivity, exposed to low levels or with very low probability of contact will require a less detailed description and evaluation.
- Duration of exposure is a relevant consideration in evaluating the consequences associated with oil contact at various concentrations. Application of duration of exposure should consider the different exposure pathways in context of the range of receptors that are present in the receiving environment.
- Where duration is incorporated directly into modelling exposure values for the purpose of evaluating consequences of a spill, this should be in conjunction with instantaneous exposure values that set the context in relation to identification of environmental values and sensitivities that may be contacted.

Principles for presenting oil spill modelling

Because of its complexity and, at times counter-intuitive, nature oil spill modelling outputs require careful communication and relevant context to ensure accurate interpretation for risk assessment and response planning. NOPSEMA provides the following advice:

Presenting spatial data

- A mix of geographic representations (mapped) and tabular formats should be used to present the outputs of oil spill modelling.
- Geographic representations of oil spill risks should be presented to depict the probability of and time to contact for moderate and high exposures based on stochastic modelling of the worst case spill. Text and tabular description may be suitable for lower exposure levels relevant to water quality and informing design of monitoring programs.
- The scales and symbology adopted to classify hydrocarbons presented in geographic representations should reflect relevant scientific literature and standards. For example, surface expression of oil can be presented according to the Bonn Agreement Oil Appearance Code (BAOAC). For dissolved and entrained hydrocarbon any geographic representation should reflect exposure values derived from relevant scientific literature and/or ecotoxicological studies.
- Tabular representation of modelling outputs is an effective approach to describe predicted contact with spatially defined receptors (e.g. shorelines, fauna congregations, protected areas etc). Modelling output tables should include predictions of minimum time to contact at relevant exposure concentrations, peak exposure concentrations, worst case loadings and periods of exposure.
- Deterministic modelling outputs are effective for communicating point-in-time predictions at intervals relevant to the spill duration (e.g. Day 1, Day 5 … etc), which provides relevant context for response planning.
- Presenting mitigated and non-mitigated scenarios is helpful to demonstrate the predicted effectiveness of oil spill response measures. For example, comparing the modelled extent of surface oil and shoreline accumulations, with and without dispersant application.

Communicating oil spill risk

- Geographic or mapped representations should be at a suitable scale, use consistent symbology and be adequately labelled to allow ready interpretation of the modelling presented.

- Graphics displaying probability of contact should clearly identify the exposure value presented, number of individual scenarios and probability of contact in the event of a worst case spill.
- The purpose for undertaking modelling at varying exposure values should be clearly communicated and outputs presented in a form relevant to the purpose. For example, predictions of the overall extent of water quality changes for the purpose of informing monitoring program design can be described more generally than predictions of high exposure.
- Exposure values should be clearly communicated in terms of the appearance and significance of oil spill risk in real terms. For example, describing concentrations of surface oil in terms of predicted appearance as per the Bonn Agreement Oil Appearance Code.

The legislation

Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009:

- Regulation 13(2)(a) states that an environment plan must describe the existing environment that may be affected by the activity.
- Regulation 13(5)(a) & (b) states that the environment plan must include details of the environmental impacts and risks for the activity; and an evaluation of all the impacts and risks, appropriate to the nature and scale of each impact or risk.
- Regulation 13(6)(b) states that to avoid doubt the evaluation mentioned in 13(5)(b) must evaluate all the environmental impacts and risks arising directly or indirectly from potential emergency conditions, whether resulting from accident or any other reason.

Further reading

Guidance note GN1488 – Oil pollution risk management
Fact sheet - Oil spill modelling at a glance

Contact

Enquiries should be directed to communications@nopsema.gov.au and quote ‘Bulletin #1 - Oil spill modelling’.

Attachment 1: Commonly used exposure values for oil spill modelling

Exposure values for oil spill modelling are selected to approximate the spatial extent and variability of the receiving environment's contact with oil and subsequently inform risk evaluation and planning for oil spill response and monitoring. Applicable values may vary depending on the purpose and the specific circumstances relevant to the risk. For instance, oil type influences the concentrations at which toxic effects may occur.

NOPSEMA has seen a range of exposure values used in EPs. The actual exposure value(s) should be selected and justified taking into consideration the values and sensitivity of the environment. Most importantly, NOPSEMA can accept a range of exposure values as long as the applicant/titleholder justifies their use. Below are some examples of exposure values used in the past along with a basic description of their use.

<table>
<tr><th colspan="4">Floating oil</th></tr>
<tr><td colspan="2">Exposure values</td><td>Description</td><td>Appearance/references</td></tr>
<tr><td>Low</td><td>1g/m^2

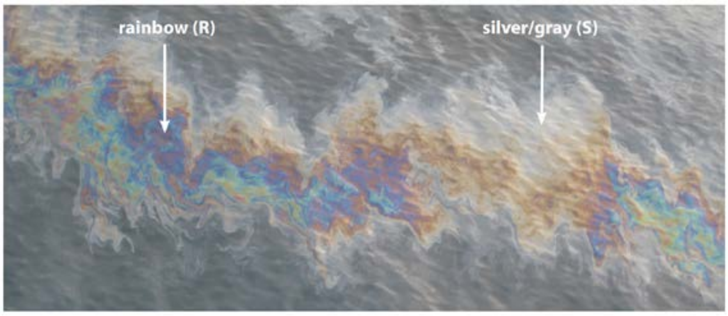
(~1,000 litres/km^2)</td><td>Approximates range of socio-economic effects and establishes planning area for scientific monitoring</td><td rowspan="3">The Bonn Agreement Oil Appearance Code (BAOAC) is a series of five categories or 'codes' that describe the relationship between the appearances of oil on the sea surface to the thickness of the oil layer (Table 1)
<table>
<tr><th>Code</th><th>Description – Appearance</th><th>Layer Thickness Interval (µm)</th><th>Litres per km^2</th></tr>
<tr><td>1</td><td>Sheen (silvery/grey)</td><td>0.04 to 0.30</td><td>40 – 300</td></tr>
<tr><td>2</td><td>Rainbow</td><td>0.30 to 5.0</td><td>300 – 5000</td></tr>
<tr><td>3</td><td>Metallic</td><td>5.0 to 50</td><td>5000 – 50,000</td></tr>
<tr><td>4</td><td>Discontinuous True Oil Colour</td><td>50 to 200</td><td>50,000 – 200,000</td></tr>
<tr><td>5</td><td>Continuous True Oil Colour</td><td>More than 200</td><td>More than 200,000</td></tr>
</table>


Image credit: NOAA Office of Response and Restoration</td></tr>
<tr><td>Moderate</td><td>10g/m^2

(~10,000 litres/km^2)</td><td>Approximates lower limit for harmful exposures to birds and marine mammals</td></tr>
<tr><td>High</td><td>50 g/m^2

(~50,000 litres/km^2)</td><td>Approximates surface oil slick and informs response planning</td></tr>
</table>

<table>
<tr><th colspan="4">Shoreline oil</th></tr>
<tr><td colspan="2">Exposure values</td><td>Description</td><td>Appearance</td></tr>
<tr><td>Low</td><td>10 g/m^2</td><td>Predicts potential for some socio-economic impact</td><td>10 mL of oil per m^2 (2 teaspoons)</td></tr>
<tr><td>Moderate</td><td>100 g/m^2</td><td>Loading predicts area likely to require clean-up effort</td><td>May range from 1mm thick coating over approximately 1m^2

Approximately 100mL of oil per m^2</td></tr>
<tr><td>High</td><td>1000 g/m^2</td><td>Loading predicts area likely to require intensive clean-up effort</td><td>Approximately 1L of oil per m^2</td></tr>
</table>

Water column				
Exposure values *			Description	Appearance
Dissolved	Low	10ppb	Establishes planning area for scientific monitoring based on potential for exceedance of water quality triggers	No visible oil
	Medium	50ppb	Approximates potential toxic effects, particularly sublethal effects to sensitive species	
	High	400ppb	Approximates toxic effects including lethal effects to sensitive species	
Entrained	Low	10ppb	Establishes planning area for scientific monitoring based on potential for exceedance of water quality triggers	
	High	100ppb	As appropriate given oil characteristics for informing risk evaluation	
References			Bridges et al, 2018; French McCay, D, 2016; French McCay, D, 2018.	

**These refer to instantaneous concentrations, where instantaneous would be generally be determined by the model time step. Contemporary models used to inform risk assessments generally utilise a 1 hr time-step.*

References

Bonn Agreement Oil Appearance Code (BAOAC) Jan 2004. Available online at: https://www.bonnagreement.org/publications

Bridges, KN, Krasnec, MO, Magnuson, JT, Morris, JM, Gielazyn, ML, Chavez, JR, Roberts, AP. Influence of Variable Ultraviolet Radiation and Oil Exposure Duration on Survival of Red Drum (*Sciaenops ocellatus*) larvae, Environmental Toxicology and Chemistry 37(9), pp 2372–2379, 2018.

French McCay, D., Potential Effects Thresholds for Oil Spill Risk Assessments, Proceedings of the 39th AMOP Technical Seminar, Environment and Climate Change Canada, Ottawa, ON, pp. 285-303, 2016.

French-McCay, D, Crowley,D Rowe JJ,Bock, M, Robinson, H, Wenning, R, Hayward Walker, A, Joeckeld, J, Nedwede, JT, Parkerton, TF, Comparative Risk Assessment of spill response options for a deepwater oil well blowout: Part 1. Oil spill modelling, Marine Pollution Bulletin 133, pp 1001-1015, 2018.