ARTICLE IN PRESS

Marine Pollution Bulletin xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Comparative Risk Assessment of spill response options for a deepwater oil well blowout: Part 1. Oil spill modeling

Deborah French-McCay[a,*], Deborah Crowley[a], Jill J. Rowe[a], Michael Bock[b], Hilary Robinson[c], Richard Wenning[b], Ann Hayward Walker[d], John Joeckel[d], Tim J. Nedwed[e], Thomas F. Parkerton[f]

[a] *RPS ASA, South Kingstown, RI, USA*
[b] *Ramboll, Portland, ME, USA*
[c] *Ramboll, Arlington, VA, USA*
[d] *SEA Consulting Group, Cape Charles, VA, USA*
[e] *ExxonMobil Upstream Research Company, Spring, TX, USA*
[f] *ExxonMobil Biomedical Sciences, Spring, TX, USA*

A R T I C L E   I N F O

Keywords:
Oil fate modeling
Oil exposure modeling
Gulf of Mexico
Net Environmental Benefit Analysis
Oil spill response
Subsea dispersant injection

A B S T R A C T

Oil spill model simulations of a deepwater blowout in the Gulf of Mexico De Soto Canyon, assuming no intervention and various response options (i.e., subsea dispersant injection SSDI, in addition to mechanical recovery, in-situ burning, and surface dispersant application) were compared. Predicted oil fate, amount and area of surfaced oil, and exposure concentrations in the water column above potential effects thresholds were used as inputs to a Comparative Risk Assessment to identify response strategies that minimize long-term impacts. SSDI reduced human and wildlife exposure to volatile organic compounds; dispersed oil into a large water volume at depth; enhanced biodegradation; and reduced surface water, nearshore and shoreline exposure to floating oil and entrained/dissolved oil in the upper water column. Tradeoffs included increased oil exposures at depth. However, since organisms are less abundant below 200 m, results indicate that overall exposure of valued ecosystem components was minimized by use of SSDI.

1. Introduction

Subsea dispersant injection (SSDI) was a new oil spill response method first deployed to mitigate the effects of a deepwater oil-well blowout during the Deepwater Horizon incident in 2010. Since then, a significant amount of research has been completed to understand how injecting dispersants into a jet of oil released in deepwater modifies the oil fate (Brandvik et al., 2016, 2017; Nedwed, 2017). This and other research has been used to validate near-field blowout and oil spill transport and fate models that predict the volume and location of water that will contain oil above a specified concentration, the thicknesses and locations of surface oil, and the amount and locations of oil that could strand on shorelines with and without SSDI application (French-McCay, 2003, 2004; French-McCay and Rowe, 2004; Spaulding et al., 2015, 2017; French-McCay et al., 2015, 2016, 2018a,b,c; Li et al., 2017a,b). Further, these models can be used to estimate how application of various oil spill response methods or combinations of methods modify the fate of the oil (e.g., USCG, 2009; French-McCay et al., 2004, 2005; Buchholz et al., 2016). A logical next step to guide response decisions is combining the results of oil spill modeling with a method for quantifying the exposure and recovery of various valued ecosystem components (VECs) that could potentially be exposed to oil. That is, a well-constructed methodology would allow a quantitative comparison of exposure and recovery of organisms within an ecosystem to a hypothetical oil spill depending on the oil released, the magnitude and location of the release, the environmental conditions present during the release, and the response strategy.

For this reason, we developed a Comparative Risk Assessment (CRA) approach to combine predictions from an oil spill fate model with a novel method of quantifying valued ecosystem component (VEC) exposures and recovery to evaluate an offshore deepwater well-control incident in order to identify an oil spill response strategy (including considering SSDI) that would minimize relative risks to local organisms, reduce exposure of surface dwelling wildlife and response workers to volatile organic compounds (VOCs), and minimize socioeconomic disturbance. The approach was used to evaluate the implications of various response strategies, i.e., no intervention, mechanical recovery, in-situ burning (ISB), surface dispersant application, and SSDI at the

DOI of original article: http://dx.doi.org/10.1016/j.marpolbul.2018.02.057

* Corresponding author.
E-mail address: debbie.frenchmccay@rpsgroup.com (D. French-McCay).

https://doi.org/10.1016/j.marpolbul.2018.05.042
Received 16 December 2017; Received in revised form 24 April 2018; Accepted 22 May 2018

Please cite this article as: French-McCay, D., Marine Pollution Bulletin (2018), https://doi.org/10.1016/j.marpolbul.2018.05.042

source, individually and in combination. Stakeholders typically accept the use of mechanical recovery equipment when it is feasible and available. However, both the use of ISB and dispersants usually require more in-depth analysis of potential trade-offs. This study endeavored to inform that decision-making process, specifically with respect to SSDI for deep-sea blowouts, using a quantitative approach based on state-of-the-art scientific understanding.

Thus, the overall objective of the study was to develop an approach to provide decision makers with science-based and transparent information to enable technically-sound choices regarding appropriate strategies for mitigating impacts from oil and gas released during a deepwater blowout. The goal of this modeling-based analysis was to quantitatively evaluate each of the considered response strategies to facilitate a comparison in order to select the most effective response that minimizes long-term impacts. The approach was first to use probabilistic modeling to evaluate the influence of variable metocean conditions (i.e., meteorological and oceanographic conditions, such as winds, currents, salinities, and temperatures, present during the spill) on oil trajectory and fate. Using individual runs representative of specific metocean conditions, several different modeling simulations and combinations of response options were compared to quantify oil fate, the amount of oil surfaced as opposed to dispersed, and the area or volume of different surface and subsurface environmental compartments in which predicted exposure concentrations exceeded screening thresholds for potential effects. The objective was not to perform an impact assessment of the Deepwater Horizon (DWH) or any other (hypothetical) spill, rather a Comparative Risk Assessment methodology was used to compare the benefits of various oil spill response options using relative exposure metrics. This work was undertaken in consultation with a large group of stakeholders who provided input and guidance on all aspects of the modeling, input assumptions and assessment. This process and the connections between the modeling, the Comparative Risk Assessment, and stakeholder engagement are depicted in Fig. 1.

In this paper, we describe the oil spill modeling portion of a project to complete a CRA for an offshore deepwater blowout in the Gulf of Mexico. The companion paper by Bock et al. (Part II, 2018) describes how the oil spill modeling was used to develop exposure metrics that quantified the relative portions of the VEC populations exposed in a pre-defined model domain, as well as the relative time scales over which exposed VECs would recover. The approach utilizes: (1) the surface areas or water volumes and days of exposure above threshold concentrations, which are estimated by the oil spill modeling; (2) the relative density distributions of valued ecosystem components (VECs) across environmental compartments (ECs), which determines the fraction of the VEC in the domain evaluated that would be exposed; (3) the relative ability of the VECs to recover; and (4) the relative weights implicitly or explicitly given to VECs and ECs that are applied by the decision-maker or his/her advisor when comparing the modeled exposures. A third paper by Walker et al. (Part III, 2018) describes the engagement process used to guide the project as it progressed and then present results to and solicit feedback from external stakeholders upon completion.

2. Methods

2.1. Oil spill models

Oil and gas discharged subsea typically starts as a jet and then behaves as a buoyant plume (Fig. 2), which gradually loses buoyancy as it entrains ambient seawater and cools, and as the gas within it dissolves or escapes as bubbles. Due to the ambient density gradient in the ocean, the buoyant plume is arrested, or "trapped", as it rises through the water column, and one or more intrusion layers form, typically within a few hundred meters above the release point (Socolofsky et al., 2011, 2015). The initial jet/plume breakup into gas bubbles and oil droplets is believed to occur very close to the source, and is simulated by a droplet size distribution model, either based on empirical equations (e.g., Johansen et al., 2013; Li et al., 2017a) or dynamic population evolution models (e.g., Bandara and Yapa, 2011; Zhao et al., 2014). The oil droplets are released from the intrusion(s) and transition to a Lagrangian particle transport phase in the far field (Socolofsky et al., 2015).

In this work, oil spill trajectory and fate modeling was performed

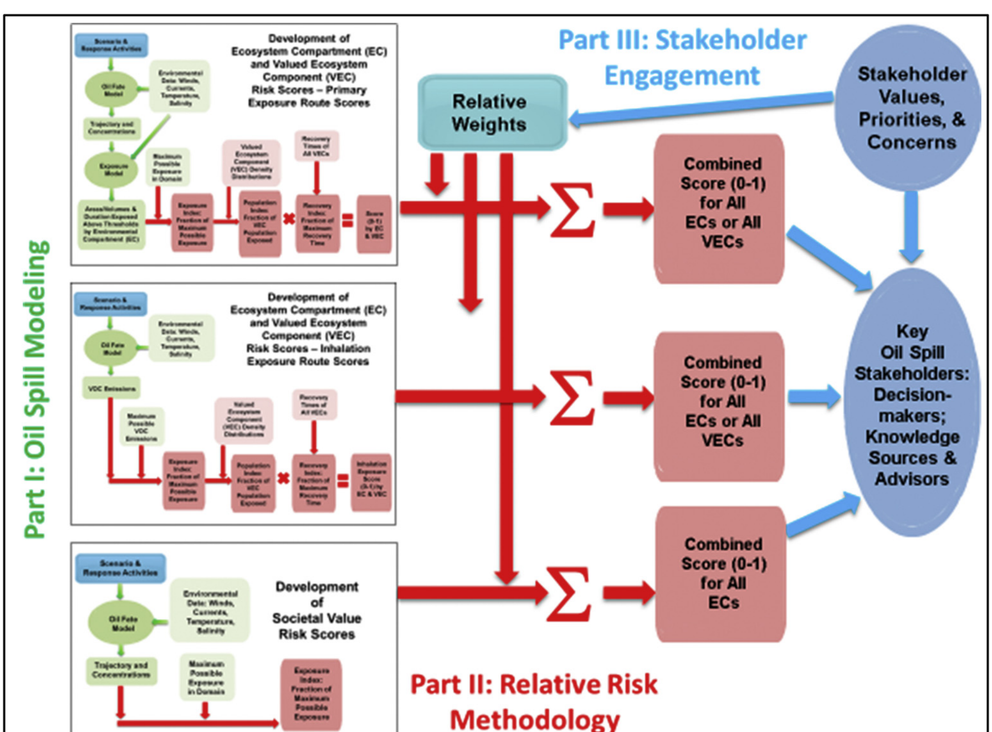

Fig. 1. Schematic of the Comparative Risk Assessment (CRA) methodology. The oil spill fate and exposure modeling (three purple boxes containing detailed flow charts) is described herein as Part I of the study. The relative risk methodology is described by Bock et al. (Part II, 2018). The stakeholder engagement process is described by Walker et al. (Part III, 2018). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)