**Great Australian Bight
Exploration Program**

Great Australian Bight
Exploration Drilling Program
Stromlo-1 and Whinham-1

FATE AND EFFECTS OIL SPILL MODELLING ASSUMPTIONS, PARAMETERS AND RESULTS

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1. Introduction

Important notice

This report is published for public information purposes. It contains the inputs to, and results of, oil spill modelling which has been conducted by BP to inform its impact assessment analysis and its planning of oil spill response strategies to support preparedness for safe and compliant exploration drilling in the Great Australian Bight.

For a number of reasons, it should not be read as a reliable prediction of potential future outcomes:

- The modelling assumes that a Worst Credible Discharge has taken place. None of the measures designed to prevent this from happening are considered as part of this report.
- The modelling assumes that no attempts to control, contain, disperse or recover an oil spill are attempted. The fact that all of these measures would be employed in an actual spill event is not considered in this report.
- Careful consideration needs to be given to the distinction between stochastic and deterministic modelling and to understand that stochastic modelling is not generating a picture of an oil spill.

BP Developments Australia Pty Ltd (BP) proposes to drill two exploration wells in Commonwealth marine waters in the Great Australian Bight (GAB): Stromlo-1 and Whinham-1.

The Great Australian Bight Exploration Drilling Program (Stromlo-1 and Whinham-1) Environment Plan (EP) (Rev 0) and The Great Australian Bight Exploration Drilling Program Oil Pollution Emergency Plan (OPEP) (Rev 0) were submitted to the National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) on 18 August 2016.

In order to inform the EP and OPEP, BP commissioned an independent expert consultancy to model the oil spill trajectories which could result from a Worst Credible Discharge (WCD) for either of the Stromlo-1 and Whinham-1 wells.

The scope of the oil spill modelling is to examine the potential risk of exposure to the surrounding waters (surface and subsurface) and contact to shorelines for three distinct seasons;

(i) summer (October to the following March),

(ii) the transitional periods (April and May) and

(iii) winter (June to September).

Oil spill models have a useful purpose in guiding response plans, but also have limitations and can readily be misinterpreted. The purpose of the modelling is to provide an indication of the potential extent and magnitude of a spill to inform a qualitative risk assessment (in the EP) and oil spill response planning (in the OPEP). For the purposes of modelling, it has been assumed that no mitigation measures have been deployed in any of the scenarios that have been assessed, which is useful for planning purposes because of its inherent conservatism, but also illustrates why models can be misinterpreted if they are considered to be predictions of actual scenarios.

2. Model Description

Oil spill modelling was conducted using the ‘Spill Impact Model Application Package’ (SIMAP) which is designed to simulate the fate and effects of spilled hydrocarbons for surface or subsea releases.

The SIMAP trajectory model separately calculates the movement of the material that:

- is on the water surface (as surface slicks),
- in the water column (as either entrained whole oil droplets or dissolved hydrocarbons),
- has stranded on shorelines, or
- has precipitated out of the water column onto the seabed.

The model calculates the transport of surface slicks from the combined forces exerted by surface currents and wind acting on the oil. Transport of entrained oil (oil that is below the water surface) is calculated using the currents only.

A subsea blowout model, OILMAPDEEP was also used in the development of the oil spill modelling. The OILMAPDEEP model simulates the plume rise dynamics in two phases: the initial jet phase as oil and gas are released from the seabed; and the buoyant plume phase as the oil dissipates in the water column. The initial jet phase governs the plume dynamics directly above the release location and is predominately driven by the exit velocity of the spill volume. During this phase, the crude and gas droplet size distribution is calculated. Next, the rise dynamics are taken over by the buoyant nature of the plume, which controls the plume rise until the termination of the plume phase (known as the trapping depth). This is the depth at which there is no further rise of the plume, due to the loss of momentum of the gas and droplets and entrained water within the plume. At this point, the far-field model SIMAP is used to simulate the rise of the individual crude droplets due to their own buoyant nature.

There are two types of model simulations that can be generated in oil spill modelling: stochastic simulations and deterministic simulations. Both simulation types are used in different ways during the modelling process to inform the various stages of assessing the risk posed by the scenarios. Together, the two model types provide an indication of both likelihood and magnitude of any potential effects.

Stochastic Modelling

Stochastic modelling is used to predict the probability of sea surface, shoreline or water column oiling that may occur following a spill event. This type of modelling accounts for the variability of metocean conditions in the study area over the anticipated operational period to provide insight into the probable behaviour of the potential spills. Stochastic modelling involves running numerous individual spill trajectory simulations using a range of prevailing wind and current conditions that are historically representative of the season and location of where the spill event may occur. The trajectory results are then combined to produce statistical outputs that include the probability of where oil might travel and the time taken for the oil to reach a given shoreline. The stochastic model output does not represent the extent of any one oil spill event (which would be substantially smaller) but rather provides a summary of the total individual simulations for a given scenario or oil type. Stochastic models are used for emergency response planning purposes.

For the stochastic modelling presented below, 100 single spill trajectories per season/scenario were simulated using the same spill information (release location, spill volume, duration and oil type) but with varied start dates and times. During each simulation, the model records the grid cells exposed by the spill trajectory, as well as the time elapsed. The model combines the results of all 100 spill trajectories to determine the following:

- Probability of oil exposure on the sea surface;
- Minimum time before oil exposure on the sea surface;
- Zones of potential oil exposure on the sea surface;

- Probability of oil contact to shorelines;
- Maximum potential oil loading to shorelines;
- Probability of entrained hydrocarbon exposure;
- Zones of potential entrained hydrocarbon exposure;
- Probability of dissolved aromatic exposure; and
- Zones of potential dissolved aromatic exposure.

Deterministic Modelling

Deterministic modelling (or single spill trajectory analysis) is used to predict the fate (transport and weathering behaviour) of spilled oil over time under predefined hydrodynamic and meteorological conditions.

When carrying out deterministic modelling, the conditions that give rise to the simulation with the greatest shoreline oiling from the stochastic modelling are typically selected.

The examples of outcomes of deterministic modelling given below provide a reasonable approximation of what an oil spill could look like under certain prevailing conditions, but not the probability of those conditions being prevalent. Conversely, stochastic modelling provides a probabilistic analysis but not an accurate prediction of what an individual spill could look like.

3. Hydrodynamic and Wind Data

The GAB is a large open body of water located offshore Western Australia and South Australia, and forms part of the south-eastern Indian Ocean. The varied geography and bathymetry of the region, in addition to the forcing of the south-eastern Indian Ocean and local meteorology lead to complex shelf and slope circulation patterns (Middleton and Bye, 2007). To accurately account for the movement of oil, it is necessary to include the influence of ocean and tidal currents as part of the study.

Ocean Currents

3D ocean current data from 2011 to 2015 (inclusive) was obtained from the Hybrid Coordinate Ocean Model (HYCOM), which is operated by the HYCOM Consortium, and sponsored by the Global Ocean Data Assimilation Experiment. HYCOM is a three-dimensional ocean model and is self-validating, meaning that it automatically integrates actual observations of sea surface heights, sea surface and in-situ temperatures and salinity measurements (Chassignet et al. 2009). Hence, the automatic integration of available measurements makes these latest generation ocean models more reliable than traditional models.

Tidal Currents

Tidal current inputs were generated using RPS Applied Science Associates (RPS ASA) advanced ocean/coastal model, HYDROMAP. The HYDROMAP model has been thoroughly tested and verified using field measurements throughout the world over the past 26 years.

HYDROMAP tidal current data has been used as input to forecast (in the future) and hind cast (in the past) condensate spills in Australian waters and forms part of the Australian National Oil Spill Emergency Response System operated by the Australian Maritime Safety Authority (AMSA).

Wind Data

Wind data from 2011 to 2015 (inclusive) was sourced from the National Centre for Environmental Prediction Climate Forecast System Reanalysis (CFSR). The CFSR wind model includes observations from many data sources: surface observations, upper-atmosphere air balloon observations, aircraft observations and satellite observations. The model is capable of accurately representing the interaction between the earth's oceans, land and atmosphere.

4. Ocean Temperature and Salinity

To accurately represent the water column temperature and salinity within the region, the monthly temperature and salinity values for the two exploration wells was obtained from the World Ocean Atlas 2013 database produced by the National Oceanographic Data Centre (National Oceanic and Atmospheric Administration) and its co-located World Data Centre for Oceanography.

The World Ocean Atlas 2013 is a set of objectively analysed (1° grid) fields of in situ parameters (e.g. temperature, salinity and dissolved oxygen) at standard depth levels for annual, seasonal, and monthly periods for the global oceans. The dataset represents the largest collection of restriction-free ocean profile data available internationally.

5. Model Inputs

The model settings and assumptions used in the modelling are summarised in Table 1.

Table 1 - Model settings and assumptions

Relief well scenario (149-day release duration), stochastic modelling	
Permit block	EPP 39
Water depth	2,250 m
Release location	Seabed (blowout from wellhead scenario)
Release season	All seasons modelled. The assessment was completed for three distinct 'seasons': • Winter - June to September • Summer - October to March • Transitional -April and May
Release duration	149 days (see below)
Number of simulations	100 per season
Simulation period	209 days

Spill Scenario

Although multiple potential spill scenarios have been considered, the most significant spill event in terms of potential adverse impacts has been identified and considered (the worst credible discharge (WCD) scenario). The WCD scenario is used to inform both impact assessment and oil spill response planning, as it provides the worst case in terms of potential impact and required response resources.

The scenario that has been classified as the WCD for the drilling program is a major release of unstabilised crude oil or condensate as a result of a loss of well control (ie a blowout). A loss of well control from both Stromlo-1 and Whinham-1 were modelled. Due to differences in predicted reservoir properties between Whinham-1 and Stromlo-1, results from Whinham-1 predicted a significantly smaller area of exposure for surface, in-water and shoreline hydrocarbons when compared with the results from Stromlo-1. Thus, Stromlo-1 was used as the base-case 'WCD scenario' for impact assessment and oil spill response planning.

There are a number of factors that are used as input into defining the WCD scenario, including duration of release, release rate and hydrocarbon characteristics.

Duration of release

In the event of a loss of well control event, it is BP's intention to initiate multiple source control measures, including direct BOP intervention activities, well capping activities and relief well drilling operations.

The availability of these multiple response options gives BP confidence that flow from a well blowout would be stopped in less than 35 days of a loss of well control event occurring. Once the well is closed in, further discharge of hydrocarbons into the marine environment is prevented while the well is permanently controlled (via a relief well or top kill).

However, for the sake of the WCD assessment, the duration of release for a loss of well control event is based on the time it would take to drill a relief well and kill the blowout. In accordance with the relief well plans provided in the WOMP and accepted by NOPSEMA, BP have determined a realistic and achievable time to drill a relief well is 149 days. It should be noted however, that although a relief well is required to permanently kill the well, other control measures and response techniques such as BOP closure via remotely operated vehicle (ROV) intervention or the deployment and engagement of a capping stack may significantly reduce the release duration. Therefore, the use of a 149 day spill duration is considered to present a conservative modelling scenario.

Note that, while the duration of the release is 149 days, the model was run for a longer duration of 209 days to map the trajectory of oil after release.

Release rate

The WCD rate from a well is determined based on a range of factors, including predicted rock properties of the formations to be penetrated such as porosity, permeability, temperature and pressure. The WCD rate for the GAB exploration wells was calculated by BP subject matter experts following the methodology outlined in BP's proprietary engineering practices.

Hydrocarbon characteristics

Given that Stromlo-1 and Whinham-1 are exploratory wells, the exact nature of the hydrocarbons that may be encountered are unknown. As none of the wells drilled previously in proximity to these wells encountered hydrocarbons, there are no hydrocarbons to be assayed to determine likely characteristics of these wells. Therefore, petroleum fluid properties have been predicted using a petroleum system analysis approach. These hydrocarbon characteristics were then compared to those of known produced oils (contained in a crude oil assay database).

The most appropriate analogue oils were selected from a survey of oils contained in the SINTEF oil weathering database and CrudeSuite oil assay database. Given the predicted oil properties, the Snorre Tension Leg Platform (TLP) oil has been chosen as the best analogue oil for Stromlo-1, and Cossack as an analogue for the gas condensate of Whinham-1.

6. Response and Impact Thresholds

Following a spill, it is expected that oil will rise through the water column and once on the surface spread across the waters. The SIMAP model is able to track hydrocarbons to levels lower than biologically significant or visible to the naked eye. Therefore, reporting thresholds have been specified (based on the scientific literature) to account for exposure on the sea surface and contact to shorelines at meaningful levels. Results at low, moderate and high threshold levels have been presented for the sea surface, shoreline and in the water column (Table 2).

A 'low' or minimum threshold is considered below levels which would cause environmental harm and are more indicative of the areas perceived to be affected due to its visibility on the sea surface/shoreline. This low threshold can also be referred to as the social threshold. A 'moderate' threshold has been identified as potentially resulting in ecological impacts. A 'high' threshold has also been presented and is indicative of oil levels that are amenable to oil spill response measures. This threshold is used for oil spill response planning, but not for impact assessment purposes.

Surface exposure

The minimum reporting threshold for each spill trajectory was 1 g/m^2, which equates to an average thickness of approximately 1 µm. Oil of this thickness is described as a rainbow sheen in appearance, according to the Bonn Agreement Oil Appearance Code (Bonn Agreement 2009) and is close to the practical limit of observing oil in the marine environment (AMSA 2012). Furthermore, this threshold is considered below levels which would cause environmental harm and it is more indicative of the areas perceived to be affected due to its visibility on the sea surface and potential to trigger temporary closures of areas (eg fishing grounds) as a precautionary measure.

Ecological impact has been estimated to occur at 10 g/m^2 (approximately 10 µm) according to French et al. (1996) and French-McCay (2009) as this level of oiling has been observed to mortally impact some birds and other wildlife associated with the water surface. The appearance is described as a metallic sheen (Bonn Agreement, 2009).

In-water exposure

The in-water exposure to receptors is represented by entrained and dissolved aromatic hydrocarbons.

The threshold value for species toxicity in the water column is based on global data from French et al (1999) and French-McCay (2002, 2003), which showed that species sensitivity (fish and invertebrates) to dissolved aromatics exposure > 4 days (96-hour LC_{50}) under different environmental conditions varied from 6 to 400 µg/l (ppb) with an average of 50 ppb. This range covered 95% of aquatic organisms tested, which included species during sensitive life stages (eggs and larvae). Based on scientific literature (eg Tsvetnenko, 1998), a minimum threshold of 6 parts per billion (ppb) over 96-hours or equivalent was used to assess in-water low exposure zones. French-McCay (2002) indicates that an average 96 hour LC_{50} of 50 ppb and 400 ppb could serve as an acute lethal threshold to 5% and 50% of biota, respectively. Hence, the thresholds were used to represent the moderate and high exposure zones, respectively.

While dissolved aromatics are the largest contributor to the toxicity of solutions generated by mixing hydrocarbons into water, it is still important to model the fate of entrained hydrocarbons because they are the mechanism of delivering soluble aromatics to the water column.

Exposure thresholds used to assess entrained hydrocarbon exposure were based on OSPAR guidelines. OSPAR has published a predicted no effect concentration (PNEC) for produced formation water (PFW) which accounts for the dispersed fractions of oil which is more representative of entrained oil droplets. The OSPAR PNEC is 70 ppb (median estimate (50% confidence) at 5% of the hazardous concentration (HC_5)) and is based on biomarker and whole organism testing to total hydrocarbons (THC) by Smit et al. (2009). This PNEC represents an acceptable long term chronic exposure level from continuous point source discharges in the North Sea, which is one of the most concentrated areas in the world for oil and gas production. The chronic effect concentrations examined in Smit et al. (2009) are based on effects ranging from oxidative stress and DNA damage to impacts on growth, reproduction and survival. An appropriate threshold value can be extrapolated from the effect concentrations examined in Smit et al. (2009) to indicate an appropriate acute threshold, which has been set at 700 ppb. Results are presented based on dosage (concentration vs duration).

Shoreline contact

In previous risk assessment studies, French-McCay et al. (2005a; 2005b) used a threshold of 10 g/m^2 to assess the potential for shoreline contact. This is a conservative threshold used to define regions of socio-economic impact, such as triggering temporary closures of adjoining fisheries or the need for shore clean-up on beaches or man-made features/amenities (breakwaters, jetties, marinas, etc.). It would equate to approximately 2 teaspoons of oil per square meter of shoreline contacted. The appearance is described as a stain/film. On that basis, the 10 g/m^2 shoreline contact threshold has been selected to define the zone of potential 'low shoreline contact' or 'social impact' zone.

French et al. (1996) and French-McCay (2009) have defined an oil exposure threshold for shorebirds and wildlife (fur bearing aquatic mammals and marine reptiles) on or along the shore at 100 g/m^2, which is based on studies for sub-lethal and lethal impacts. This threshold has been used in previous environmental risk assessment studies (eg French-McCay et al. 2011; 2012; NOAA 2013). The 100 g/m^2 shoreline contact threshold is also recommended in the AMSA foreshore assessment guide as the acceptable minimum thickness that does not inhibit the potential for recovery and is best remediated by natural coastal processes alone (AMSA 2007). It equates to approximately half a cup of oil per square meter of shoreline contacted. The appearance is described as an oil coat. Therefore, 100 g/m^2 has been selected to define the zone of potential 'moderate shoreline contact' or 'ecological impact' zone.

Table 2 – Summary of oil spill modelling thresholds

Zone	Surface Threshold	In-water Threshold	Shoreline Threshold
Social - Potential for reduction in intrinsic values / visual aesthetics (low level)	1 g / m^2	11,760 ppb-hrs (entrained) 576 ppb-hrs (dissolved)	10 g / m^2
Ecological - Potential Toxicity effects / Physical Oiling (moderate level)	10 g / m^2	67,200 ppb-hrs (entrained) 4,800 ppb-hrs (dissolved)	100 g / m^2
Spill response – Potential for effective spill response on surface waters and shorelines (high level)	> 25 g/m^2	676,800 ppb-hrs (entrained) 38,400 ppb-hrs (dissolved)	1000 g/m^2

7. Modelling Results

A loss of well control event at Stromlo-1 is characterised at the outset as a continual flow of oil from the well, rising through the water column with some lateral spreading and movement influenced by sub-sea currents, with a majority of oil droplets rising to coalesce at the sea surface. The oil will undergo weathering, a series of physical and chemical changes, involving principally evaporation, spreading out, dissolution, emulsification, biodegradation and breaking up into patches under the action of currents and wind. The oil will continue to move on the water surface until eventually some amounts reach discrete parts of the shore along a wide stretch of the southern Australian coastline.

Stochastic Results

The stochastic model output does not represent the extent of any one oil spill event (this is illustrated by deterministic results, discussed below) but rather, provides a summary of all the predicted individual simulations. Stochastic modelling results are therefore used to determine the probability of spill direction based on these aggregated results. Results can be analysed to predict the probability of hydrocarbons contacting specific areas. For the GAB oil spill modelling, the specific areas examined included Commonwealth Marine Reserves (CMRs); Key Ecological Features (KEFs), Biologically Important Areas (BIAs) and coastal settlements.

Stochastic modelling predicts that there is the potential for highest exposure of sea surface oil close to the source and extending across a significant proportion of the GAB, as well as in the nearshore waters adjacent to Port Lincoln to Mt Gambier on the South Australian (SA) coast and along the south eastern coast of Western Australia (WA). The potential for exposure to high levels of in-water oils are limited close to the source, with moderate levels extending to around 50km from the source. Areas of low levels of in-water exposure extend approximately 200 km from the source, however with limited exposure to nearshore areas. The highest areas of shoreline exposure include the south east coast of WA and Mount Gambier region of SA.

It should be noted that these results are for ‘no response’ scenarios (i.e., no oil spill response measures are deployed). In reality, a number of response measures would be deployed, such as dispersant application and mechanical recovery. These results are therefore considered as highly conservative.

Sea Surface

Sea surface trajectories are predicted to drift in any of a range of directions, but they extend out more towards the east and south-east. Table 3 summarises the maximum distances travelled by spills from the release site over 209 days to varying levels of oil exposure on the sea surface for each season. When tracked to the low exposure (rainbow to metallic sheen) the maximum distance travelled by a spill from Stromlo-1 was approximately 2,650 km in an easterly direction for all seasons. When tracked to the moderate exposure (metallic sheen) the maximum distance travelled ranged from approximately 2,330 km – 2,630 km in an easterly direction (all seasons).

Table 3 - Greatest distances and directions of sea surface exposure for each season. Results are calculated from 100 spill trajectories and tracked for 209 days. Note – results are with no oil spill response.

Season	Distance and direction	Exposure thresholds on the sea surface		
		Low	Moderate	High
Summer	Greatest distance travelled (km) by a spill trajectory	2,655	2,329	1,723
	99th percentile greatest distance travelled (km) by a spill trajectory	2,300	1,595	1,083
	Direction	East-Southeast	East	East
Transitional	Greatest distance travelled (km) by a spill trajectory	2,664	2,494	2,470
	99th percentile greatest distance travelled (km) by a spill trajectory	2,426	1,931	1,365
	Direction	East	East	East
Winter	Greatest distance travelled (km) by a spill trajectory	2,660	2,633	2,256
	99th percentile greatest distance travelled (km) by a spill trajectory	2,345	1,820	1,284
	Direction	East	East	East-Southeast

The probability and minimum time before exposure to hydrocarbons on the sea surface for range of receptors have been assessed. For the CMRs, Western Eyre and GAB (Special Purpose Zone and Marine National Park Zone) CMR's were predicted to record the greatest probability of exposure at the moderate sea surface threshold ranging between 69 - 87% and 53 - 84%, respectively, depending on the commencement season. The spill trajectories were predicted to reach the CMR boundaries in a minimum of 6.4 and 10 days for Western Eyre and GAB, respectively.

The probability of moderate exposure to Kangaroo Island Pool, canyons, adjacent shelf break, and Eyre Peninsula upwellings ranged between 68% for spills commencing summer and 100% for spills commencing in transitional conditions. A number of BIA's are predicted to have a high probability of contact with surface hydrocarbons, including sperm whale, pygmy blue whale, sea lion, fairy tern, Pacific gull, short tailed shearwater and white-faced storm-petrel.

The probability of spill trajectories reaching SA and WA coastal waters at the moderate sea surface threshold ranged between 63 - 100% and 9 - 60% respectively, depending on the commencement season. It took a minimum of 13.1 days for the trajectories to reach the SA coastal waters (spills commencing in winter) and 23.5 days to reach the WA coastal waters (spills commencing in summer).

Shoreline

Regardless of the commencement season, there was a 100% predicted probability of shoreline contact at the low (10 g/m^2 or film/stain), moderate (100 g/m^2 or coat) and high (1,000 g/m^2 or cover) thresholds. The minimum time before shoreline loading at the low threshold was 9.2 days based on spills commencing in winter compared to 18.7 days in summer. The highest maximum volume of crude ashore occurred for a spill commencing in winter and the greatest average volume of crude ashore resulted from spills commencing in transitional months.

For spills commencing during summer the shorelines between Elliston to Coffin Bay (low: 97%, moderate 96% and high 89%) and Kangaroo Island (low 95%, moderate 95% and high 93%) recorded the greatest probability of contact. The minimum time before low shoreline loading was 19 days between Elliston to Coffin Bay.

For spills commencing during transitional months, a 100% probability of low and moderate shoreline loading were predicted for: Elliston to Coffin Bay; Kangaroo Island; Streaky Bay; Port Lincoln; York Peninsula; Victor Harbour; Robe and Beachport; and Discovery Bay and Cape Otway. The minimum time before shoreline contact at the low threshold was predicted for the coastline between Elliston to Coffin Bay (17 days).

Winter commencing spills resulted in the greatest probabilities of shoreline contact to Elliston to Coffin Bay (low: 100%, moderate 100% and high 89%), Kangaroo Island (low 94%, moderate 94% and high 84%), Great Australian Bight Marine National Park (low: 97%, moderate 97% and high 79%) and Port Lincoln (low: 98%, moderate 98% and high 28%). The minimum time for low shoreline contact for Elliston to Coffin Bay was 9 days.

Table 4 - Summary of shoreline contact for each season for each threshold: relief well scenario (149 days) with no oil spill response.

Shoreline statistics	Summer			Transitional			Winter		
	Low (film/ stain)	Moderate (coat)	High (cover)	Low (film/ stain)	Moderate (coat)	High (cover)	Low (film/ stain)	Moderate (coat)	High (cover)
Probability of contact to any shoreline (%)	100	100	100	100	100	100	100	100	100
Absolute minimum time to shore (days)	18.7	18.8	22.8	16.5	16.5	21.0	9.2	10.0	14.5
Maximum volume of crude ashore (STB)	141,684			158,137			179,673		
Average volume of crude ashore (STB)	77,175			104,843			96,270		
Maximum length of shoreline contacted (km) at the low threshold	3,511			3,974			4,025		
Average length of shoreline contacted (km) at the low threshold	2,252			2,723			2,435		

Table 5 – Stochastic modelling results – summary of moderate shoreline contact: relief well scenario (149 days) with no oil spill response

Shoreline	Season	Probability of moderate shoreline contact	Minimum time before moderate shoreline contact (days)
Albany	Summer	14%	56
	Winter	23%	83
	Transitional	1%	203
Esperance	Summer	29%	39
	Winter	64%	61
	Transitional	7%	164

Great Australian Bight Marine National Park	Summer	20%	44
	Winter	97%	43
	Transitional	8%	183
Ceduna	Summer	17%	46
	Winter	56%	66
	Transitional	37%	29
Elliston to Coffin Bay	Summer	96%	19
	Winter	100%	10
	Transitional	100%	17
Port Lincoln	Summer	91%	37
	Winter	98%	15
	Transitional	100%	28
Yorke Peninsula	Summer	82%	51
	Winter	4%	102
	Transitional	100%	30
Adelaide	Summer	58%	66
	Winter	86%	20
	Transitional	97%	36
Kangaroo Island	Summer	95%	50
	Winter	94%	15
	Transitional	100%	27
Tasmania	Summer	46%	80
	Winter	19%	60
	Transitional	66%	61
Apollo Bay and Wilsons Promontory	Summer	56%	73
	Winter	70%	37
	Transitional	91%	61
New South Wales South Coast	Summer	3%	201
	Winter	41%	48
	Transitional	21%	110

Water column – Entrained and dissolved hydrocarbon exposure

The potential entrained hydrocarbon exposure (low threshold) at the 0–10 m depth layer was predicted to extended in a diameter approximately 500km around the well location (225-275 km from the release point). Results were relatively consistent between seasons, however the diameter of exposure was slightly higher in winter, and smallest in the transitional season. The modelling did not show any entrained hydrocarbon at the 50-100m and 150-200m layers.

The probability and minimum time before exposure to hydrocarbons entrained or dissolved in the water column for range of receptors have been assessed.

Few CMRs are predicted to be exposed to hydrocarbons at the 0-10 m water depth. Both GAB and Western Eyre CMRs have a low probability of exposure in all seasons and at all thresholds.

Few KEFs are predicted to be exposed to water column hydrocarbons at the low threshold. The KEF with the greatest probability of exposure to water column hydrocarbons was the Ancient coastline (with probabilities of exposure between 2-7%). With the exception of Kangaroo Island Pool, canyons, adjacent shelf break, Eyre Peninsula upwellings (1-2% probability of low exposure during all seasons) no other KEFs were predicted to experience exposure to water column hydrocarbons in the 50-100 m water depth.

During all three commencement seasons, the short-tailed shearwater BIA recorded the highest probability of low exposure to water column hydrocarbons (0-10 m water depth) varying between 57 - 100%. The probability of low exposure for the sperm whale BIA was predicted to be between 3-31% for all seasons, and for the pygmy blue whale BIA was 3-20% for all seasons.

Deterministic Simulation Results

One hundred spill trajectories were simulated per season, and tracked for a period of 209 days. The spill trajectory resulting in the highest volume of oil contacting shorelines was identified for each season, and is discussed below.

Summer

From the 100 simulations commencing in summer, the spill trajectory starting at 7pm on 7 March 2014 was identified as resulting in the greatest volume of oil on shorelines.

During the 209 days the crude on the water surface travelled predominantly east. Low shoreline loading was predicted to occur between Port Lincoln and Flinders Island. The longest stretch of shoreline with high loading was predicted between Cape Jaffa to Mount Gambier.

Transitional

From the 100 simulations commencing in transitional months, the spill starting at 4am on 28 April 2013 was identified as resulting in the greatest volume of oil on shorelines.

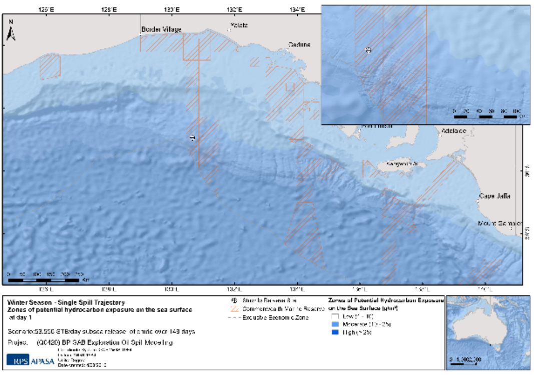
The spill trajectory predominately drifted east. Low shoreline loading was predicted to occur between Lake Newland (north of Port Lincoln) and north of Lakes Entrance. Note the shoreline loading was sporadic northeast of Flinders Island. The longest stretch of shoreline with high loading was predicted to occur north of Cape Jaffa and south of Mount Gambier.

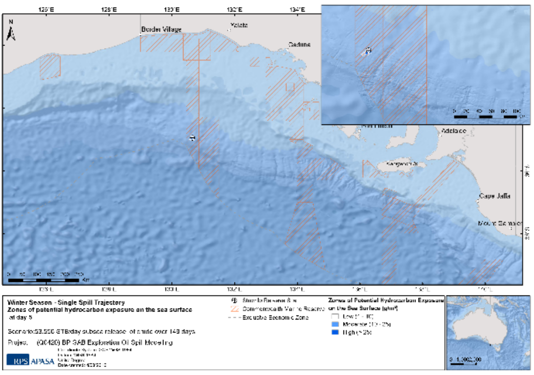
Winter

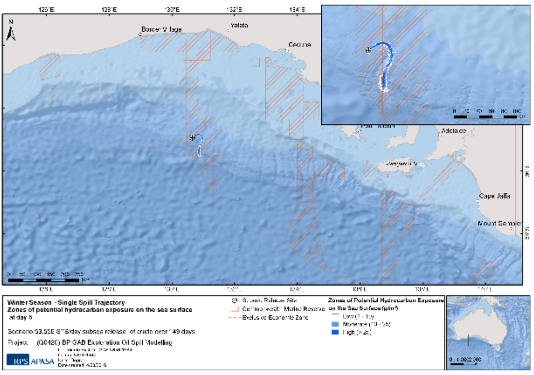
From the 100 simulations commencing in winter months, the spill starting at 2pm on 15 June 2013 was identified as resulting in the greatest volume of oil on shorelines.

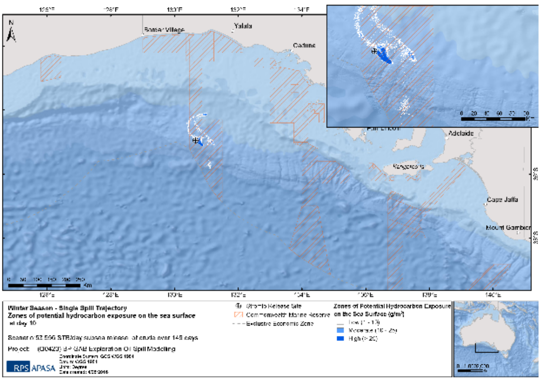
The crude on the sea surface predominantly drifted east, however, as the winds and currents changed direction high exposure zones were also predicted west towards Esperance. Low shoreline loading was predicted to between Lake Newland (north of Port Lincoln) and Flinders Island to the east. Additionally, contact above the reporting threshold was predicted for shorelines between Israelite Bay and Albany. High shoreline loading was predicted to occur mostly along the coastline north of Cape Jaffa and south of Mount Gambier.

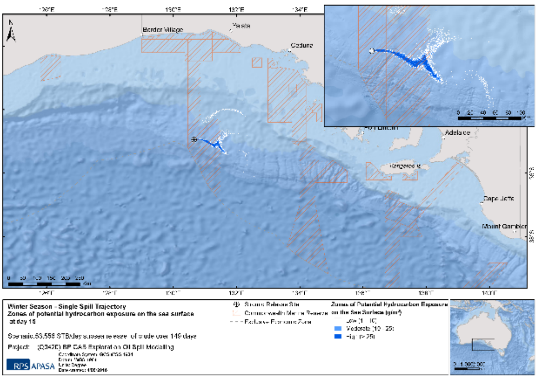
To further illustrate the fate and effects of a spill, a single trajectory (sea surface exposure during winter) is shown in Figure 1 at various time intervals: day 1, day 2, day 5, day 10, day 15, day 25, day 50, day 100 and day 150.

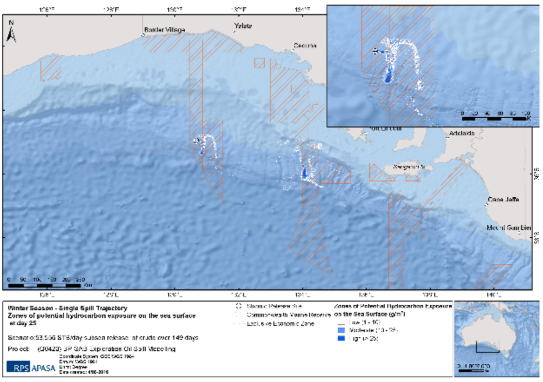












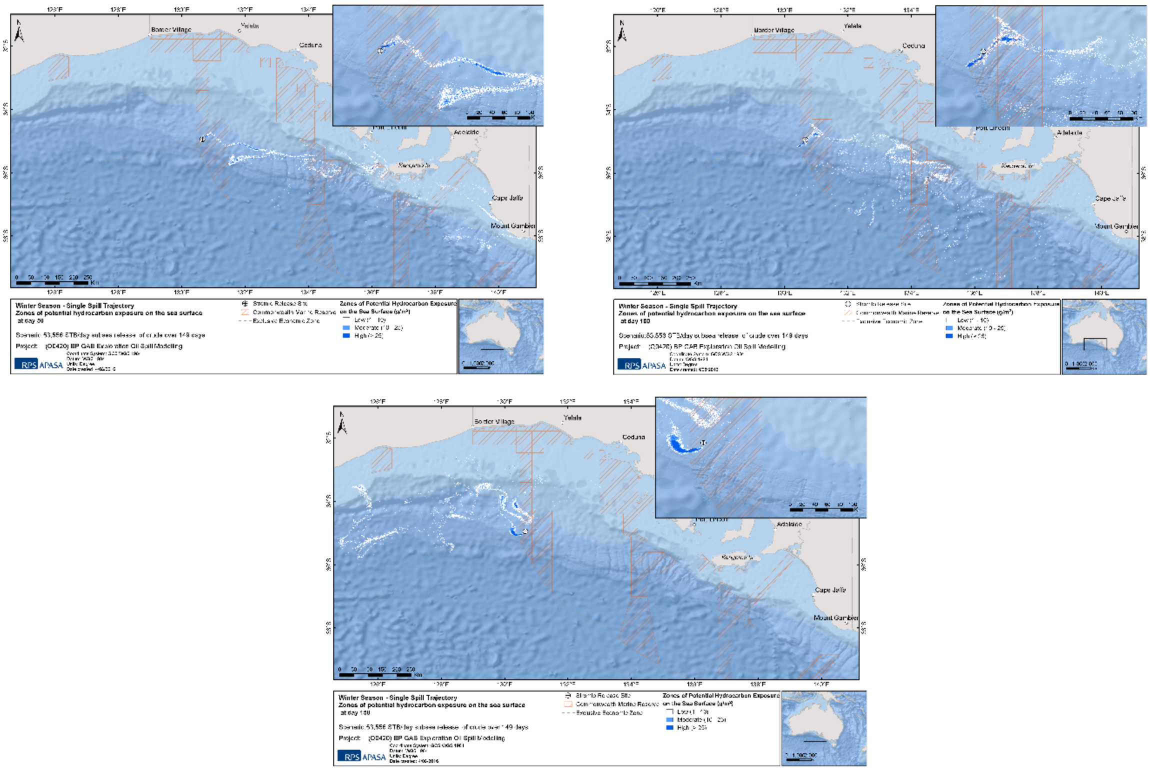


Figure 1 - Single spill trajectory showing sea surface exposure at various time intervals.

8. Utilisation of Modelling Results

The fate and effects oil spill modelling is used to predict both the probability of different geographical areas that may be contacted in the event of a spill, and the volume of oil that may contact these different areas.

This information is then utilised to conduct impact assessment (outlined in the Environment Plan) and to prepare oil pollution response plans (the Oil Pollution Emergency Plan and Tactical Response Plans). A summary of the Environment Plan and the response tactics that are available, and would be employed in the unlikely event of an oil spill, is provided on the GAB project website http://www.bpgabproject.com.au.

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