Environment plan Appendix 7-5 Risk assessment for unmitigated worst-case scenario

Stromlo-1 exploration drilling program

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Table of contents

Page

1.0 Background 1
1.1 Worst case vs worst credible case 1
1.2 WCD and dispersant application 2
1.3 Modelling outputs 3
1.4 Risk assessment 4
1.4.1 Offshore air quality 5
1.4.2 Seabirds 5
1.4.3 Shorebirds 7
1.4.4 Marine reptiles 8
1.4.5 Plankton 8
1.4.6 Fishes (bony fishes and sharks) 9
1.4.7 Marine mammals – pinnipeds 11
1.4.8 Marine mammals – cetaceans 13
1.4.9 Benthic invertebrates (other than corals) 15
1.4.10 Deepwater and other coral species 18
1.4.11 Benthic habitats 18
1.4.12 Mangroves and saltmarshes 20
1.4.13 Seagrass 21
1.4.14 Macroalgae 22
1.4.15 Shorelines 23
1.4.16 Coastal settlements 24
1.4.17 Protected areas (including AMPs, KEFs and Ramsar sites) 25
1.4.18 Socio-economic values 27
2.0 Figures 31
3.0 References 44

Figures

Figure 1.1: Extent of unmitigated plumes of dissolved oil at or above moderate effect thresholds for the worst-case discharge and worst credible case discharge scenarios 2
Figure 1.2: Extent of unmitigated plumes of entrained oil at or above moderate effect thresholds for the worst-case discharge and worst credible case discharge scenarios 3
Figure 1.3: Predicted weathering and fates graphs over the 189 day period. Based on the simulation resulting in the greatest volume of oil ashore commencing 26 April 2009 at 06:00 hrs. Modelling examined an average 8943 m^3/day subsea release of crude oil over 129 days tracked for 189 days 4
Figure 2.1 Zones of potential weathered sea surface hydrocarbon exposure (unmitigated) from 100 oil spill simulations in October to May from an average 8943 m^3/day subsea release of crude oil over 129 days, tracked for 189 days on shy albatross, little penguin and short tailed shearwater BIAs and breeding colonies 32
Figure 2.2 Maximum potential shoreline loading (g/m^2) from weathered oil (unmitigated) from 100 oil spill simulations in October to May from an average 8943 m^3/day subsea release of crude oil over 129 days, tracked for 189 days on little penguin and eastern curlew 33

Figure 2.3 Zones of potential weathered sea surface hydrocarbon exposure (unmitigated) from 100 oil spill simulations in October to May from an average 8943 m^3/day subsea release of crude oil over 129 days, tracked for 189 days on whales BIA and SBT distribution 34

Figure 2.4 Zones of potential entrained (ppb.hours) and dissolved (ppb.hours) hydrocarbon exposure (unmitigated and dispersant mitigated scenarios) in the 0-10 m layer below the sea surface from 100 oil spill simulations in October to May from an average 8943 m^3/day subsea release of crude oil over 129 days, tracked for 189 days on SBT distribution and great white shark BIAs 35

Figure 2.5 Maximum potential shoreline loading (g/m^2) from weathered oil (unmitigated) from 100 oil spill simulations in October to May from an average 8943 m^3/day subsea release of crude oil over 129 days, tracked for 189 days on Australian sea lion, New Zealand fur seal and Australian fur seal 36

Figure 2.6 Zones of potential entrained (ppb.hours) and dissolved (ppb.hours) hydrocarbon exposure (unmitigated and dispersant mitigated scenarios) in the 0–10 m layer below the sea surface from 100 oil spill simulations in October to May from an average 8943 m^3 subsea release of crude oil over 129 days, tracked for 189 days on AMPs, KEFs, deep water coral, macroalgae, and seagrass.....37

Figure 2.7 Zones of potential weathered sea surface hydrocarbon exposure (unmitigated) from 100 oil spill simulations in October to May from an average 8943 m^3/day subsea release of crude oil over 129 days, tracked for 189 days on mangroves, saltmarshes, and Ramsar wetlands 38

Figure 2.8 Maximum potential shoreline loading (g/m^2) from weathered oil (unmitigated) from 100 oil spill simulations in October to May from an average 8943 m^3/day subsea release of crude oil over 129 days, tracked for 189 days on mangroves, saltmarshes and Ramsar wetlands 39

Figure 2.9 Zones of potential weathered sea surface hydrocarbon exposure (unmitigated) from 100 oil spill simulations in October to May from an average 8943 m^3/day subsea release of crude oil over 129 days, tracked for 189 days on AMPs, KEFs, and coastal settlements 40

Figure 2.10 Zones of potential weathered sea surface hydrocarbon exposure (unmitigated) from 100 oil spill simulations in October to May from an average 8943 m^3/day subsea release of crude oil over 129 days, tracked for 189 days on defence areas, commercial fisheries, shipping traffic and SBT ranching.....41

Figure 2.11 Maximum potential shoreline loading (g/m^2) from weathered oil (unmitigated) from 100 oil spill simulations in October to May from an average 8943 m^3/day subsea release of crude oil over 129 days, tracked for 189 days on aquaculture leases, Heritage sites, Native Title determinations, ports 42

Figure 2.12 Probability of weathered oil contact to shorelines at or above the moderate threshold from 100 oil spill simulations in October to May from an average 8943 m^3/day subsea release of crude oil over 129 days, tracked for 189 days 43

1.0 Background

This appendix describes the risk review of the Worst-Case Discharge (WCD) scenario. It is based on an unrestricted, open hole, continuous spill at an average flow rate of 8943 m^3/day for 129 days with no mitigation. The assessment was undertaken by considering the potential presence of sensitive receptors and locations within the area where stochastic modelling has shown that pre-set thresholds have been triggered by any one or more of the 100 runs for the October to May period.

This extreme worst-case outcome of a major spill represents the upper limits of possible outcomes. It is an open-hole scenario with maximum reservoir flow rate; even though the drill pipe would be in-hole during reservoir exposure and therefore slower annulus flow would occur in a Loss of Well Control (LOWC). It is not generally considered a credible scenario in the industry; however, has been assessed herein to meet expectations outlined in NOPSEMA's Oil pollution risk management guidance note (GN1488 Rev 2; February 2018).

The time estimate for drilling a relief well at the Stromlo location was conservatively set at 129 days for the initial modelling. The initial modelling was used to set a very conservative Risk EMBA for response planning. The relief well response time was then reduced during the ALARP process as logistical plans were refined; this resulted in a reduced relief well time of 102 days. This was modelled as the maximum spill duration in the oil spill risk assessment in Rev 1 EP. The risk assessment in Section 7.7 of the EP is based on a credible scenario where the flow is through the annulus and the main mitigation strategy of applying dispersants subsea and at the surface has an effect on reducing the flow of oil to the sea surface (the worst credible case scenario, or WCCD).

For comparison, the worst case open-hole scenario with no mitigation has been assessed herein. The oil spill modelling report (Appendix 7-1) has been updated to provide more information on this scenario. The assessment herein is consistent with the WCCD assessment in Section 7.7 in terms of effect thresholds and assumptions used.

1.1 Worst case vs worst credible case

Key differences between the worst credible case discharge (WCCD) risk assessment in Section 7.7 and the current assessment of risks for the worst-case discharge (WCD) are:

- the flow rates for the WCD are higher (33% higher) than the more likely scenario (WCCD) of annulus flow
- the duration of 129 days for the WCD is considerably longer (by 26%) than the re-assessed time realistically required to drill a relief well of 102 days as modelled for the WCCD
- no mitigation of the spill by subsea and surface application of dispersants assumed in the WCD. In addition, no credit is taken for installing the Blow out Preventer nor the Capping Stack which are both designed to stop the flow of hydrocarbons
- the WCCD assessment is based on the original drilling period of October to May; however, the WCD assessment is based on the reduced drilling period, which now runs from November to April. Modelling assumes scenarios run in October and May - two months that have subsequently been dropped from the drilling schedule. May has metocean conditions resulting in runs with some of the highest volumes to shore and the quickest times to shore, which skews average statistics and contour locations towards more severe results.

Section 7 of the EP describes the impacts of dissolved and entrained oil for the WCCD (with dispersant) and Section 8 assessed the increase in exposure to dissolved and entrained oil for the WCCD as a result of chemical dispersion. The WCD modelling and risk assessment does not consider mitigation such as dispersant, hence quantification of increases of dissolved and entrained oil as a result of chemical dispersion for the WCD has not been modelled.

1.2 WCD and dispersant application

An additional review was undertaken by considering the receptors that may be exposed to a WCD if it were treated with dispersant. Upon reviewing and comparing the modelling results for the unmitigated WCD and unmitigated WCCD, it was found that although the surface exposure and shoreline loadings were different in extent and location, the areas exposed to dissolved and entrained hydrocarbons above the moderate thresholds were similar in size and location. Figure 1.1 and Figure 1.2 depict the dissolved and entrained plumes for an unmitigated WCD and an unmitigated WCCD scenario (overlaid so that the lower scenario is only visible in areas where it is larger than the upper scenario).

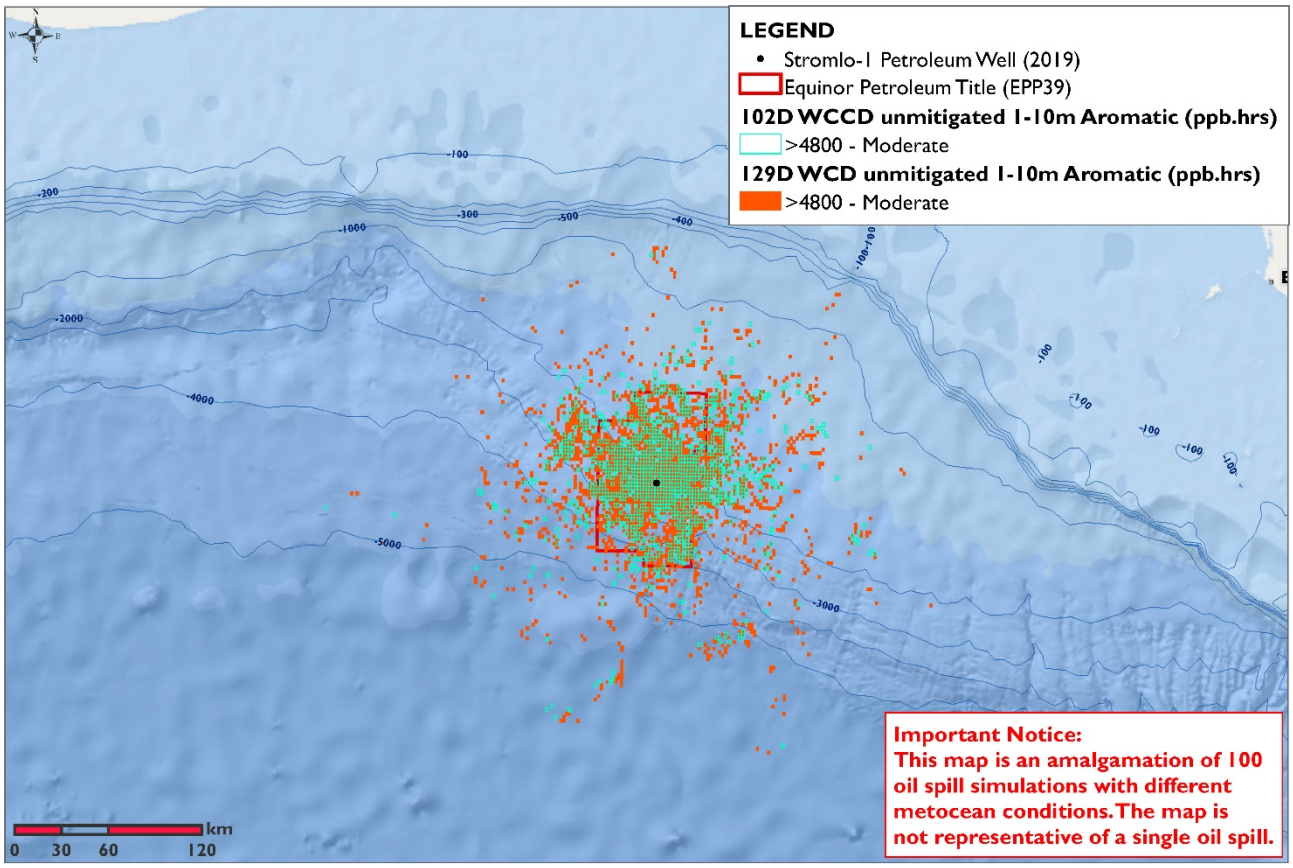

Figure 1.1: Extent of unmitigated plumes of dissolved oil at or above moderate effect thresholds for the worst-case discharge and worst credible case discharge scenarios

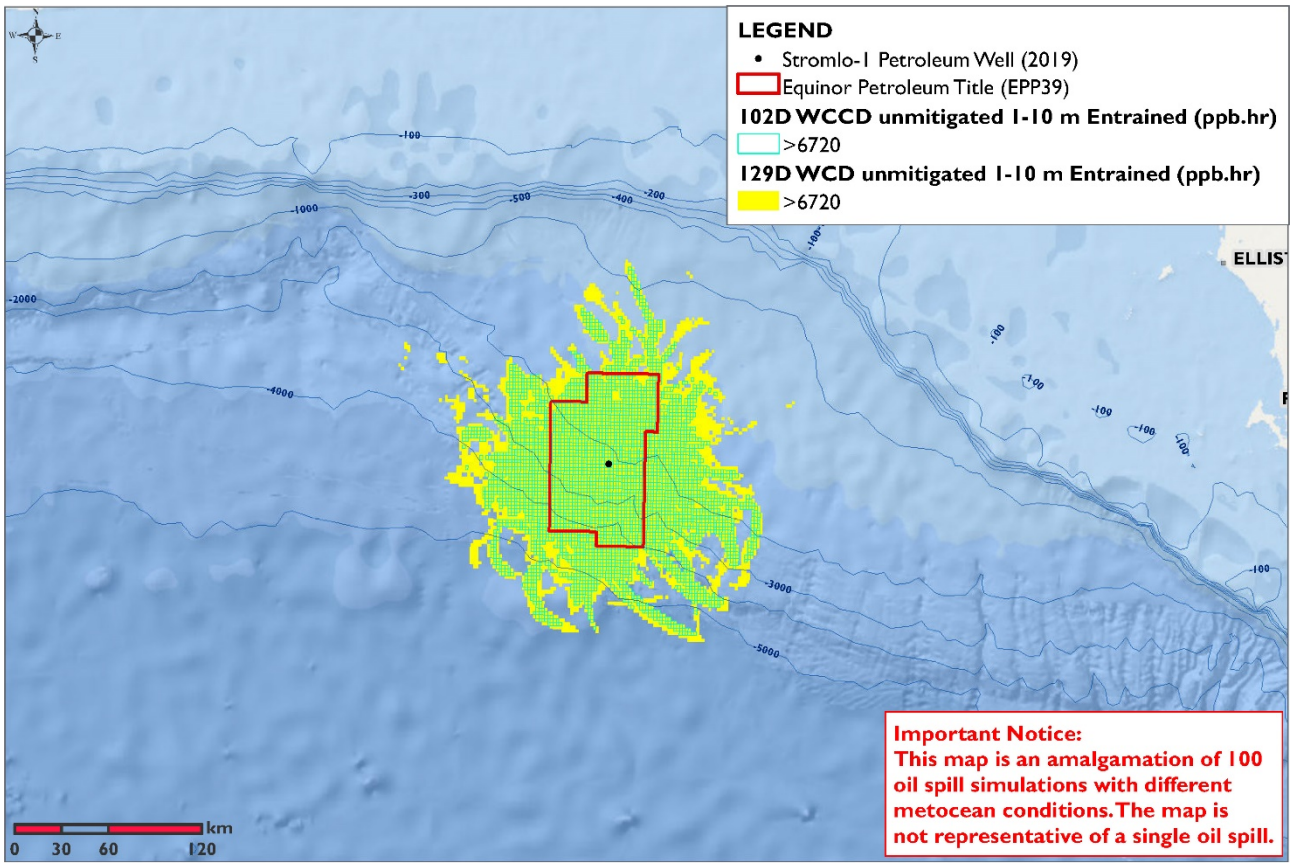

Figure 1.2: Extent of unmitigated plumes of entrained oil at or above moderate effect thresholds for the worst-case discharge and worst credible case discharge scenarios

This similarity may be attributed to the carrying capacity of the ambient waters, oil rising quickly to the surface and evaporating, and ongoing biodegradation. Over time, the in-water oil is most likely to continue to biodegrade and dilute to low concentrations below the modelling thresholds as new oil is added daily.

As such, the assessment of the risk of receptor exposure to in-water oil will be similar for both the WCD and WCCD for entrained and dissolved oil.

As the WCD is not the credible base case, a high-level review was considered appropriate. The increase in the area exposed to moderate or above entrained and dissolved oil thresholds for the unmitigated WCCD was compared to when dispersant is applied and was found to roughly double. As the area of the WCCD (at or above a moderate in water oil concentration, no dispersant) is very similar to the area of the WCD (at or above a moderate in water oil concentration, no dispersant), it can be estimated that the results of applying dispersant to the WCD will cover a similar area as the mitigated WCCD. As such, the risk review (EP Rev1, Section 8) already assesses the potential risks from increased in-water concentrations for a similar sized spill and Appendix 7-5 below assesses all the pathways to receptor exposure (floating, in-water and oil ashore) for the WCD.

1.3 Modelling outputs

The oil spill modelling study (Appendix 7-1) provides the basis and predictions of floating surface oil, in-water oil and oil ashore in the form of maps and of tabulated data (Section 10) in the same manner that the WCCD was modelled and described in Section 7.7 of the EP. The unmitigated spill modelling leads to different weathering characteristics due to the reduced entrainment (by subsea dispersant application) and greater evaporation at the sea surface. Figure 1.1 shows the mass balance of oil subject to different fates and weathering forces. Note that no fresh oil is predicted to reach shorelines.

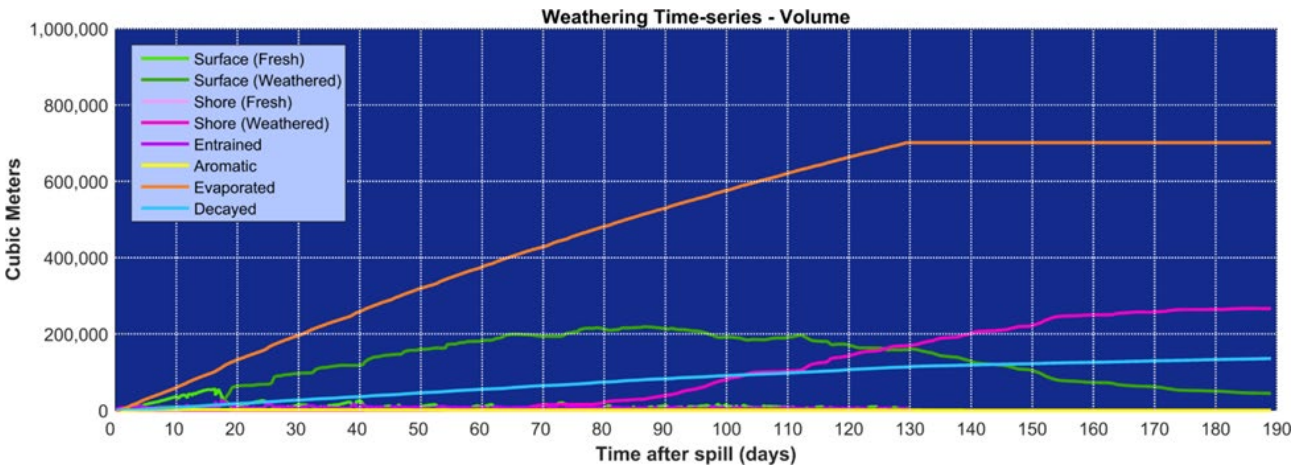

Figure 1.3: Predicted weathering and fates graphs over the 189 day period. Based on the simulation resulting in the greatest volume of oil ashore commencing 26 April 2009 at 06:00 hrs. Modelling examined an average 8943 m³/day subsea release of crude oil over 129 days tracked for 189 days

By the end of the simulation (day 189), 701,259 m³ had evaporated and 135,763 m³ had decayed. The maximum volume of weathered crude oil ashore was 244,466 m³. Furthermore, 44,844 m³ of weathered crude remained on the sea surface, while 237 m³ was predicted to remain entrained in the water column.

1.4 Risk assessment

The same risk assessment methods and approaches were followed for the worst-case discharge (WCD) assessment herein as for the worst credible case discharge (WCCD) in Section 7.7 of the Rev 1 EP. A brief overview is presented below.

In the risk assessment, sensitive receptors / locations (defined in Appendix 7-3) were reviewed for their possible exposure to low, moderate and high impact thresholds for sea surface, entrained, dissolved (thereafter referred collectively to as in-water unless specified) and shoreline oil accumulations on the basis of the worst case discharge modelling.

The contour maps showing the potential impact thresholds for surface, shoreline accumulated oil and in-water oil have been overlaid on the sensitive receptors/locations. Restitution times have been based on literature as described in Section 7.7.

Definitions of consequence categories, and the qualitative and quantitative risk levels are provided in Section 5.

The range of potential effects depends on the distance of the receptor/value from the source and therefore how dispersed and weathered the oil is when it makes contact. Shorelines will not receive any oiling for at least three weeks (50% of the simulations took at least 52 days to reach the shore at or above the low threshold), during which time oil will weather considerably and present a much lower threat of toxicity or smothering than fresh oil. Consequences for receptors/values includes:

- potential toxicity effects to flora and fauna (and potentially spill responders) resulting from exposure to surface, sedimented, entrained and dissolved hydrocarbons
- potential coating and smothering of marine and shoreline flora and fauna from exposure to surface, entrained hydrocarbons and accumulation of hydrocarbons on shorelines
- potential human health, economic, social, amenity, aesthetic, heritage (including native title), research and environmental protection effects resulting from direct exposure to surface, dissolved and entrained hydrocarbons and accumulated hydrocarbons on shorelines; or resulting from effects to biota of socio-economic importance (e.g. impacts to fish affecting fisheries).

1.4.1 Offshore air quality

Sensitivity	
Offshore air quality for the purposes of this evaluation relates the composition of the air surrounding Stromlo-1 to an altitude that could affect receptors (seabirds) if the quality of air deteriorated as a result of release of gas or particulate matter following a WCD at Stromlo-1. Based on calculated probabilities and historical data, the likelihood of a 129-day WCD resulting in a gaseous release is 1.9E-5 (i.e. 0.000019, Table 7.4 of EP), As no well has yet been drilled at the Stromlo-1 site, no accurate gas to oil ratio (GOR) is available. As the GOR will deplete over time, the Oil Spill Modelling Study (RPS (2019), Appendix 7-1, Rev 1) estimated the GOR to be roughly 122–129 m^3/m^3 i.e. 1,091,046–1,153647 m^3 gas per day released from the seabed. Evaporation (especially of the lighter volatiles) will account for some of the gas loss to the atmosphere. Entrainment could be increased through the use of surface or /and sub-sea dispersants and will reduce the volume to atmosphere (see weathering and fate graphs for mitigated case in Section 7 where the volume evaporated dropped by about 75% when dispersant is applied for the WCCD after around 55 days. Depending on the duration, such a release will result in local airshed degradation and contribute to the global GHG inventory.	
Predicted effects in context of this event	
Management of health and safety risks to offshore staff (vessels, MODU and response personnel) are detailed in the Well Operation Management Plan and Safety Case. Given the distance offshore (more than 370 km) and exposure to the open ocean winds (average 13–16 knots of variable direction), the gas release is not predicted to affect any coastal community or population centre. Transient seabirds including threatened and migratory species protected under the EPBC Act, may be exposed to elevated atmospheric hydrocarbons while directly in the gas plume, however, being highly mobile, they are largely able to avoid the area. Air breathing marine mammals and reptiles are discussed further below. In 2010, air monitoring conducted following the Macondo spill (April 2010) had not found any air pollutants at levels expected to cause long term harm (USEPA, 2010b) As such effects predicted are largely behavioural on an individual as opposed to population level. The overall consequence Category 1–3 (i.e. short-term effects on local populations with restitution times <1 month after cessation of the spill).	
Receptor	Qualitative risk assessment for unmitigated 129-day WCD
Offshore air quality	1-3

1.4.2 Seabirds

Sensitivity
Seabirds are birds that have adapted to live in or near a saltwater environment and can be found from coastal to pelagic marine environments. Birds foraging at sea have the potential to directly interact with oil on the sea surface. Species most at risk include those that readily rest on the sea surface (such as shearwaters) and surface plunging species (such as terns). As seabirds are top order predators, any effect on other marine life may disrupt and limit food supply both for adults and young. In the case of seabirds, direct contact with floating surface oil is likely to stick to feathers, which may result in hypothermia due to a reduction in the ability of the bird to thermo-regulate and impair waterproofing. Direct contact with surface hydrocarbons may also result in dehydration, drowning and starvation (Australian Maritime Safety Authority 2013; DSEWPaC 2011b). The greatest vulnerability in this case occurs when birds are feeding or resting at the sea surface (Peakall et al. 1987). Toxic effects of hydrocarbons on birds may result where the product is ingested as the bird attempts to preen its feathers. Whether this toxicity ultimately results in mortality will depend on the volume of hydrocarbons consumed and other factors (health, age, sensitivity of the species etc.). Birds that are coated in oil can also suffer damage to external tissues including skin and eyes, as well as internal tissue irritation to lungs and stomachs. Engelhardt (1982), Clark (1984), Geraci and St. Aubin (1988) and Jenssen (1994) indicated that the threshold thickness of oil that could impart a lethal dose to wildlife is 10 microns (~10 g/m^2). Scholten et al. (1996) indicates that a layer 25 micron thick would be harmful for most birds. Diving birds are not likely to be significantly affected by in-water concentrations of hydrocarbons due to their limited exposure time in the water column. Seabirds rafting, resting, diving, or feeding at sea have the potential to come into contact with surface oil at various thresholds. If seabirds have a long duration of exposure to areas of heavy surface oiling, it is likely that some individuals may die as a result of this exposure. As many species forage at sea for prolonged periods (e.g. albatrosses), or undergo seasonal migration, mortalities may not be easily identified. It may therefore take several years to identify potential effects at the populations level, and scientific monitoring programs will take this into consideration (e.g. with direct input to the design and termination of relevant monitoring plans from relevant state relevant persons in the OSMP Scientific Advisory Group (SAG)).

Predicted effects in context of this event
Seabird species listed as threatened and/or migratory under the EPBC Act, which are known to occur or have biologically important areas, within the area that may be affected by floating surface oil above 10 g/m^2 and shore loadings above 100 g/m^2 are considered at risk of adverse effects. The seabirds of the Risk EMBA are fully described in Appendix 7-3. Most species are abundant and have wide distributions across southern Australia. Three species have been assessed as representative of the seabirds to demonstrate the possible range of scale of effects: the little penguin (*Eudyptula minor),* the endemic shy albatross (*Thalassarche cauta*) and the short-tailed shearwater, or "muttonbird" (*Puffinus tenuirostris*). They differ in feeding characteristics, abundance and protection status and are considered reasonable representatives of seabird receptors. Little penguin In Australia, the distribution of the little penguin ranges from Perth, Western Australia to Tasmania and New South Wales (Figure 2.1). In South Australia, the status, abundance and distribution of this species is not fully known (Evans et al. 2017). The little penguin is not considered at risk globally, but some colonies are at risk on a regional scale (Cannell et al. 2016). However, (Evans et al. 2017) reported declines in the populations of two little penguin colonies found on the west side of the Eyre Peninsula. Declines in the status of this species has also been reported from Tasmania (Stevenson & Woehler 2007). This species has several traits that make it particularly vulnerable to a WCD: the species does not fly and thus is consistently in contact with water when away from resting and breeding locations and; this species has strong attachment to its natal area (Colombelli-Négrel 2016). Consequently, birds are likely to retain a strong attachment to a site even if the site and adjacent waters are severely contaminated by oil. Weathered oil in concentrations >10 g/m^2 are reported to be toxic to some bird species (French-McCay 2009; French et al. 1996). Based on the Oil spill modelling study (Appendix 7-1, Rev 1), oil concentrations at these thresholds could potentially reach colonies on the South Australian (Ceduna, Eyre Peninsula, Spencer Gulf - Figure 2.1) and parts of NW Tasmania (e.g. King Island, Flinders Island Hunter Island), and Victoria (near Port Phillip Bay). Given the quickest time to shore for a plume at or above the moderate threshold is ~ 3 weeks for South Australia (and ranging from 44 days - 105 days for Victoria and NSW respectively), the toxicity of the weathered residue is expected to have decreased with the loss of the more volatile components. The probability of oil ashore above the moderate threshold level is low (0-5% probability) for the WA coast from Israelite Bay west (minimum times to exposure around 56-127 days). Probability of accumulation at moderate thresholds is also low around Ceduna and Streaky Bay and the Eyre west coast with oil but maximum loadings are high and nearby islands have higher probabilities as does Kangaroo Island. Hunter Island and King Island (NW Tasmania) which may receive high loadings (Figure 2-2). The Victorian coast (Port Fairy-Warrambool-Portland) where colonies may forage around Lady Percy Island and Middle Island, may receive high loadings. From Port Phillip Island and Flinders Island eastwards there is still potential for moderate and above weathered oil ashore, but probability falls off rapidly past Gippsland and north along the NSW coast. Given the decline of certain colonies and their widely spread locations (not all colonies would be affected by a single spill), their time spent in water as non-flyers, site fidelity and their breeding cycles, the effect of a WCD unmitigated release of oil could have a long-term consequence. The predicted restitution time on the local populations of little penguins is 3–10 years in the Great Australian Bight and a Consequence Category ranked 6. Shy albatross The shy albatross population in Australia (~ <17,000) is spread across three breeding colonies on islands off Tasmania (Figure 2.1) – Albatross Island in the Bass Strait approximately 28 km off the north-west coast of Tasmania and Mewstone and Pedra Branca, both approximately 25 km off the south coast of Tasmania. A study by Brothers et al. (1997) indicated that the main foraging area for this species was over the south-eastern continental shelf of Australia, but within 200 km of the colony. Hedd et al. (2001) found that during the incubation and chick-brooding periods, many birds from Albatross Island foraged extensively over the western side of Bass Strait. Nests are well above the high tide mark. As with other species of albatross, the shy albatross is currently threatened by fishing activity (Thomson et al. 2015). Phillips et al. (2010) recorded over 40 albatross deaths in 2006 due to entanglement in long lines and nets. Albatross Island is home to ~5000 pairs and lies about 1137 km away. Albatross forage ~<200 km from the nests in the waters west of north-west Tasmania during nesting. The Oil spill modelling study (Appendix 7-1, Rev 1) indicated that under a WCD, low oil concentrations (1–10 g/m^2) could potentially reach waters surrounding Tasmania (Figure 2.1). Concentrations >10 g/m^2 extend as far east as the north west western tip of Tasmania (close to Albatross Island) and western shores of the Bass Straits, hence parts may overlap with the 200 km foraging range of the shy albatross (as well as foraging grounds for the Bullers and Antipodean albatross). Surface oil could affect albatrosses local to the NW of Tasmania at a population level but not at other breeding locations, with indirect effects through the ingestion of prey contaminated by entrained and dissolved oil possibly affecting individual birds. A small number of non-nesting individuals may be exposed to fresh oil while foraging further across the central Great Australian Bight. The population on Albatross Island is considered stable whilst other populations are declining, or their status is unknown.

As such, consequences from a WCD could impact a small number of individual foraging birds but there remains a low probability of affecting populations at Albatross Island. Juveniles take ~10 years to reach maturity and usually only lay one egg every two years; therefore, population restitution would be slow. National (and international) populations are expected to recover from loss of individuals over successive breeding seasons and a conservative estimate for the recovery of Albatross Island populations (three to 10-year period, Bock et al. 2018) results in a consequence ranking of Category 7.

There are no actions described in this EP that hinder or contravene the objectives and actions contained in the National Recovery Plan for Threatened Albatrosses and Giant Petrels 2011–2016 (DSEWPaC 2011a).

Short tailed shearwater

Over 23 million short tailed shearwaters breed on ~ 285 coastal islands in south-east Australia and Tasmania, foraging in groups of up to ~20,000 birds (Figure 2.1 and Figure 2.2). Hence large numbers could be exposed to fresh oil at one time and areas of elevated shoreline loading. The breeding and foraging BIA for this species overlaps areas where predicted surface oil concentrations are predicted to exceed >10 mg/m^2 and moderate and above shoreline oil.

Approximately 200,000 short tailed shearwaters are harvested in Tasmania each year (Tasmanian Parks and Wildlife, 2019, https://www.parks.tas.gov.au/?base=5100), and this harvest rate is considered sustainable for the Tasmanian nesting population; therefore, loss of one or more large flocks of foraging birds could potentially be offset by a temporary closure of the shearwater harvest. A WCD could result in large number of birds being affected but population level effects are unlikely and due to rapid breeding rates, widely spread BIA and large population size. Restitution is likely within 1–3 years and consequences are ranked as Category 5.

Species	Qualitative risk assessment for unmitigated 129-day WCD
Little penguin	6
Shy albatross	7
Short tailed shearwater	5

1.4.3 Shorebirds

Sensitivity

Shorebirds are likely to be exposed to oil when it directly effects the intertidal zone and onshore due to their feeding habitats. Shorebird species foraging for invertebrates on exposed sand and mud flats at lower tides will be at potential risk of both direct effects through contamination of individual birds (ingestion or soiling of feathers) and indirect effects through ingestion of contaminated prey items and/or the contamination of foraging areas that may result in a reduction in available prey items (Clarke 2010).

Toxic effects of hydrocarbons on birds may result where the product is ingested as the bird preen its feathers. Whether this toxicity ultimately results in mortality will depend on the volume of hydrocarbons consumed and other factors (health, age, sensitivity, etc.). Birds that are coated in oil can also suffer damage to external tissues including skin and eyes, as well as internal tissue irritation to lungs and stomachs. Engelhardt (1982), Clark (1984), Geraci & St. Aubin (1988) and Jenssen (1994) indicated that the threshold thickness of oil that could impart a lethal dose to some intersecting wildlife individual is 10 microns (roughly 10 g/m^2). Scholten et al. (1996) indicates that a layer 25 micron thick would be harmful for most birds that contact the oil.

There are many listed threatened and migratory shorebird species likely to occur over a wide geographic area in the Great Australian Bight region overlapping the Risk EMBA and beyond. In the event of a loss of well control, these birds are potentially at risk of coastal surface and shoreline exposure. Birds are not likely to be significantly affected by in-water concentrations of hydrocarbons due to their limited exposure time in the water column. Shorebirds foraging in intertidal areas or along the high tide mark and splash zone, or nest in coastal areas particularly close to the high-water mark, are most at risk of exposure effects.

Predicted effects in context of this event

Shorebirds, also known as waders, inhabit intertidal areas of coastal and freshwater wetlands. As detailed in Appendix 7-3, shorebirds are principally found along the shores of beaches, estuaries, rock platforms and wetlands. Shorebirds typically have long legs in relation to their body size and do not swim. Henkel et al. (2012) noted that declines in shorebird populations were possible from oil pollution due to acute mortality, as well as habitat modification and effects such as loss of intertidal invertebrate prey.

The eastern curlew (*Numenius madagascariensis*) is listed as critically endangered under the EPBC Act due to an ongoing decline of its population and loss of habitat. It migrates between Australia and its breeding grounds in the northern hemisphere. Australia (all the States) probably supports the greatest numbers of this species during the non-breeding period. In Australia, numbers of this species are reported to be declining at most monitored sites (Lilleyman et al. 2016). In the area potentially affected by the spill, this species has been reported along shorelines from the western coast of Victoria, Bass Strait and Streaky Bay (Figure 2.2). The Oil Spill Modelling Study (Appendix 7-1, Rev 1) suggested that there is a risk of oil coming ashore at some of these locations during an unmitigated WCD scenario, but the oil will be weathered after more than 21 days minimum (South Australia). Figure 2.12 shows the probabilities

of shoreline contact with weathered oil for state coastal waters during summer. Modelling results indicated that some shoreline and tidal flats oiling could occur at concentrations >100 g/m^2 along some sections (e.g. Coorong to Port Fairy), the extent and likelihood of exposure in those areas are significantly varied between individual runs. The eastern curlew could be present in the Risk EMBA during drilling as they start to arrive on the east coast from September to November. Most leave the east coast from late February to March. As such, a WCD could result in oil reaching some populations on islands in the western Bass Straits and colonies from near the Coorong north west to Streaky Bay in South Australia. WA roosting sites (e.g. near Albany and Israelite Bay) and east coast populations have very low probabilities of exposure to oil at impact thresholds. For reasons described above, the effect of a WCD could have a long-term consequence (restitution time 3-10 years for populations of national importance, ranked Category 6) for the eastern curlew.

Species	Qualitative risk assessment for unmitigated 129-day WCD
Eastern curlew	6

1.4.4 Marine reptiles

Sensitivity
Marine reptiles include marine turtles and sea snakes. Marine reptiles are potentially directly affected by the toxicity of in-water and surface hydrocarbons through ingestion, volatile organic compounds through inhalation, as well as effects of physical contact with surface hydrocarbons. Contact with oil does not necessarily result in mortality for marine reptiles. During the Macondo spill in the Gulf of Mexico, many oiled marine turtles were collected and eventually released back into the environment. However, a conservative threshold of 10 g/m^2 floating surface oil was used in this assessment for marine reptiles because it is the lowest concentration that may cause effects on other wildlife. There are five turtle species listed under the EPBC Act as identified in the PMST report (Appendix 7-2). While they may potentially occur in the Risk EMBA, they are not noted to reside in the area in significant numbers. There are no known aggregations or nesting beaches along the Risk EMBA coastline that could be affected by shoreline loadings and no reptile BIA in the region. The yellow-bellied sea snake (*Pelamis platurus*) may also be present in the area that may be exposed to oil above 10 g/m^2 floating surface oil, but this and other species are likely to be vagrants from tropical regions.
Predicted effects in context of this event
No listed marine reptiles are known to reproduce and or aggregate in the area. Although an unmitigated WCD may affect individuals of these species, it is highly unlikely to result in population-level responses or reductions in the area of occupancy of a protected or threatened species in the region. For these reasons the consequences for marine turtles and sea snakes are ranked Category 1–3.

Species/Receptors	Qualitative risk assessment for unmitigated 129-day WCD
Turtles and sea snakes	1-3

1.4.5 Plankton

Sensitivity
Plankton constitute a diverse range of microscopic organisms, many of which are unable to swim against a current. Plankton include algae, bacteria, protozoans, crustaceans, molluscs and coelenterates. They provide a crucial source of food to many large organisms, such as fishes and whales. Floating surface oil cover has the potential to impact plankton in the top metre of the water column when plankton come close to the surface during dial cycles. But plankton also has the potential to be directly affected by in-water hydrocarbons as a result of toxicity effects. Oil can affect the rate of photosynthesis and inhibit growth in phytoplankton, depending on the concentration range. For example, photosynthesis is stimulated by low concentrations of oil in the water column (10–30 ppb) but becomes progressively inhibited above 50 ppb. Conversely, photosynthesis can be stimulated below 100 ppb for exposure to weathered oil (González et al. 2009). The threshold of 70 ppb for in-water hydrocarbons is considered appropriate given the variability in the levels at which phytoplankton is affected. In addition, the potential for effects to photosynthesis from shading caused by continuous surface slicks may also be a consideration, though a prolonged surface coverage over an extensive area would be required. A process identified at many sites during the Macondo spill should also be considered – where plankton and other surface material were found to be sinking at rates of more than 10 times the normal level. It was hypothesised that the weathered spilled oil catalysed clumping of organic particles (Schrope 2013). It is currently unclear as to whether this effect was caused by the chemical characteristics of the weathered oil, or a bacterial effect.

The ecological implications of a potential reduction in productivity and/or loss of phytoplankton include localised reduction in feeding opportunities for planktivores, loss of a proportion of the annual recruitment potential (through loss of planktivorous larval stages) and survival rates of organisms with planktonic larval stages due to developmental abnormalities to e.g. spine deformities and brain development/impairment of higher-order cognitive function in ichthyoplankton (Johansen et al. 2017). Reproduction by survivors or dispersion from unaffected areas (via sea surface currents) would be likely to rapidly replenish any losses from permanent zooplankton (Abbriano et al. 2011). Plankton have life cycles based on rapid reproduction with levels of high productivity. It is also in the nature of plankton to be dispersive – it is why many benthic taxa have adopted a pelagic early life history stage to increase dispersion via a vector with a consistent food supply. Field observations from oil spills have shown minimal or transient effects on marine plankton (Abbriano et al. 2011). Once background water quality conditions have re-established, the plankton community may take weeks to months to recover (ITOPF 2011), allowing for seasonal influences on the assemblage characteristics. Plankton found in open waters of the exposure zone is expected to be widely represented within waters of the wider Great Australian Bight region and generally across all waters in the southern offshore region, which aids in the re-establishment of communities.
Predicted effects in context of this event
Central Great Australian Bight slope and offshore waters were sampled for plankton during the Great Australian Bight Research Program. Highest concentrations of chlorophyll-a (used as an indicator of phytoplankton abundance) occurred at depths of 60 m (0.43 ug/L) at the 200 m and 400 m isobaths. Chlorophyll-a declined with distance from the shelf edge to low concentrations (0.19 ug/L) at stations at the 1000 m and 2000 m isobaths. A study of the western Great Australian Bight during summer found that zooplankton biomass was only 2% of that in the Gulf of Carpentaria, with other research indicating that the zooplankton assemblage is dominated by small copepods, meroplanktonic larvae and cladocerans (McLeay et al. 2003). Copepods and appendicularia were dominant in shelf and offshore waters in the central GAB (Kloser et al.2017). The Stromlo-1 well location is in 2200 m water depth. An oil spill would therefore result in potential exposure of plankton to high thresholds of sea surface oils in the proximity of the well. The area of direct exposure of plankton to dissolved/entrained oils is likely to be off the shelf edge. Plankton are at their highest concentrations below surface waters (e.g. 60 m water depth for phytoplankton during the day) and undertake a vertical migration patterns which would likely reduce their potential for (and duration of) exposure to dissolved and entrained hydrocarbons in comparison to surface waters (0–10 m) oil exposure. However, should a proportion of the plankton population be affected by a WCD, then the rapid rate of reproduction and tidal mixing are likely to result in a short term (< year) restitution period. The risk to plankton at the regional scale is therefore predicted to be Category 5 (short term effects on populations of regional importance, <1-year restitution time).

Species	Qualitative risk assessment for unmitigated 129-day WCD
Plankton	5

1.4.6 Fishes (bony fishes and sharks)

Sensitivity
This section evaluates risk to bony fishes and sharks. Bony fishes include syngnathids, handfishes and southern bluefin tuna (SBT). Shallow inshore fish species include various syngnathids (seahorses, pipefish, pipehorses and seadragons) that are categorised as “listed marine species” under the EPBC Act. Some syngnathid species prefer shallow sheltered inshore waters often in association with seagrasses and macroalgae and may occur in water depths from just beneath the surface to up to 50–100 m or with rafts of floating seaweed. However, surface species are potentially more at risk of exposure to weathered surface oils and may be at risk from oil toxicity or being displaced from critical habitat. Syngnathids are highly unlikely to be found within the around the well location given the deep waters and lack of suitable protective habitat. Various species of handfish are listed as ‘vulnerable’ and ‘critically endangered’. They are highly unlikely to occur in the vicinity of the well, as preferred habitats are typically soft sediment in shallow and sheltered environment (e.g. bays in southern and eastern Tasmania). Fish species of commercial value, including the southern bluefin tuna (SBT) (*Thunnus maccoyii*), are known to be present in the area (see “Socio-economic” below for more detailed discussion on potential impacts to specific commercial species). Most adult fishes in the Great Australian Bight region, including sharks, tend to remain in the mid-pelagic or demersal zones and are likely to encounter in-water oils rather than surface oils. External exposure, ingestion or absorption of oils in the water column from ventilation is possible for many species of adults and juveniles; however generally these species are highly mobile and as such are not likely to suffer extended exposure.

Shallow inshore species are less likely to be able to move away from in-water oils and hence may be exposed for longer periods (e.g. up to a few days near Kangaroo Island and Port Lincoln). As fish are most vulnerable to oils during their embryonic, larval and juvenile life stages, nursery areas are more likely to suffer developmental effects, morbidity and/or mortality at the lower concentrations.

Compared with early life stages, there is little knowledge on what concentrations juvenile or adult SBT and other pelagic bony fish predators can tolerate before resulting in mortality or sub-lethal responses (Esbaugh et al. 2016; Incardona et al. 2014). Oil related effects to prey, such as sardines (Evans et al. 2017), could also directly or indirectly affect SBT and their recovery in the Great Australian Bight. Potential for exposure to dissolved and entrained oil above moderate concentrations is predicted to lie within approximately 150 km of the well within the offshore central Great Australian Bight (Figure 2.4).

The values of the Great Australian Bight MP include the KEF – the Small Pelagic Fish of the South West Marine Bioregion which includes the commercially targeted sardine (see too 'socio economic'). The assemblage of small pelagic fishes that occur across the Great Australian Bight is relatively diverse compared to other bioregions with at least 10 species belonging to 6 families common in the region (Rogers et al 2013). Despite being a KEF, little information is available on their population size/dynamics in the western and central Great Australian Bight. Common abundant species include sardines, anchovy, herring, jack mackerel and sprat are found mainly in inshore waters of the eastern Great Australian Bight (Rogers et al. 2013). Sardines are assessed here as representative of the small pelagic fishes as they are important in the food web, are feedstock for the SBT ranching industry, have spawning grounds in the coastal regions of the Great Australian Bight, can be exposed to surface oils, are commercially fished and were of stakeholder interest in the public comment period.

The great white shark (*Carcharodon carcharias*), which is listed as Vulnerable under the EPBC Act, is more likely to be found foraging in near shore waters and with breeding BIA around Corner Inlet off the Gippsland Coast and the south-east of Tasmania (Figure 4.15 of Appendix 7-3 for whole BIA and Figure 2.4 for overlap of BIA with entrained/dissolved oil). The low-density distribution areas overlap offshore SA, Victoria, Tasmania and in Bass Straits. Densities of mature great white sharks are likely to be higher around fur seal and sea-lion haul out sites and rookeries.

Listed migratory fish species in the Great Australian Bight are the porbeagle shark (*Lamna nasus*), the giant manta ray (*Mobula birostris*) and the whale shark (*Rhincodon typus*). These species are widely distributed. No critical habitat for these species is identified within the Risk EMBA (Appendix 7-3, Section 4.3). While individuals may be affected by oils, significant effects to these species are not considered likely and no population effects predicted.

Predicted effects in context of this event

Bony fish - syngnathids

Surface species of syngnathids are potentially more at risk of exposure to weathered surface oils in nearshore and coastal waters and may suffer effects. Given their preferred habitats are typically widespread and within sheltered coastal waters, they are unlikely to be severely impacted by sustained exposure to elevated levels of entrained and dissolved oils as thresholds above moderate levels stay offshore. Impacts at worst are predicted to be local on individual organism levels with consequences ranked Category 1-3.

Bony fishes - handfishes

Despite their highly restricted distributions, the critically endangered or vulnerable handfishes (*Brachionichthys hirsutus*, *Brachiopsilus ziebelli* and *Thymichthys politus*) (described in Appendix 7-3) are not considered to be at risk from a loss of well control associated with Stomolo-1. This is because the habitats of all three species are not predicted to be contacted by elevated concentrations of entrained or dissolved oil (Appendix 7-1, Rev 1). Handfishes are unlikely to be exposed to oil above biological effect thresholds and consequences are ranked Category 1-3.

Bony fishes – southern bluefin tuna

Southern bluefin tuna (SBT) occur throughout the Atlantic, Pacific and Indian oceans feeding on fish, cephalopods, crustaceans and salps. The spawning grounds for the SBT population that migrates to the Great Australian Bight occur between Indonesia and north-western Australia. Juvenile SBT are known to occur in the Great Australian Bight from about November to March, leaving between March and July (Appendix 7-3), hence they could be in the Great Australian Bight if the spill occurred early during the activity period. By maturity, most fish have migrated into the deeper waters of the South Atlantic, Indian and south-west Pacific oceans to spawn (DEE 2018) – but not the whole population migrates. Juveniles SBT are likely to be more sensitive to oil and other contaminants than adults. In the Great Australian Bight, SBT form schools near the sea surface (<200 m deep) during the day, feeding on sardines or krill. Given these behavioural traits, juvenile SBT could be exposed to moderate levels of surface (Figure 2.3), entrained and/or dissolved oil following a loss of well control (Figure 2.4). Zones of moderate and above in-water oil lie within approximately 150 km from Stromlo-1. Depending on exposure time, individual fish exposed to these levels could result in mortality. Given this species has a wide distribution, pelagic habitat, marked movement patterns of adults and juveniles even over short temporal scales (e.g. days) and the absence of spawning in the Great Australian Bight, it is unlikely that a WCD would lead to an ecologically important population level response. However, taking a conservative approach, SBT are apex predators so medium term (1-3 years) effects on local populations may occur and consequences are ranked Category 5.

Importantly, recovery of the SBF population following a WCD will be, in part, dependent on the recovery of impacted sardine stocks. Sardines are known to be able to recover from large, population-level mortality events. Mass mortality events in 1995 and 1998 are thought to have killed more fish over a larger area than any other recorded fish kills, each event estimated to have killed over 70% of spawning biomass in South Australian waters (PIRSA 2017; Ward et al. 2001).

Other bony fishes

Pelagic (or "open sea") bony fish species are most at risk from exposure to fresh and thus more toxic oil (when within approximately 200 km from the well site), compared with coastal bony fish species. This is because concentrations of the more toxic components of oil will have reduced before contacting coastal environments. Pelagic species will also be at risk from entrained and dissolved oil. Zones of moderate and above entrained and dissolved oil lie within approximately 150 km from Stromlo-1 for the 0–10 m water depth (Figure 2.4) and do not impact shallow water habitats or coastlines. The Great Australian Bight MP was predicted to experience exposure to entrained or dissolved oil at or above the moderate threshold.

Most bony fishes, including small pelagic fishes, are at risk of exposure to oil above low thresholds have extensive distributions across temperate Australia. However, the contours delineating the moderate and high thresholds of surface, entrained and dissolved oil do overlie the distributions of several fish species listed as threatened and/or migratory under the EPBC Act (Appendix 7-3, Section 4.3). Large-scale population level effects following a loss of well control on fish species (including abundance or assemblage composition) would be unlikely due to their wide geographical distribution. There is potential for rapid re-colonisation especially in the cases of widely distributed relatively common small pelagic species such as sardine and herring. The economic importance of sardines to commercial fisheries is discussed under Section 1.4.18 Socio-economic values. Given their broad spawning areas and timing (spring-summer in the southern part of their range and summer-autumn in the northern part) and quick breeding, sardines are predicted to have short term impacts for local populations with consequences ranked Category 4.

Sharks

Large pelagic shark species, such as the shortfin mako and porbeagle, and possibly the great white shark, are at greatest risk of being exposed to dissolved/entrained oil following a loss of well control given their wide foraging areas and risks of consuming contaminated prey. Great white sharks are known to aggregate near Corner Inlet-90 Mile beach off eastern Victoria as well as around seal colonies (hence are unimpacted by in-water oil within their BIA, Figure 2.4). Philopatric characteristics means they may return to the place of birth to breed even if habitats are contaminated. These species have a global distribution and thus are unlikely to suffer ecologically important declines following a loss of well control. However, taking a conservative approach, they are apex predators so medium term (1–3 years) effects on local populations may occur and consequences are ranked Category 5.

There are no actions described in this EP that hinder or contravene the objectives and actions contained in the Recovery Plan for the White Shark (*Carcharodon carcharias*) (DSEWPaC 2013a).

Species/receptor	Qualitative risk assessment for unmitigated 129-day WCD
Syngnathids	1-3
Handfishes	1-3
Southern bluefin tuna	5
Other bony fishes	4
Great white shark	5

1.4.7 Marine mammals – pinnipeds

Sensitivity

Australian sea lions are endemic to Australia, found only in South Australia and Western Australia (Gillanders et al. 2013). The distribution of the species extends from the Houtman Abrolhos Islands on the West Australian coast through the Pages Islands (SA) to the east of Kangaroo Island in South Australia (DSEWPaC 2013b), with aggregations more likely to be found on rocks and sandy beaches on sheltered sides of islands.

There are many sites considered to be critical habitats and only eight sites produce more than 100 pups per season, these being North and South Page islands, Seal Bay on Kangaroo Island, Dangerous Reef (near Port Lincoln), Lewis Island, West Waldegrave Island, Olive Island and Purdie Island, all of which are in South Australia (Edyvane 1999; P.J. Rogers et al. 2013).

Both the long-nosed or New Zealand fur-seal (*Arctocephalus forsteri*) and the Australian fur-seal (*Arctocephalus pusillus doriferus*) are listed marine species with habitat and breeding sites known to occur in the area. No specific foraging areas were identified for the Australian fur seal. However, for the New Zealand fur seal, Baylis (2008) reported that this species utilised the seasonally predictable Bonney Upwelling, but foraged in more oceanic waters when the Bonney Upwelling declined in autumn.

Pinnipeds (seals and sea lions) are directly at risk from effects associated with the exposure to surface and shoreline oils, particularly given they spend much of their time on or near the sea surface to breathe, and regularly haul out on to beaches/rocks. Pinnipeds are also sensitive as they will stay near established colonies and haul-out areas, meaning they are less likely to practice avoidance behaviours. A likely ingestion pathway for pinnipeds is through contaminated prey and grooming of oil from fur, with exposure to a range of different weathered stages from fresh oil (if foraging >200 km offshore) to tar balls encountered at haul-out areas.

As a result of exposure to surface oils, pinnipeds, with their relatively large, protruding, eyes are particularly vulnerable to effects such as irritation to mucous membranes that surround the eyes and line the oral cavity, respiratory surfaces, anal and urogenital orifices.

For some pinnipeds, fur is an effective thermal barrier because it traps air and repels water and as such oiling can have significant effects to this function if foraging in areas with fresh oil. The oiling effect from weathered oil is unknown.

The Long-Term Environmental Impact and Recovery report for the Iron Barren oil spill (Tasmanian SMPC 1999) concluded that “the numbers of pups born at Tenth Island in 1995 was reduced when compared to previous years. There was a strong relationship between the productivity of the seal colonies and the proximity of the islands to the oil spill wherein the islands close to the spill received fresher oil and showed reduced pup production and those islands more distant to the oil spill did not”.

Australian sea lions (*Neophoca cinerea*) have “naturally poor recovery abilities” (TSSC 2005). Due to the extreme philopatry of females and limited dispersal of males between breeding colonies, the removal of only a few individuals annually may increase the likelihood of decline and potentially lead to the extinction of some of the smaller colonies.

There are three pinniped species recorded (including breeding grounds of the vulnerable Australian sea lion) under the EPBC Act as potentially occurring within the contours of low, moderate and high thresholds for surface oil and shore loading of weathered oil (Figure 2-5). A Recovery Plan is in place for the Australian sea lion which requires the evaluation of the risk of an oil spill on this species and appropriate mitigations to be in place.

There is limited peer-reviewed information on the response of individual sea lions to contact with fresh and weathered oil. Potential pathways that could compromise the health of marine mammals include skin contact and absorption, inhalation and ingestion (Helm et al. 2015). The same authors suggested that inhalation of the toxic components associate with fresh oil was the most likely mechanism of mortality for marine mammals exposed to oil. French-McCay (2016) proposed that exposure to oil concentrations of 10 g/m^2 could have lethal effects on marine mammals and sub-lethal effects with exposure to concentrations as little as 1 g/m2.

The Australian fur seal is not listed under the EPBC Act as Threatened or Migratory and it does not have recognised BIAs within the Risk EMBA. Section 4.5.2.3 of Appendix 7-3 describes its range as along the coast of the eastern Great Australian Bight, eastwards along Tasmanian coasts (where it is the most common seal species), along the Victorian coast and northwards up the coast of NSW. It breeds on small isolated rocks in Bass Strait and coastal Victoria between October and January. Populations have largely recovered since sealing (Evans et. al, 2017) but restitution times in the event of severe population effects can be around 40 years (Bock et al. 2018).

Predicted effects in context of this event

Of the three pinnipeds known to breed in the Risk EMBA (Appendix 7-3), the Australian sea lion is most vulnerable to human disturbance due to its small population size (DSEWPaC 2013b) and lack of population recovery following historical harvesting, hence the focus in this section.

Australian sea lion

Of the 58 regular breeding colonies for the Australian sea lion, 48 are in South Australia. All 58 colonies are considered critical habitat for the survival of this species (Appendix 7-3; DSEWPaC 2013b). In terms of pup numbers, the most important regions in South Australia are Nuyts Archipelago, Eyre Peninsula and Kangaroo Island (DEWHA 2010). In South Australia there are <3000 pups per breeding cycle (Shaughnessy et al. 2011). There are few long-term studies examining trends in pup numbers and estimates from year to year are variable making interpretation challenging. However, limited evidence suggest pup production at some sites is stable while at other sites, numbers may be in decline (Goldsworthy et al. 2011). For instance, long term monitoring of pup numbers at Seal Bay indicate a general decline from 1985 to 2007 (DSEWPaC 2013b).

Australian sea lions are known to forage considerable distances from breeding and haul out sites in South Australian waters (Appendix 7-3). Foraging habitat requirements are broad ranging from coastal areas to the shelf break. The mean foraging grounds for sea lions at Dangerous Reef is 28 ± 18 km and 189 ± 25 km at Bunda Cliffs (Hamer et al. (2013) cited in DSEWPC (2013b)). Even pups of about 15 months old can forage a mean distance of 20.8 km from their natal colony (Fowler et al. 2007). Tagged lactating female Australian sea lions demonstrated that individuals can range considerable distances south of Kangaroo Island and Eyre Peninsula (DSEWPaC 2013b; Hamer et al. 2013).

Based on the oil spill modelling results there is a risk that breeding colonies ranging from Esperance to Kangaroo Island could be exposed to shoreline oil of ≥100 g/m^2 following a loss of well control and nursery sites affected by shoreline accumulations near Port Lincoln, from west of the Head of the Bight to Ceduna, Kangaroo Island, Bass Strait islands, Portland to Cape Otway and in the western Great Australian Bight near Esperance (however, probabilities here are low). The direct effect to pups from exposure to shoreline oil at these concentrations could result in mortality, while indirect effects could be negative behavioural changes associated with the smell of shoreline oil or contamination of prey.

Given the population of this species may already be in decline due to fishing and other human pressures (DSEWPaC 2013b), it is plausible that mortality of even a small number of pups or adults as a direct or indirect result of shoreline oiling could increase the rate of decline (DEWHA 2010). Further, shoreline oiling of breeding colonies could potentially reduce the area of occupancy for this species. This issue is particularly pertinent for female Australian sea lion that exhibit extreme natal site fidelity (Campbell et al. 2008).

Exposed to surface oil at concentrations of >10 g/m^2 and elevated shoreline loadings>100 g/m^2 (Figure 2.5) could result in reduced reproduction and reduced viability of smaller colonies, possibly leading to colony collapse). Sea lions may not avoid oiled nurseries due to site fidelity and high natal philopatry. Hence there is potential for long term (>10 years) effects on a nationally important population that have not yet recovered to pre-sealing levels. Conservatively, the effect of a WCD on Australian sea lions could have a very long or permanent impact on a fragile population resulting from the loss of individual breeders. The Consequence is ranked Category 8.

The Recovery Plan for the Australian sea lion (DSEWPaC 2013b) lists oil spills as a threat to sea lions and contains the requirement to "implement jurisdictional oil spill response strategies as required" with management actions developed to mitigate effects of oil spill on populations. This EP is aligned with the objectives of this Recovery Plan, notably focussing on spill prevention in the first instance. Equinor will support the state agencies in implementing their oiled wildlife response plans (further described in the OPEP).

New Zealand fur seal

In contrast to the Australia sea lion, the long-nosed or New Zealand fur seal is increasing in abundance and expanding its range in Australia (Figure 2.5) (Campbell et al. 2014). However, this species is vulnerable to a population decline following a loss of well control because its major breeding locations are found between Kangaroo Island and the Eyre Peninsula (Shaughnessy et al. (2015)). New Zealand fur seals are at risk to surface oil while at sea and shoreline accumulated oil at haul out sites or rookeries. Like the Australian sea lion, the direct effect to pups from exposure to shoreline oil at ≥100 g/m^2 could result in mortality, while indirect effects could be negative behavioural changes associated with the smell of shoreline oil or contamination of prey. Also, this species may be more vulnerable to oil because oil is believed to adhere more readily to its coat compared with that of the Australian sea lion. Therefore, for the New Zealand fur seal, a WCD could also have a long or permanent effect (restitution time >10 years) on its regionally important populations and ranked Category 7.

Australian fur seal

The Australian fur sea has a foraging and breeding range that is largely eastwards of the SA/Victorian border (Figure 2.5) across the Bass Strait to the NSW border. Colonies and haul out sites may be exposed to surface and shoreline oil at or above a moderate threshold in the western part of their range. The effects of oil on this species would be like New Zealand fur seals. Given that restitution could take >10 years for local populations of regional importance, the consequences are ranked Category 7.

Species/Receptors	Qualitative risk assessment for unmitigated 129-day WCD
Australian sea lion	8
New Zealand fur seal	7
Australian fur seal	7

1.4.8 Marine mammals – cetaceans

Sensitivity

Whales and dolphins can be exposed to the oil toxicity through:

- internal exposure by consuming oil or contaminated prey
- inhaling volatile oil compounds when surfacing to breathe
- absorption from external exposure, by swimming in oil and having oil directly on the skin and body
- maternal transfer of contaminants to embryos (NRDA, 2012).

Dolphins listed in the PMST report (Appendix 7-2) are widely distributed regionally and no BIA were identified in the areas potentially exposed to effects thresholds. As such, risks to dolphins are considered sufficiently represented by considering similar physical impacts to whales but are not listed as endangered or vulnerable under the EPBC Act.

Direct surface oil contact is considered to have little deleterious effect on cetaceans, possibly due to the skin's effectiveness as a barrier to toxicity, and effect of oil on cetacean skin is probably minor and temporary (Geraci and St. Aubin, 1988). However, Helm et al. (2015) suggested that inhalation of toxic compounds associated with fresh oil was of greater concern than absorption through the skin and ingestion. French-McCay (2016) proposed exposure to oil concentrations of 10 g/m^2 could result in mortality to marine mammals.

The physical effects from ingested oil with subsequent lethal or sub-lethal effects are both applicable to dissolved and entrained oil. However, the susceptibility of cetaceans varies with feeding habits. Baleen whales are likely to ingest oil as they feed at the surface and in the water column. Toothed whales and dolphins may be susceptible to ingestion of

dissolved and entrained oil as they gulp feed at depth. Many marine mammals appear to have the necessary liver enzymes to metabolise some oils and excrete them as polar derivatives (Ball and Truskewycz (2013).

Entrained and dissolved oil in offshore waters could lead to temporary changes in the behaviour of whales (e.g. avoidance of the plume if their eyes are irritated), but their relatively impermeable skins mean entrained and dissolved oil is not predicted to result in mortality of individuals and thus is unlikely to lead to population level responses.

The restitution time for cetaceans affected at a population level is assumed to be long term, i.e. 40 years, based on consensus on recovery times for marine mammals following the Macondo spill (French-McKay et al. (2018), Bock et al. (2018)).

Predicted effects in context of this event

Thirty-five species of cetaceans have been recorded in the Great Australian Bight; comprising 11 species of baleen whales and 24 species of toothed whales (PMST report, Appendix 7-2). Of the 35 species, only three have biologically important areas in the Risk EMBA; namely the pygmy blue whale (*Balaenoptera musculus*), the southern right whale (*Eubalaena australis*) and the sperm whale (*Physeter macrocephalus*). Consequently, this evaluation of the potential effects of a Level 3 oil spill focuses on these species. Appendix 7-3 describes aggregation, feeding, migration and calving BIAs for pygmy blue whales, southern right whales and sperm whales in relation to the Stromlo-1 well location. Only the migration BIA of the pygmy blue whale overlaps the well location; the others have BIA that overlap the Risk EMBA. Risks to populations of other cetacean species are predicted to be lower because the area is considered less critical to their ongoing survival.

It is plausible that individual whales could encounter dissolved and entrained oil above a moderate threshold as well as fresh surface oil at high concentrations within ~150 km of the well location; however, it is difficult to predict with certainty if a spill would lead to levels of mortality or reproductive depression that would manifest in terms of a population-level response. Nevertheless, given that the populations of some species remain small relative to pre-whaling days (Appendix 7-3) and are thought to have a multi-decadal recovery time, it is conceivable that mortality of even a small number of adults and or calves as result of oiling could inhibit or retard species recovery.

Biologically important areas for breeding and calving dolphins extends up the NSW coast from the Victorian border north. This area is not exposed to sea surface (or in water) oils above the moderate thresholds and no impacts predicted.

The species described in detail in this assessment represent a range of feeding habits, likely activities (e.g. calving versus migrating), protection status and abundance. The effects of the unmitigated WCD on three representative whale species are summarised below.

Southern right whale (SRW)

SRW calve close to the shore (Figure 2.3) and their calving areas fringe the mainland and Kangaroo Island; the Head of Bight is a nationally important area. Mother and calf pairs generally stay within the calving grounds for 2–3 months (DSEWPaC 2012b), their presence in the Head of Bight peaks from mid–late July to mid–late August.

SRW are absent from this region from about December to April and will mainly be at risk if a major spill was to occur in February or later and run for 129 days, because the end of the spill period would overlap the start of the next whale migration period and weathered oil may be present in coastal aggregation areas.

Based on the modelling results (Appendix 7-1, Rev 1) it is possible that weathered surface oil exceeding the moderate threshold concentration could contact areas of aggregation, feeding, migration and or calving and affect the SRW if they are present. Migrating southern rights may be exposed to fresh oil and associated VOCs when traversing the central Great Australian Bight. Breeding and calving grounds at the southern end of the Eyre Peninsula, Kangaroo Island, Encounter Bay and the South Australian–Victorian border *Portland to Port Campbell) as well as near the Bonney Upwelling are predicted to be at risk of exposure to weathered oil at moderate or higher concentrations of oil following a WCD.

Exposure to moderate or higher threshold concentrations following a WCD could potentially lead to mortality of individual SRW and or negatively influence reproductive rates. Fresh oil could also temporarily affect habitat occupancy.

Breeding and calving grounds at the southern end of the Eyre Peninsula, Kangaroo Island, Encounter Bay and the South Australian–Victorian border (largely around Portland to Port Campbell) as well as near the Bonney Upwelling are predicted to be at risk of exposure to weathered oil at concentrations of >10 g/m^2 following an unmitigated WCD (Figure 2.3).

The eastern Australian population (Victoria, Tasmania and NSW) currently shows no evidence of recovery and is limited to <300 individuals. The consequences of a WCD scenario on SRW is therefore ranked a conservative Category 8 due to potential long-term effects on the population (restitution time >10 years) if exposed to impact thresholds of oil for extended durations. Risks to the SRW are mitigated as a result of the following factors: i) by the unlikely overlap between the most of the drilling window and the timing of SRWs presence in the areas that may be exposed to oil at concentrations high enough to have biological effects ; ii) that only a small proportion of the population re-migrates each year and therefore only a small proportion may be exposed; the highly weathered state of the oil reaching nearshore waters; and iv) greater part of the population residing in the west – away from the main areas of oil exposure.

Pygmy blue whale (PBW)
PBW are known to migrate through and forage in deep water of the Risk EMBA (Figure 2.3). In the event of a WCD, PBW could be exposed to fresh oil and associated VOCs when traversing through a spill. A WCD could result in weathered oil contacting feeding aggregation areas of PBW near the Bonney Upwelling during November–March, or in direct contact with individual PBW transiting across the Great Australian Bight. As a KEF, one of the values of The Bonney Upwelling is the aggregation of PBW which is considered of national importance. PBW exposed to fresh surface oil could, depending on the concentration and exposure time, result in habitat avoidance behaviour, sub-lethal effects or mortality. Given the predicted long restitution time (>10 years) and possible population-level effects if the spill was to occur at peak aggregation time and a few individual breeding females were to die due to oil toxicity, the predicted risk is conservatively ranked Category 8.
Sperm whale
Male sperm whales may be present in the Great Australian Bight throughout the year, though it is likely that sperm whale densities in the region vary in response to seasonal changes in localised productivity associated with upwelling events which may occur 4–5 times a year (Ward et al. 2017; Mackay et al. 2018).
Sperm whales may be exposed to fresh oil and associated VOCs when traversing the central Great Australian Bight. Foraging areas for the species are closely associated with the sub-marine canyons of the continental slope, particularly the Albany Canyon group (>1000 km west of Stromlo-1) and the Kangaroo Island Pool KEF (Bailleul et al. 2017). Of most relevance to the current assessment is the foraging BIA ~100 km north of the well site and the area to the south-west of Kangaroo Island – noted as a key location for sperm whales (Bannister et al. 1996). These are the important sperm whale areas most likely to be affected by a major spill. Groups of sperm whales may be susceptible to ingestion of dissolved and entrained oil, as they gulp feed at depth, if high concentrations of oil reach their foraging areas. They are less susceptible to weathered surface oil contact with their relatively impervious skin.
A WCD could result in weathered floating oil reaching parts of the sperm whale foraging BIA (Figure 2.3) particularly around the Bonney Upwelling; however, sperm whales are unlikely to ingest weathered floating oil due to their deep-water feeding habits. They are more vulnerable to inhalation of toxic compounds when surfacing from deep dives in offshore areas with fresh oil which may overlap some of their foraging area BIA. Sperm whales are unlikely to ingest large quantities of the in-water oil components while gulp feeding at depth in the Albany Canyons, Bonney Upwelling or Kangaroo Island Pool canyon area as modelling predicts no exposure to elevated in-water oil. As such, sub-lethal physiological and behavioural effects are possible, but no mortality of individuals are predicted at these aggregation areas. Given the uncertainty in the actual distribution of sperm whales and their travel routes, and the potential for haphazard exposure to fresh floating oil offshore, the effects are predicted conservatively to range from behavioural and physiological effects on foraging groups, to worst case mortality of a small number of individuals.
There is no evidence of recovery of sperm whale populations since commercial whaling ceased in 1978 and as such even a small number of individual mortalities may affect the recovery of the regional population. The potential for population-level effects is mitigated by the sex-bias in southern Australian waters, where males dominate the herds of sperm whales recorded in the Great Australian Bight (Gill et al. (2015), Johnson et al. (2016)). While males have historically been targeted by whalers off south-west Australia and their numbers remain depressed, loss of a small number of males is not expected to affect the reproductive output of the national population; however, it may have a long-term (>10 years) effect on the recovery of the regional population and ranked Category 7. Loss of individuals, should it occur, is not predicted to affect the viability of the regional population because it is a small perturbation in relation to natural mortality levels and episodic events such as the mass stranding (115 individuals) in 1998 (Evans et al. 2002), which the current population status has absorbed.

Species/receptors	Qualitative risk assessment for unmitigated 129-day WCD
SRW – breeding, foraging, distribution and migration BIAs	8
PBW – foraging, distribution and migration BIAs	8
Sperm whale – foraging BIA	7

1.4.9 Benthic invertebrates (other than corals)

Sensitivity
Benthic invertebrates include sponges, sea pens, crustaceans, echinoderms, cnidaria, molluscs, annelid worms and many other taxa. Benthic invertebrates inhabit the seabed and are potentially at risk of toxic effects of exposure to dissolved/entrained oils, as well as toxicity and physical oiling resulting in smothering from floating oils in intertidal areas. Benthic fauna inhabit three main aspects of the vertical seabed profile, namely:
i. The sediment–water interface (includes epibiota). Organisms are sessile (live fixed to or in the seabed and grow upwards into the water column) or motile. A wide range of feeding types are represented, though filter feeders comprise a greater proportion of communities/assemblages than in subsurface habitats. Organisms inhabiting the sediment-water interface are likely to have the greatest risk of exposure to in-water oils, either directly (exposure to dissolved or entrained oils) or indirectly though feeding (e.g. filter feeders, surface detritus feeders, surface deposit

feeders, herbivores, scavengers and carnivores) due to oil on external surface or within the feed item (absorbed, bioaccumulated or in the gut). Ventilation of respiratory surfaces will also be a method of uptake of oils.

ii. The bioturbation zone (i.e. upper 10 cm of "soft" sediment habitats), is a refuge for infaunal biota (i.e. organisms that actively burrow into sediments). The transition from a well-oxygenated environment to an anoxic environment generally occurs in this zone. Many infaunal species have adapted to this environment by having specialist methods to either irrigate their burrow, or to siphon oxygenated water from the sediment surface. Organisms in this environment are generally surface deposit feeders, subsurface deposit feeders, scavengers or carnivores, though several species can adopt multiple methods for obtaining food. Such as *Nereid polychaete* worms which are active hunters but can also filter feed by producing a mucous net that they hold in their burrow, which catches particles drawn down by the irrigation current. The worm then eats the mucous net with the items caught on it. Organisms drawing water from the sediment surface or feeding on organic material in the upper sediments would be at risk of exposure from spill oils.

iii. Deep sediments (>10 cm below the sediment surface). This zone is generally anoxic, and organisms have adapted to living here by either building deep burrows (e.g. scampi can build burrows >1 m deep), have modified appendages to draw down oxygen from oxygenated sediments (e.g. some infaunal sea urchins have modified tube feet that extend into the oxygenated layer), move between the oxygenated and anoxic layers, or have adapted to low-oxygen conditions. Taxa that draw down oxygenated water from the surface are at potential risk of oil exposure from a spill in this zone.

Acute or chronic exposure through surface contact, respiration and/or ingestion can result in toxicological risks. The presence of an exoskeleton (e.g. crustaceans) will reduce the effect of oil absorption through the surface membrane, except for e.g. respiratory membranes. Other invertebrates with no exoskeleton and larval forms may be more prone to effects from in-water oils.

There are multiple mechanisms through which benthic invertebrates may be exposed to spill oils. Firstly, oils are likely to contact the seabed within the close vicinity of the release, hence effects by direct contact localised. Secondly, dissolved and entrained oils are likely to adsorb to organic material in the water column or be incorporated into it e.g. copepod faecal pellets. These oils may be deposited on the seabed in "marine snow" (clumping, sinking and deposition of organic material from the water column. This process explained oil contamination at depths of 1600 m, below the depth where diffuse oil was found (Schrope 2013), after the Macondo spill. In this way, oils may be distributed over a wider area but at lower concentrations. Thirdly, where a plume of dissolved/entrained oils travels at depth in close proximity to the seabed, benthic biota may be directly exposed to oils and may also take up oils through respiration and burrow irrigation). A fourth mechanism was identified during the Macondo spill, where the vertical movement of the plume of dispersed oils from the well head was inhibited by stratification of the water column (i.e. halocline/ thermocline). The plume was carried tens of kilometres at depth from the release site, moving into areas with shallower water depth by prevailing currents (at depths of 900–1300 m), where it came into contact with the seabed, and oils adhered to sediments (Schrope 2014).

Effects from entrained oil may potentially include the effects of oxygen depletion in bottom waters resulting from the metabolic processes of bacteria degrading the oil.

Studies undertaken since the Macondo spill have shown that fewer than 2% of the more than 8000 sediment samples collected exceeded the United States Environmental Protection Authority sediment toxicity benchmark for aquatic life, and these were largely limited to the area close to the well head (BP p.l.c. 2015). However, the US EPA states that Oil-Related Organic Compounds are assessed jointly (via a mixture approach) as they have the same type of effect on aquatic organisms. Therefore, potency divisors are not determined from chemical-specific benchmarks, but are intermediates used in calculating aggregate toxicity (i.e. toxicity of the whole mixture). The potential risk to aquatic organisms is assessed by comparing the sum of the calculated values to an event index of 1. Values of greater than 1 indicate a potential to cause acute or chronic effects on sediment-dwelling organisms (such as annelid worms, crustaceans and molluscs). Subsequent studies of the effects of the spill on benthic infauna (e.g. Reuscher et al. 2017)) have identified significant differences in benthic infaunal communities between the identified effect zone and un-affected zone. The sediment effect zone extended up to 16 km from the release location (in the direction of prevailing current flow), with surficial sediments found to have an average polycyclic aromatic hydrocarbon (PAH) concentration of 218 ppb and total petroleum hydrocarbon (TPH) concentration of 1166 ppb. The un-affected zone was determined to be outside of the effect zone based on multivariate analysis, where average PAHs were 14 ppb and TPHs were 102 ppb. Significant differences between these zones were identified from surveys in 2010, 2011 and 2014.

The ecological implications of potential reduction in diversity and abundance of benthic invertebrates will be dependent on the habitat affected. Areas of highly mobile sediment, where diversity and abundance are relatively low, will likely recover quickly. Complex assemblages (e.g. sponge habitat) or deep-water slow-growing sessile invertebrates (e.g. deep-water coral) are likely to recover much more slowly, and loss of these epibiota could change seabed habitat complexity. A reduction in habitat complexity has a knock-on effect on benthic, demersal and pelagic biota though loss of e.g. nursery habitat and food sources (through loss of refugia and ecological niches).

Localised effects to benthic larval stages may occur where hydrocarbons accumulate in seabed sediments, which could affect population recruitment that year. If invertebrates of commercial interest are contaminated by hydrocarbons, tissue taint can remain for several months, although taint may eventually be lost. For example, it has been demonstrated that it took 2–5 months for lobsters to lose their taint when exposed to a light hydrocarbon (NOAA 2002). However, several habitat-modifying/stabilising species are long-lived and require decades to become sexually mature (especially in deep sea habitats), and in such recovery could take longer. A degree of uncertainty is involved in estimates of recovery of benthic habitats due to the great range in data from an understanding of the benthic habitats

found in the Risk Environment that May Be Affected. For example, benthic particulate habitats in Australia (and their value) are poorly understood, despite the global weight of information derived from studies of the environmental effects of benthic trawling, which targets such habitats. Studies have shown that benthic trawling reduces habitat heterogeneity and benthic biological diversity, with resulting effects to e.g. commercial fisheries and higher trophic levels (e.g. Hiddink et al. 2006; Jørgensen et al. 2016; Sköld et al. 2018). Uncertainty will be managed through consideration of the data derived from the Commonwealth Scientific and Industrial Research Organisation/SARDI baseline surveys to assist development and implementation of the Operational and Scientific Monitoring Program (OSMP).

Predicted effects in context of this event

Studies of marine invertebrates within the Great Australian Bight region have largely concentrated on shallow nearshore environments with the Great Australian Bight MP extending the knowledge about the marine invertebrate communities on the shelf-break, continental slope, continental rise and abyssal plane, i.e. at depths of 200–5000 m.

Highly diverse soft-sediment benthic invertebrate communities occur intermittently along most of the Great Australian Bight shelf, amongst vast expanses of bare sandy sediments (Currie et al. 2008; DSEWPaC 2012b). While not spatially defined, the Benthic Communities of the Eastern Great Australian Bight are recognised as a KEF of the South-west Marine Region (DSEWPaC 2012a) but the majority of the shelf and shelf break in the Eastern Great Australian Bight likely support thigh levels of productivity that in turn support diverse benthic invertebrate communities.

The high levels of biodiversity are attributed to the unusual width of the continental shelf, the high degree of geographic isolation from similar habitats, and the opportunities for incursions by tropical species in the Leeuwin Current (DSEWPaC 2012a). Community structure changes progressively across the shelf with depth. The species that make up these communities decrease in abundance moving away from the coast. The largest shift in community composition is a significant decline in species richness and biomass that occurs between the inner (0–65 m depth) and mid-shelf (65–200 m) (Currie et al. 2008). A survey undertaken in 2010 of benthic macrofauna in deep offshore waters of the Great Australian Bight Marine Park reported considerably lower densities with 50–450 individuals/m^2 at 500–2000 m (Currie & Sorokin 2011). There was a clear peak in abundance of infauna at intermediate depth (400 m) and very low abundance in deep waters; the Great Australian Bight appears to have relatively low infaunal abundance compared to other areas in this depth range (Tanner et al. 2017). Most species were represented in only a few samples. Infaunal densities peaked at 400 m depth (1320 ± 175 (se) m^2) and declined consistently to 2800 m (268 ± 55 (se) m^2) and were low (268–1320 individuals/m^2) compared to densities documented elsewhere (Tanner et al. 2017).

In 2002 and 2006 SARDI surveyed the shelf within and around the Great Australian Bight Commonwealth Marine Reserve to a depth of 200 m (see Appendix 7-3) and sampled a total of 661 kg of living benthos, including a total of 735 benthic invertebrate species (Currie et al. 2008). Sessile suspension feeding organisms dominated the samples, comprising over 98% of the biomass and 85% of the species collected (Currie et al. 2008). The shelf communities sampled included 360 species of sponge, 138 ascidians and 93 bryozoans, many of which were new to science (Currie et al. 2008). The most common free-living organisms were echinoderms and molluscs, which comprised only 2% of the biomass and 12% of the species collected (Currie et al. 2008).

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The Tasmanian live bearing seastar (*Parvulastra vivipara*), listed as “Vulnerable” under the EPBC Act, was the only threatened marine invertebrate species identified in the PMST report for the Risk EMBA (Appendix 7-2). This species is endemic to south-east Tasmania. Stochastic modelling of an unmitigated WCD has identified that the habitat of *P. vivipara* is outside of the area exposed to moderate (or above) sea surface and in-water thresholds, and therefore this species is unlikely to be affected.

Scientific monitoring following the Macondo spill identified several pathways through which hydrocarbons from a loss of well control could cause effects to benthic invertebrate communities. These include direct exposure to dissolved and entrained hydrocarbons in the vicinity of the well, and sedimentation of entrained hydrocarbons absorbed to organic matter are likely to affect populations at the local scale. Further afield, potential effects to planktonic early life stages (eggs and larval stages) in surface waters and smothering by hydrocarbons in nearshore areas (e.g. tar mats) or intertidal areas (shoreline accumulation) are also likely to affect benthic invertebrates at regional-scale population levels.

Being resident on the seabed, benthic communities will be less affected by floating oil and shoreline accumulation, but it is noted there is a wide range of habitats hence communities within the EMBA, each with different sensitivities and exposure duration. No benthic invertebrates within the AMPs (excluding the Great Australian Bight MP) or KEFS are predicted to be exposed to dissolved or entrained oil above a moderate threshold. As such for the conservative worst case, a WCD may have long term effects on local populations, with restitution times from 3–10 years and consequences are ranked Category 6.

Species/receptors	Qualitative risk assessment for unmitigated 129-day WCD
Benthic invertebrates	6

1.4.10 Deepwater and other coral species

Sensitivity
Deepwater corals (azooxanthellate scleractinian corals) are located in offshore benthic habitats and are most likely to be susceptible to exposure to in-water hydrocarbons i.e. dissolved and dispersed hydrocarbons. Coral gametes or larvae in the surface layer where they are exposed to the slick may also be fouled (Epstein et al. 2000). Physical oiling of coral tissue can cause a decline in metabolic rate and may cause varying degrees of tissue decomposition and death (Negri and Heyward 2000). Effects to deep-water corals from the hydrocarbons and dispersed hydrocarbon plume were identified up to ~25 km from the Macondo release location (Fisher et al. 2014). Corals were covered with clumps of flocculated brown material containing oil droplets (NOAA 2018). Stress indicators observed included tissue loss, sclerite enlargement and excess mucous production (White et al. 2012). While cnidarian corals are generally associated with tropical waters, they can also be found in deep, dark, cold waters worldwide, including species such as *Solenosmilia variabilis*, which has a worldwide distribution and may form dense aggregations in depths of 1000 to 1400 m in waters off southern Australia (Althaus et al. 2009; Freiwald et al. 2004; Koslow et al. 2001). The Anna's Pimple and Murray's Mount pinnacles are within the Risk EMBA and are expected to support diverse and unique benthic faunas, such as stony corals, black corals and octocorals (Currie & Sorokin 2011). However, towed camera surveys by Commonwealth Scientific and Industrial Research Organisation during the Great Australian Bight Deepwater Marine Program (which was completed in 2018) did not find evidence of large aggregations of these species, although some individual colonies were recorded. Three reef-building species occur in the shallow waters of the Great Australian Bight and more than 50 non-reef-building species in the Risk EMBA in waters up to 900 m deep (Shepherd and Veron 1982). Alderslade (2003) notes that records of soft corals are very rare from Albany to the Great Australian Bight and that there are "no records of shallow-water soft corals from the western and central Great Australian Bight". Montagna et al. 2005 found solitary deep-water scleractinian coral at 1000m water depth in the central Great Australian Bight (Figure 2.6) and the Tasmanian Parks and Wildlife Services list stony corals as found in the shallow reefs around the Kent Group of islands in Bass Strait, off north-east Tasmania. These corals may be sensitive to deposited or entrained hydrocarbons. The nearest known deep-water coral colonies are located approximately 100 km to the north-east of EPP39 with other isolated communities directly north more than 160 km distant (close to the 400 m water depth) and north west near the 1000 m water depth (Figure 2.6). The closest habitats which may support deep water coral colonies are Anna's Pimple and Murray's Mount pinnacles which are approximately 20 km to the north-east of the Stromlo-1 well.
Predicted effects in context of this event
Surveys following the Macondo oil spill identified effects to the health and survival of deep-water corals from entrained oil in flocculant organic matter up to a distance of around 25 km from the well location (Fisher et al. 2014). The modelling predicts known coral locations to fall outside the moderate dissolved and entrained threshold contours. There may be unmapped deep-water coral locations within the higher threshold contours which may have long restitution times. However, the Great Australian Bight Research Program did not identify large aggregations (Williams, 2015), just individual colonies. Such deep-water coral may be slow to recover (>10 years) and consequences are ranked Category 6-7 for these sparsely distributed local populations. As the area potentially impacted by entrained oil above the moderate threshold lies deeper than 900 m, the corals shallower than 900 m such as those in the nearshore areas around the Kent Group of Islands (approximately 30 m water depth, Parks and Wildlife Services Tasmania) will not be exposed to entrained or dissolved oil above the moderate threshold. Given the sparse known abundance in the shallow waters where elevated in-water hydrocarbons are unlikely be encountered, potential consequences are ranked Category 1-3.

Species/receptors	Qualitative risk assessment for unmitigated 129-day WCD
Deep water corals	6-7
Other corals	1-3

1.4.11 Benthic habitats

Sensitivity
Benthic habitats are generally exposed in-water (dissolved and entrained) and depositional hydrocarbons (e.g. absorbed by organic marine snow, in faecal pellets or in the tissues of sunken dead organisms). Nearshore and intertidal benthic species may be exposed to surface and shoreline accumulation of oil. Exposure can lead to effects including mortality, and recovery of benthic habitats exposed to entrained hydrocarbons may be expected to return to background conditions within months to years of contact. However, several studies have indicated that rapid recovery rates may occur even in cases of heavy oiling (Burns et al. 1993; Dean et al. 1998 in

Committee on Oil in the Sea 2003), though this will dependent on e.g. water depth and the community or assemblage of organisms and their life histories.

The Risk EMBA supports a diverse range of particulate ("soft") sediment habitats, comprising many species of sponges, echinoderms, annelid worms, crustaceans, molluscs, ascidians, cnidarians and bryozoans. Infaunal abundance was found to peak around 400 m water depths, declining consistently with increasing depth (Tanner et al. 2017).

Shallow-water hard substrate (emergent bedrock and consolidated mixed substrate) habitats in ≤30 m water depth, are likely to be dominated by epibiota such as macroalgae, seagrass, sponges, hydroids, bryozoans or ascidians. These habitats are highly productive and provide a wide range of food sources and ecological niches for biota, increasing local biodiversity. They are home to a wide range of invertebrate flora and fauna and demersal fish species, including species of commercial importance (e.g. scallops, crabs, lobsters and various demersal and pelagic fish species).

Unconsolidated mixed and particulate sediments are likely to be dominated by burrowing fauna (e.g. annelid worms, molluscs, echinoderms, crustaceans, cnidarians) and may have sporadic high densities of motile filter feeders (such as scallops, sea pens or brittlestars) in areas of high current flow. Many of the organisms that live in these habitats are habitat modifiers (e.g. through burrows or shell production), stabilising and/or oxygenating the sediments around them, and providing additional ecological niches for colonisation by other fauna – increasing local biodiversity.

Deep-water habitats (off the continental shelf) are generally characterised by low densities of biota. However, habitat-forming and habitat-modifying organisms may be larger, long lived and have slower growth rates – with some taxa becoming sexually mature after decades (e.g. infaunal bivalve molluscs).

Inshore and intertidal benthic habitat may be exposed to surface and shoreline oil. Resident fauna such as annelid worms, molluscs and crustaceans may suffer lethal effects if oil penetrates the sediments, especially in highly productive sheltered shorelines where oil is more likely to be retained.

Predicted effects in context of this event

Several unique factors combine to contribute to the high level of biodiversity and endemism in the Great Australian Bight. These include a long period of geological isolation, a persistent high wind and wave energy environment, warm water intrusion via the Leeuwin Current from Western Australia, and cold water, nutrient-rich upwellings in the east (DSEWPaC 2012b). Taxonomic groups with exceptional diversity in this area include red algae, ascidians (sea squirts), bryozoans (including lace corals), molluscs (shellfish) and echinoderms (such as sea urchins and sea stars). Rogers et al. (2013) stated that about 70% of the seabed in the Great Australian Bight is composed of soft unconsolidated particulate sediments. Due to large variations in bathymetry, however, there are marked differences in sedimentary composition and benthic assemblage structure across the region (Rogers et al. 2013). The inner coastal regions of the Great Australian Bight support a diverse range of seagrasses, macroalgal habitats and sponge-dominated communities but the autotrophic habitats (such as seagrass and macroalgae, discussed later) are restricted by light penetration and therefore are generally limited to water depths less than 100 m (DEWHA 2007; McLeay et al. 2003). Due to the waters of the well location being considerably deeper than this (>2000 m), it is expected that deep-water sponge communities (e.g. associated with the ancient coastline KEF) and communities associated with sea mounts are likely to be present and of potential conservation interest.

Direct effects from dissolved and entrained hydrocarbons to deep water benthic habitats in the Great Australian Bight may occur within 25 km of the well location (based on Macondo oil spill scientific monitoring surveys), but to apply a precautionary approach because of likely differences between Stromlo-1 location and oil type and the Macondo oil spill situation, this may be considered as the 40 km extent of the Impact EMBA (planned activities). Habitat persistence, cyclicity and successional processes may also be affected by effects to planktonic early life history stages, and subsequent poor recruitment. This may result in the shift in the trajectory of the habitat, resulting in the change in nature of and ecosystem services provided by the habitat affected.

Shallow water threatened ecological communities (TECs; such as the giant kelp (*Macrocystis* spp. or *Posidonia*) may also be affected by spill hydrocarbons (e.g. ecotoxic effects, smothering, light reduction if persistent surface slicks are present) and are discussed separately. Marine plants and macroalgae are sensitive to surface, dissolved and entrained hydrocarbons. As habitat-forming species, loss of habitat will have significant effects to a wide range of dependent biota (see further under "macroalgae" and "seagrasses" below).

The consequences of a WCD on benthic habitats is potentially Category 6 due to the regional-to-national scale of the potential effects and the worst case long-term (restitution time 3-10 years) effects on local ecosystems.

Species/receptors	Qualitative risk assessment for unmitigated 129-day WCD
Benthic habitats	6

1.4.12 Mangroves and saltmarshes

Sensitivity
The effects of surface hydrocarbons on mangroves include damage by smothering of lenticels (mangrove breathing pores) on pneumatophores or aerial prop roots, or the lower trunk; or by the loss of leaves (defoliation) due to chemical burning. It is also known that mangroves take up hydrocarbons from contact with leaves, roots or sediments, and it is suspected that this uptake causes defoliation through leaf damage and tree death (Wardrop et al. 1987). At worst, oil affected mangrove habitats could take decades to full recovery (Burns et al. 1993). Entrained and dissolved oil may affect mangrove communities through the sediment/mangrove root or sea water/root interface. Entrained and dissolved hydrocarbons contain contaminants that may become persistent in the sediments (e.g. trace metals, PAHs), leading to direct effects on mangroves due to direct uptake, or indirect effects due to effects on benthic infauna and thus leading to reduced rates of bioturbation and subsequent oxygen stress on the plants root systems. Observed thresholds for effects are likely to vary depending on the health of the system, the hydrocarbon spilled and the environmental conditions; however, observations by Lin and Mendelssohn (1996) demonstrated that more than 1 kg/m^2 of oil during the growing season would be required to affect salt marsh or mangrove plants significantly. Mangroves grow in intertidal mud and sand, with specially adapted aerial roots (pneumatophores) that provide for gas exchange during low tide (DEWR 2006). In South Australia, mangroves can reach a height of 5 m and are found mainly in low energy, muddy, sheltered coastal areas such as gulfs and bays, (McLeay et al. 2003, DEWR 2006). Key mangrove locations include: • along the west coast of Eyre Peninsula – at Tourville Bay, Murat Bay, St Peters Island, Laura Bay, Smoky Bay, Streaky Bay, and Venus Bay • Fleurieu Peninsula and Spencer Gulf – at Tumby Bay, Arno Bay, Franklin Harbour, Whyalla, northern Spencer Gulf (Two Hummock Point to Yatala Harbour), Port Germain, Port Pirie, Port Broughton, and near Wallaroo (with Spencer Gulf having the most extensive areas in South Australia) in the top northern end and eastern Gulf St Vincent (DEWR 2006; Edyvane 1999; Gillanders et al. 2013) • River Murray to the Millicent Coast, including Kangaroo Island. Mangroves are also present at coastal locations within the wider Risk EMBA, typically within sheltered bays and inlets. In Victoria, mangroves are known to occur at Western Port, Lakes Entrance and Corner Inlet, and at larger estuaries like the Yarran and Barwon rivers. The number of species and distribution increases further north where mangroves are found. In New South Wales, many species occur along the coast within tidal estuaries, coastal lakes and bays such as Tweed Heads to Hastings River, Nowra to Cape Howe, Taree to Wollongong Coast and Curtis island to Currumbin Creek on the Gold Coast. “Subtropical and temperate coastal salt marsh” (otherwise referred to as coastal salt marsh) is listed as a vulnerable Threatened Ecological Community (TEC) under the EPBC Act. This TEC is usually associated with soft substrate shores of estuaries and bays (sandy and/or muddy) along low wave energy coastlines (DoE 2013). The physical environment for the TEC is coastal areas under regular or intermittent tidal influence, with salt marsh being the key vegetation type – that being salt-tolerant grasses, herbs, sedges, rushes and shrubs generally less than 50 cm high (DoE 2013). Salt marshes occur in sheltered conditions, commonly in the strandline zone, and the vegetation offers a large surface area for oil absorption and trapping. Additionally, many salt marsh grasses, which can be dominant over large areas, have corrugated leaf surfaces which increase their holding capacity. Evidence from case histories and experiments shows that the damage resulting from oiling is very variable – as are recovery times. Lighter, more penetrating oils are more likely to cause acute toxic damage than heavy or weathered oils. In areas of light to moderate oiling where oil is mainly on perennial vegetation with little penetration of sediment, the shoots of the plants may be killed, but recovery can take place from the underground systems. Good recovery commonly occurs within one to two years. Where thick deposits of viscous oil or mousse accumulate on the marsh surface, vegetation is likely to be killed by smothering and recovery delayed because persistent deposits inhibit recolonization and restitution may take more than 4 years (Bayers et al. 2015). There are small isolated salt marshes present along the coast of the Risk EMBA (e.g. Oyster Harbour at Albany, Davenport Creek near Ceduna, Baird Bay, Streaky Bay, Kangaroo island and Coffin Bay and parts of the middle and upper reaches of the Spencer and St Vincent gulfs).
Predicted effects in context of this event
The Oil Spill Modelling Study (Appendix 7-1, Rev 1) predicts that under an unmitigated Level 3 oil spill, concentrations of oil (sea surface oil >10g/m^2, Figure 2.7 and oil accumulations ashore >100 g/m^2, Figure 2.8) could contact areas of the Risk EMBA that support mangrove and salt marsh habitats. These concentrations potentially pose a moderate to high level of threat to mangrove and salt marsh species, but not all habitats would be exposed by a single spill. Based on the modelling results, mangrove habitats at most risk, are those approximately between Ceduna / Streaky Bay, Port Phillip bay and Wilsons Promontory. The modelling results indicates that some mangroves with the fastest contact are sites on the Eyre Peninsula (IBRA, Talia-Eyre Mallee) is around 21-38 days. Areas near Port Phillip Bay (IBRA, Wilsons Promontory-Strzelecki) and beyond may be contacted after approximately 66-88 days and later.

Further north, the NSW coast mangroves may be exposed under certain conditions to shoreline accumulations of oil above moderate or high thresholds.

Based on the modelling results, salt marsh habitats at most risk are those approximately between Ceduna / Streaky Bay and around Coffin Bay, South Australia as they may be contacted fastest (Figure 2.7 and 2.8). The modelling results also indicate that some salt marsh habitats that are high up the Spencer Gulf and the Gulf St Vincent, South Australia, are beyond the contours of low floating surface oil thresholds (Appendix7-1, Rev 1) but marshes in the south of the Gulf may experience exposure to low and moderate thresholds. For NSW and WA, any oil arriving would be well weathered and likely to be in the form of stable patchy tar balls with little lasting impact on salt marshes. Isolated marshes in Victoria (e.g. inside Port Philip Bay and near Wilson's Promontory) potentially could be exposed to above moderate sea surface thresholds but probabilities are low and oil weathered.

The ecological significance of a spill on these habitats will be dependent on the degree of oiling and weathered state of the oil, and the total amount of habitat affected. Based on the modelling results, a single spill could expose a large area of coastline to moderate to high volumes of oil, but probabilities are low. (as many of the stands are in river estuaries or associated wetlands without permanent access to the open ocean).

In a review of 32 oil spill studies, the estimated recovery time of impacted marshes was <10 years for most of the sites (IPIECA, 2016). For reasons discussed above, the consequences of a WCD on salt marsh habitats could have long term effects (typically restitution times of 3–10 years). Salt marsh are important benthic primary producers and provide habitat for other species, thus the loss of salt marshes could have long-lasting indirect effects on other organisms (EPA 2016). As such, a conservative ranking of Category 6 has been applied.

Species/receptors	Qualitative risk assessment for unmitigated 129-day WCD
Mangroves	6
Salt marshes	6

1.4.13 Seagrass

Sensitivity
Seagrasses generally occur in the photic zone of intertidal and shallow subtidal waters and are common in sheltered coastal areas such as bays or lees of islands (Figure 2.6). As such, they may be exposed to surface and subsurface hydrocarbons including exposure to resuspended shoreline accumulations. Submerged (subtidal) vegetation in nearshore areas can be exposed to oil by direct contact (i.e. smothering) and by uptake by rhizomes through contaminated sediments. Exposure also can take place via uptake of dissolved/entrained hydrocarbons through plant membranes, and seeds may be affected by contact with contaminated sediment (NRDA 2012). Exposure to moderate concentrations or higher of entrained/ dissolved hydrocarbons could lead to seagrass death. When seagrass leaves are exposed to petroleum hydrocarbons, sub-lethal quantities of the soluble fraction can be incorporated into the tissue, causing a reduction in tolerance to other stress factors (Zieman et al. 1984). The toxic components are thought to be the polycyclic aromatic hydrocarbons (PAHs), which are lipophilic and therefore able to pass through lipid membranes, accumulating in the thylakoid membranes of chloroplasts (Ren et al. 1994). The sensitivity of seagrasses to hydrocarbon spills will therefore depend largely on distribution. Deeper subtidal communities will be protected from direct oiling under all but extreme weather conditions but could be affected by sediment contamination. Shallow seagrasses are more likely to be affected by dispersed oil droplets. Theoretically, intertidal seagrass communities would be the most susceptible because leaves and rhizomes may be directly oiled, and while the toxicity of the hydrocarbons is likely to have been reduced due to weathering, smothering may occur. Any reduced growth rates or temporary loss of seagrass cover (noting that rhizomes would remain intact) may result in dieback of seagrasses and some degradation of the habitat value. Seagrasses, both ephemeral genera (*Halophila* spp.) and perennial genera (*Posidonia* spp.) are found across southern Australia (Waycott et al. 2014). Seagrass distribution in the Great Australian Bight is patchy around Ceduna/Streaky Bay, within Spencer Gulf and Gulf St Vincent. Port Phillip Bay and Westernport, Corner Inlet and Gippsland Lakes, Victoria have extensive seagrass meadows. Significant areas for seagrass can be found on the New South Wales coast - the *Posidonia australis* meadows of the Manning–Hawkesbury ecoregion is listed as an "endangered" TEC within the Risk EMBA. In Western Australia, *Posidonia* spp. meadows can be found west of Eucla, around Israelite Bay/Recherche Archipelago and Nuyts Archipelago and are typically more abundant in shallow (<20 m water depth) and sheltered environments. Although most seagrass species have extensive distributions (Waycott et al. 2014), some are threatened in Australia. Short et al. (2011) listed *Posidonia sinuosa* as one of 10 threatened species of seagrass. Found from Kalbarri, Western Australia, to about Cape Jaffa, South Australia (Short et al. 2010), this species is declining in abundance at about 1% per annum (Short et al. 2011). *Posidonia* species typically take longer to recover following disturbance than most other species of seagrass (Collier et al. 2009; Kirkman & Kuo 1990). As *Posidonia* spp. are subtidal, they are unlikely to be adversely affected by surface oil but may be affected by contaminated sediments and smothering.

Predicted effects in context of this event	
The Oil Spill Modelling Study (Appendix 7-1, Rev 1) predicts that following a WCD, subtidal seagrass (such as *P. sinuosa)* will not be exposed to dissolved and entrained oil as plumes above moderate levels of entrained oil are not predicted to reach the Australian coast where seagrass meadows occur, from west of Eucla and Israelite Bay along the WA coast and east towards the Manning–Hawkesbury region in NSW (Figure 2.6). Surface oil will not contact submerged *P. sinuosa* in nearshore waters (including that of the Manning–Hawkesbury ecoregion TEC) however there may be some exposure to resuspended shoreline accumulations While impacted *Posidonia* meadows would be slow to recover, the likelihood and extent of predicted effects will be low given they are largely protected by the overlying water and the concentrations of entrained and dissolved oil predicted are at or below the impact thresholds. Intertidal seagrasses would be more likely to be affected by shoreline accumulations of oil which may exceed moderate thresholds (but at a low probability) in non-contiguous areas. The Oil Spill Modelling Study predicts it is unlikely surface oil and shoreline oil contact will occur at or above impact thresholds for intertidal seagrasses, including that of the Manning–Hawkesbury ecoregion TEC, and are unlikely to reach the upper Spencer Gulf or extend north of Adelaide. Because seagrasses are important benthic primary producers and provide nursery habitat for other species, the loss of seagrass meadows could have indirect effects on other organisms (EPA 2016). As such, consequences are ranked Category 5 for a WCD due to worst case restitution times predicted to be 1-3 years for local populations and environmentally sensitive areas.	
Species/receptors	Qualitative risk assessment for unmitigated 129-day WCD
Seagrasses	5

1.4.14 Macroalgae

Sensitivity
Macroalgae generally grow on intertidal and subtidal rocky or consolidated substrata in shallow waters to >70 m depth in the Great Australian Bight (Commonwealth of Australia 2005), although some species can grow at depths of up to >100 m (where conditions allow) (Figure 2.6) (Runcie, et al. 2008). As such, they may be exposed to in-water hydrocarbons; however, are more likely to be susceptible to surface hydrocarbon exposure in intertidal habitats as opposed to subtidal habitats. Reported toxicity responses to oils have included a variety of physiological changes to enzyme systems, photosynthesis, respiration, and nucleic acid synthesis (Lewis & Pryor 2013). Smothering, fouling and asphyxiation are some of the physical effects that have been documented from oil contamination in marine plants (Blumer et al. 1971; Cintron et al. 1981). The effect of hydrocarbons however is largely dependent on the degree of direct exposure and how much of the hydrocarbon adheres to algae, which will vary depending on the oils' physical state and relative "stickiness". The morphological features of macroalgae, such as the presence of a mucilage layer or the presence of fine "hairs" will influence the amount of hydrocarbon that will adhere to the algae. A review of field studies conducted after spill by Connell et al. (1981) indicated a high degree of variability in the level of effect, but in all instances, the algae appeared to be able to recover rapidly from even very heavy oiling. The rapid recovery of algae was attributed to the fact that for most algae, new growth is produced from near the base of the plant while the distal parts (which would be exposed to the oil contamination) are continually lost. Other studies have indicated that oiled kelp beds had a 90% recovery within 3–4 years, however full recovery to pre-spill diversity may not occur for long periods after the spill (French-McCay 2004). Exposure to in-water hydrocarbons poses the greatest threat to sensitive macroalgal assemblages, specifically the Giant Kelp Forests TEC, that grow on rocky reefs from the sea floor ≥8 m below sea level. The largest extent of this TEC is in Tasmanian coastal waters. Some patches are also found in Victoria and south-east South Australia (DSEWPaC 2012b).
Predicted effects in context of this event
Abundant macroalgae beds in the Port Stephens -Great Lakes Marine Park in NSW lie well north of predicted impact plumes. Southern Australia (Figure 2.6 and Figure 2.7) supports high macroalgae diversity (Huisman et al. 1998) and some of these species are defined as rare because they have only been recorded in a small number of locations (Scott 2013). Some species, such as the giant kelp (*Macrocystis pyrifera*) are also in decline due to climate change. Indeed, the Giant Kelp Marine Forest of south-eastern Australia has been listed as an endangered threatened ecological community (TEC) (Appendix 7-3). The "Giant Kelp Marine Forests of South East Australia" are found in shallow waters from about Cape Jaffa to Port MacDonnell, close to the South Australian–Victorian border and along the Tasmanian coast. The nearest location where the TEC is known to occur is approximately 750 km from the well location. In SA, the coast from the Head of the Bight to near Fowlers Bay is composed of bare sand with occasional patches of reef supporting macroalgal communities (mainly kelp *E. radiata* and the fucoid *Scytothalia dorycarpa*) (Rogers et al. 2013).

Modelling predicts there is a low probability of exposure to floating surface oil and oil ashore at or above impact thresholds along the coast here in shallower waters. However, parts of the west and south coast of Kangaroo Island and near Victor Harbour on the mainland (*Sargassum* spp., *Myriodesma* spp. and *Scytothalia dorycarpa*) both support diverse, dense macroalgal assemblages which, like the beds of *M.pyrifera* around Cape Jaffa, have potential for exposure at impact thresholds. The Oil Spill Modelling Study (Appendix7-1, Rev 1) predicts that under a unmitigated WCD, surface oil concentrations of between 1 to 10 g/m^2 with non-contiguous patches of 10-25 g/m^2 could contact areas supporting *M. pyrifera* from Cape Jaffa to Port MacDonnell and 1 to 10 g/m^2 along the west coast of Tasmania with exposure to moderate shoreline loadings in smaller isolated areas. Little is known about the effects of oil on *M. pyrifera*, but some studies (e.g. Edgar & Barrett 2000; Reed & Lewis 1994) suggest that this species, like other macroalgae, may be some of the least sensitive marine species to oil exposure. Further subtidal distribution of these macroalgae would reduce exposure to surface oil and in the absence of moderate to high concentration of oil in the water, effects are expected to be minimal. These systems are typically highly productive and important nurseries for fish and shellfish. Kelp is typically relatively resistant to oil (Dean et al. 1996), but the fauna associated with it may be more sensitive. The consequences of a WCD on *M. pyrifera* are ranked Category 1–3 because the modelling indicates these areas may be potentially exposed to floating surface oil above a moderate thresholds but as the degree and restitution time are dependent on the duration / probability of exposure and its depth in the water column, few locations are exposed in patches for short durations.

Species	Qualitative risk assessment for unmitigated 129-day WCD
Macroalgae - Giant Kelp Marine Forest of south-eastern Australia	1–3

1.4.15 Shorelines

Sensitivity
The fate of spilled oil reaching shorelines depends on the characteristics of the oil, the type and width of the shoreline, the area of shoreline affected and the energy environment (Reed et al. 1986, Gundlach 1987, Reed et al.1988, Reed & Gundlach 1989, Reed et al. 1989). Even when beached, oil will continue to weather. However, several additional processes become important such as re-floatation, penetration into the substrate, and retention/transport in the shore-groundwater system. A considerable study of shoreline oiling, fates and removal processes was performed as part of the development of the COZOIL model for the U.S. Minerals Management Service (Reed et al. 1986, Gundlach 1987, Reed et al. 1988, Reed et al. 1989, Reed & Gundlach 1989). The shoreline interaction algorithms used in the oil spill modelling are based on this work. The movement of oil on and off, into and out of the shoreline is a very dynamic process, changing as wind, wave and tide conditions change. In the oil spill modelling, each shoreline cell has an oil holding capacity based on oil viscosity, shoreline type, beach slope, beach width and shoreline grid cell length. Volatiles are assumed to evaporate off the shoreline immediately. Oil is removed from the shoreline or buried over time at a rate specific to the shore type. Deposition ceases when the holding capacity for the shore surface is reached (or when oil is no longer entering the shoreline system). When carrying capacity has been reached, oil subsequently reaching the area is resuspended and the slick continues to move along shore. After stranding, oil on the shoreline is removed over time through natural processes of degradation and resuspension. There are a wide variety of different types of shorelines found along Australia's southern coast and offshore islands, described as IBRAs (a group of interacting ecosystems that are repeated in similar form across the landscape for management purposes). The type of shoreline will influence the volume of hydrocarbon that could be stranded ashore and its thickness before the shoreline saturation point occurs. For instance, a sandy beach may allow hydrocarbon to percolate through the sand, and weathered oil may be buried, thus increasing its ability to hold more hydrocarbon ashore over tidal cycles and various wave actions in comparison to a rocky shore; hence hydrocarbon can increase in thickness onshore over time. The shorelines have been broken up into regions – ranging from sandy beaches to rocky headlands and mangroves and salt marshes (both assessed separately). Shoreline habitats assessed here support a suite of biota (e.g. bivalves, barnacles, worms, sea anemones) some of which are site attached or non-mobile.
Predicted effects in context of this event
The following discussion considers the potential biological /restitution effects of shoreline accumulation without any surface and SSDI mitigation for a WCD. No fresh oil was predicted to contact any shorelines and highly weathered oil has lower potential for effect. The probability and minimum time before oil contact to shorelines categorised by state is shown below and Appendix 7-1 lists these statistics by Integrated Marine and Coastal Regionalisation of Australia meso-scale bioregions, Interim Biogeographic Regionalisation for Australia subregions and local government boundaries. These divisions are useful for describing specific sections of coast as defined in the Oil spill modelling report and have been used to estimate minimum times to shore for regions. Figure 2.8 shows the maximum potential shoreline loading and Figure 2.12 shows the probability of oil ashore at or above moderate thresholds. Shorelines north and north west of the site have

low probabilities (0–5%), those north east have probabilities of 10–20% and those east and south-east >50%.shorelines east of Wilsons Promontory east and from the south-west corner of Tasmania eastwards have decreasing probabilities with outlying capes having increased exposure.

States	Probability of shoreline contact (%)			Minimum time before shoreline contact (days)			Load on shoreline (g/m^2)	Volume on shoreline (m^3)
	Low	Mod	High	Low	Mod	High	Mean	Mean
Western Australia	30	30	27	56	56	58	5,144	1,864
South Australia	100	100	100	21	21	21	27,005	108,373
Victoria	96	96	92	44	44	44	13,490	25,954
Tasmania	85	85	85	55	55	55	7,933	14,764
New South Wales	51	51	45	105	105	110	1,389	101

The probability of shoreline contact (to any shoreline in the state) of weathered oil at the moderate threshold ranges from 30% (Western Australia) to 100% (South Australia) (Figure 2.8 – Maximum shoreline loadings and Figure 2.12 – Probability of a moderate and above loading). The corresponding minimum times before moderate shoreline contact for Western Australia and South Australia were 56 days and 21 days, respectively.

The IBRA subregion which was predicted to have the greatest probability of shoreline contact at the moderate threshold was Talia (100%, on western Eyre Peninsula), while Kangaroo Island and Eyre Hills had probabilities of moderate contact of 99%.

The shortest time to shore and greatest volumes ashore have been drawn from the deterministic run (picked as the 'worst case' from 100 stochastic runs from the WCD scenario for the appropriate window of drilling. The area around Coffin Bay (South Eyre Peninsula) has the minimum time for oil to arrive ashore (predicted to be 21 days). 50% of the simulations took at least 52 days to reach the shoreline at or above the low threshold.

The effect of a WCD on individual shorelines will depend on the type of shoreline, aspect and whether they are high or low energy shores (e.g. NOAA 2002). Shoreline recovery studies link restitution times to oil type, climate, shoreline type and results range depending on the receptors monitored and level of clean up.

The oil from the 2010 *Deepwater Horizon* spill in the Gulf of Mexico was documented by shoreline assessment teams as stranding on 1,773 km of shoreline (Michel et al. 2013). Shoreline clean-up activities were authorized on 660 km, or 73.3% of oiled beaches and up to 71 km, or 8.9% of oiled marshes and associated habitats. In 2013 Michel et al. reported that one year after the spill began, oil remained on 847 km; two years later, oil remained on 687 km, though at much lesser degrees of oiling. For example, shorelines characterized as heavily oiled went from a maximum of 360 km, to 22.4 km one year later, and to 6.4 km two years later.

Hence recovery can range widely from around 2 years (Sea Empress, 1996, North Sea crude) to more than 20 years for soft sediment shorelines deeply contaminated during the 1991 Gulf War spills (IPIECA, 2016). Of the shorelines of the states potentially impacted, the consequence to shorelines in South Australia is predicted to be greatest (contacted first, highest loadings and freshest oil). It is conservatively predicted that unmitigated, impacts to the South Australian coasts are ranked Category 7 – i.e. very long-term impacts >10 years on regional populations of shoreline biota for total recovery only assuming natural attenuation.

Value	Qualitative risk assessment for unmitigated 129-day WCD
South Australian shorelines	7

1.4.16 Coastal settlements

Sensitivity
Coastal settlements are potentially at risk of effects of reduced intrinsic or visual amenity values from shoreline and surface hydrocarbon exposure. Effects potentially include loss of access, restriction of activities due to shoreline loading and fouling of coastal infrastructure with broader consequences for communities. The thresholds at which effects to coastal settlements may occur will vary depending on the aspects at risk. As an example, effects to aesthetics may be triggered by hydrocarbon visibility at the sea surface, or visible effects to fish, mangroves and other coastal habitats. The potential effects to economic values (covered in 'Socio-economic values'), effects to coastal settlements and infrastructure could include: • compromise to human physical and mental health • decline in amenity or recreational values • decline in aesthetic values • decline in water quality

- damage to public infrastructure such as desalination plants and boat ramps
- reputational damage to regions contacted by oil.

There are 104 areas defined as "Urban Centres and Localities" by the Australian Bureau of Statistics (2018) with coastal infrastructure or developments within or immediately adjacent to the Risk EMBA (Appendix 7-3). The distribution of these coastal settlements and the characteristics of the resident populations varies markedly throughout the Risk EMBA (Figure 2.9). The Oil Spill Modelling Study (Appendix 7-1) predicts the states contacted with weathered oil in less than 50 days are South Australia and Victoria (South Australia 21 days, Victoria 44 days, see 'Shorelines' above).

Of these two states, coastal settlements that have more than 10,000 people and are within the Risk EMBA are considered the key representative locations (Figure 2.9), noting that Adelaide and Melbourne fall outside the Risk EMBA:

- Port Lincoln (SA)
- Victor Harbour (SA)
- Portland (VIC)
- Warrnambool (VIC)
- Torquay-Jan Juc (VIC)
- Ocean Grove-Barwon Heads (VIC).

The well is located approximately 372 km south of the Australian mainland. This part of the mainland is dominated by the Nullarbor Plain landscape, with very few populated settlements. Most settlements in this stretch of coast are based around roadhouses that are used as stop off points for drivers from Eucla (population ~60) to Ceduna (population ~3,500).

Predicted effects in context of this event

No fresh oil is predicted to reach shorelines or coastal settlements following a LOWC. Weathered oil that could result in smothering or potential ingestion to marine biota is more of an aesthetic concern to coastal settlements, where access to the coast and recreational locales could be restricted due to clean up efforts, potentially compromising mental health, aesthetic values, water quality, and cause damage to coastal infrastructure.

Port Lincoln (as part of the Lower Eyre Peninsula LGA) is predicted to experience 35,196 g/m^2 mean volume of weathered oil on the shoreline in a 129-day release. Predicted effects in this context are short- term restricted access to coastal areas including beaches and boat ramps, a short-term decline in amenity or recreational value due to weathered oil on the shoreline, and short-term decline in coastal water quality due to the presence of oil.

Victor Harbour is predicted to experience 1,755 g/m^2 mean of weathered oil on the shoreline in a 129-day release. Predicted effects in this context are very short-term restricted access and degraded water quality.

Portland (estimated from the Glenelg LGA) and Warrnambool (estimated from Moyne LGA) are predicted to experience 29,376 g/m^2 and 6,926 g/m^2 mean loads (respectively) of weathered oil on the shoreline in a 129-day release. Predicted effects in this context are restricted access and degraded water quality.

Torquay and Ocean Grove-Barwon Heads (both estimated from Colac LGA) is predicted to experience 5,236 g/m^2 mean load of weathered oil on the shoreline in a 129-day release. Predicted effects in this context are restricted access and degraded water quality.

The effect on individual settlements will depend on the type of shoreline (e.g. muddy flats versus rocky beaches), aspect, distance from spill and whether they are high- or low energy shores, thus a range for the restitution period of 1–10 years is predicted, and the overall consequence is ranked Category 5-6.

Receptor	Qualitative risk assessment for unmitigated 129-day WCD
Coastal settlements, infrastructure-worst case: South Australia	5-6

1.4.17 Protected areas (including AMPs, KEFs and Ramsar sites)

Sensitivity

Australian Marine Parks (AMPs)

Australian Marine Parks (AMPs) in the Risk EMBA are described in Appendix 7-3 Section 1.4.3 and depicted in Figure 34 of the Oil Spill Modelling Study. AMPs vary in their conservation objectives and specific values, but all are designed to conserve fauna, habitats and water quality over the long term. Most AMPs are zoned into different sections of varying levels of protection. Zones with lower protection levels permit a range of different human activities. For instance, a Multiple-Use Zone allows extractive type activities such as fishing and oil exploration. The proposed Stromlo-1 well is inside a Multiple-Use Zone of the Great Australian Bight Marine Park (Great Australian Bight MP). As such, the Great Australian Bight MP has been assessed here as representative of the AMPS in that it has the highest

exposure to oil (surface and in water), quickest time to exposure and was raised by stakeholders during the public comment period

A temporary deterioration of water quality could still have negative effects on organisms, such as plankton, seabirds, marine mammals and fisheries resources which in turn affect the values of that Park. These effects are discussed individually within other sections.

Entrained hydrocarbons may result in negative effects to benthic sediments and habitats through deposition/ sedimentation in marine snow and faecal pellets (e.g. from copepods). Accumulation of hydrocarbons in sediments can have deleterious effects on marine benthic infauna and can be bioaccumulated through food webs. Likewise, entrained effects are discussed individually within other sections.

AMPs support populations of threatened seabirds, marine mammal and fish species. The potential effects of oil on these taxa are discussed individually within other sections.

Key Ecological Features

Key Ecological Features (KEF) are the parts of the marine ecosystem that are important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area. KEFs present within or overlapping the Risk EMBA are listed in Appendix 7-3 (Table 1.2) and shown in Figure 2.6 and 2.9. KEFS are underwater features, and hence are not at direct risk to floating surface oil or shoreline accumulated oil. Deepwater geological features, such as the Kangaroo Canyons will not be impact directly by oil. However, biological values associated with KEFs may be at risk from oil. All the KEFS themselves are underwater and offshore, hence not directly impacted by surface and oil ashore but some values of the KEFs may be.

The KEF - Commonwealth Marine Environment surrounding the Recherche Archipelago contains reef and seagrass habitats that support a high species diversity of warm temperate species (including fish, mollusc, sponges and macro algae -each discussed separately elsewhere. However, as a spatially defined area, this falls outside the moderate and above floating surface oil threshold plumes.

The KEF- Benthic Communities of the Eastern Great Australian Bight is discussed briefly under ‘benthic invertebrates’ and “Small Pelagic Fish of the SW Marine Region” discussed under “Fishes”. The Bonney Upwelling and the Kangaroo Canyons have regional importance in primary productivity and species diversity (including whale aggregations) with sensitive receptors present throughout the water column. As such these two KEFS are representative of those potentially exposed to elevated surface oil concentrations (but at or above moderate entrained and dissolved concentrations are not predicted to reach the KEFs (Figure 2.6)). The sensitive receptors (such as plankton, whales, pinniped and benthic habitats) are discussed individually in other sections.

Ramsar sites and Nationally Important wetlands

Ramsar sites are wetlands of international importance (Section 4.0), some are situated along the shoreline of the Risk EMBA and some located immediately adjacent to the Risk EMBA (Appendix 7-3). Most Ramsar sites and Nationally Important Wetlands have minimal risk of receiving oil following a loss of well control because they have no or very narrow connections to the sea. If surface oil was to enter a Ramsar site or Nationally Important Wetland, the level of effect would be dependent on the type of receptors exposed to oil and the proportion of the site exposed to oil as well as the nature of the oil (fresh versus weathered).

Predicted effects in context of this event

Australian Marine Parks (AMPs)

Surface and entrained/dissolved oil entering these AMPs will degrade water quality until the oil is broken down and or currents shift the weathering oil outside the boundaries of the AMPs. Thus, water quality effects are predicted to persist only over the short to medium term in the AMPs.

The Oil spill modelling study (Table 24, Appendix7-1, Rev 1) predicts that under an unmitigated WCD, the degree of effect to AMPs and restitution time ranges widely, depending on the nature and scale of the loss of well control, the prevailing wind and current direction, and the proximity of the AMP from the release point. Modelling indicated that seven AMPs (Great Australian Bight MP, Apollo, Eastern Recherche, Murat, South West Corner, Two Rocks, Western Eyre and Murray), could be exposed to high (here >25 g/m^2) thresholds of floating surface oil and 16 AMPs exposed to the moderate threshold for floating surface oil, with minimum time to contact (at moderate thresholds) ranging from one day (Great Australian Bight MP) to 176 days (East Gippsland) (Figure 2.9). No AMPs (other than the Great Australian Bight MP) were predicted to experience exposure to entrained /dissolved oil at or above the low thresholds (Figure 2.6).

The Great Australian Bight AMP will be most affected by an unmitigated WCD, with consequence being Category 6 (restitution period 1–3 years for environmentally sensitive areas of national or regional importance).

Key Ecological Features

The KEFs where surface oil exposure was predicted to reach the moderate or above threshold were the Bonney Coast Upwelling (87% probability), West Tasmanian Canyons (32% probability), Upwelling East of Eden (16% probability), Albany Canyons (9% probability), Recherche Archipelago (5% probability), Ancient Coastlines at 90–120 m water depth (100%) and Kangaroo Island Pool and Canyons (99% probability) (Figure 2.9). Impacts from surface oils are largely limited to aggregating surface receptors (such as rafting seabirds, whales, pelagic fish and associated food webs) as these features are submerged.

The minimum time before exposure to moderate sea surface thresholds for the Bonney Coast Upwelling KEF for the unmitigated cases was 35 days and 23 days for the Kangaroo Island Pool KEF. As noted previously, weathered surface oil loses some of the more toxic components as more volatile constituents are lost through physico-chemical weathering, becoming less bio-available as they age. As such, impacts to the values of the KEFS are assessed individually.

With respect to in water oil exposure, modelling predicted no KEFs are exposed to low or above levels of entrained or dissolved hydrocarbons at the 90–100 m depth range (Figure 2.6).

Overall, the Kangaroo Island Pool KEF, Ancient Coastline KEF and Bonney Upwelling KEFs have the highest probability of exposure to moderate and above sea surface thresholds, hence their values are most at risk from a WCD, with consequence being Category 4 (short-term effects, restitution period <1 year).

Ramsar sites and Nationally Important Wetlands

Sensitive receptors found in Ramsar sites connected to the sea could include mangroves, salt marshes, fishes, shorebirds and seabirds. The consequences of oil to these specific receptors have been described individually elsewhere. If a Ramsar site was exposed to oil following a LOWC, it is likely to have a long term or permanent effect. However, most of the wetlands are above sea level and/or closed to the ocean with seasonal or permanent sandbars and unlikely to be open in summer when there are typically lower river flows.

A number of Ramsar sites (e.g. the Coorong, Lake Alexandrina and Albert Wetland, Picaninnie Ponds Karst Wetland, Port Philip Bay, east coast of Tasmania and Flinders Island sites, Corner Inlet and Gippsland Lakes) could be exposed to low thresholds of surface oiling under specific metocean conditions. However, many of these (e.g. Picaninnie Ponds Karst Wetland) have sand dunes between the ocean and the wetlands hence the wetland itself is highly unlikely to be affected in any manner and any oil arriving would be weathered.

Likewise, several nationally important wetlands lie interspersed along the coast west of Esperance in Western Australia and from Ceduna in South Australia, though Victoria to north of Sydney (New South Wales). These could be exposed to low sea surface exposures during November to May under certain metocean conditions (Figures 2.7) and elevated shoreline loadings albeit at low probabilities (Figure 2.8, Figure 2.12). Should sea water with low levels of weathered oil enter the wetlands, the absence of toxicity effects to flora and fauna should ensure that the values of those wetlands are not compromised.

Many of the nationally important wetlands have little or no access to the open ocean, thus limiting the duration and extent of exposure. Should any wetlands such as those around Ceduna, Streaky Bay, Coffin Bay, west Kangaroo Island and south St Vincent's Gulf be exposed to above moderate sea surface thresholds under a WCD, restitution times are predicted to be long term (3–10 years) for worst case impacts to environmentally sensitive areas of national importance and the consequence is ranked 6.

Species/receptors	Qualitative risk assessment for unmitigated 129-day WCD
AMPs (GAB MP)	6
KEFs	4
Ramsar wetlands	6

1.4.18 Socio-economic values

Sensitivity

A wide range of socio-economic activities occur in the Risk EMBA largely concentrated along the coastal fringe, while shipping, defence and some commercial fisheries also operate offshore. The key sensitivities are:

- shipping and ports
- defence
- commercial fisheries
- aquaculture
- tourism and recreation (including recreational fishing and surfing)
- heritage (including Native Title).

The thresholds at which effects may occur to socio-economic values vary depending on the aspects at risk. For example, shipping and defence are likely to be affected at the level of temporary exclusions from sea areas during response; whereas commercial fisheries and aquaculture may be affected by temporary fishery closures, restrictions on sales (e.g. catches are unsafe for human consumption) or effects to market value (e.g. perceived and real tainting).The socio-economic effects of an oil spill would vary, depending on the characteristics of the specific activity affected, and the nature and scale of the spill, but have potential for long-term effects to the region and state economies. Market condition, management and behavioural responses are likely to affect the economic outcomes (e.g. Great Australian Bight fisheries; Pascoe 2018).

Port Lincoln is well regarded for its tuna fishing and on-grow (ranching) activities. Like Ceduna, its economy is based on crop, sheep and beef farming, as well as tuna, prawn, abalone fisheries and shark cage tourism. Point Lowly has a tourism industry based around viewing giant cuttlefish aggregations during winter between the months of May and August.

Aquaculture is an important industry for South Australia (District Council of Ceduna 2017 and (PIRSA 2017). Oysters are farmed in Denial Bay and Smoky Bay while Pacific oysters, finfish and mussels, are farmed in Nuyts Archipelago Marine Park, Coffin Bay, Franklin Harbour Marine Park, Upper Spencer Gulf Marine Park (Fitzgerald Bay), Lower Spencer Gulf (Boston Bay, Louth Bay, Eyre Peninsular) Lacapede Bay (fin fish) in the Upper South East Marine Park, Yorke Peninsular and Kangaroo Island. WA has aquaculture leases around Albany and Augusta while Victoria has mussel farms around Port Phillip and Western Port. Tasmanian leases (largely used for Atlantic salmon and rainbow trout) lie on the tip of the NW of Tasmania, Macquarie Harbour, Recherche Bay to Hobart and intermittently up the east coast. Leases in NSW lie scattered along the coast from the Victorian border near Eden, past Port Stephens (northern end of the EMBA) to north of Taree - well beyond the EMBA. Aquaculture varies widely from marine, estuarine and land-based farms to hatcheries, with some species such as silver perch grown widely across the states. Note that impacts to 'Benthic invertebrates' (which includes oysters and abalone) is also discussed separately within this appendix.

The socio-economic effects of a major oil spill to commercial fisheries, aquaculture and ports, defence, tourism and heritage are well documented (Cohen 1993; Smith et al. 2014; Sumaila et al. 2012). Surís-Regueiro et al. (2007) reported the economic cost to Spanish fishers resulting from the Prestige oil spill. A primary reason for the monetary cost was the temporary cessation to fishing activities following the spill. Similarly, major economic effects to fishers followed the Macondo spill (McCrea-Strub et al. 2011). This was also mainly due to fishery closures. Sumaila et al. (2012) estimated significant economic loss to both commercial and recreational fishing, and to aquaculture industries following the Macondo spill. The authors predicted long-term losses in total revenue and total profits. Major spill can also have negative effects to regional and national tourism economies (Ritchie et al. 2013).

Cultural values within the Risk EMBA range from heritage places (historical and natural) to Indigenous associations with certain sites and animals. Some of the Listed National Heritage places have coast lines that could have degraded amenity from oil ashore in the event of an unmitigated WCD. While 1037 shipwrecks lie within the Risk EMBA (seven with a protection zone declared around them), impacts from oil exposure are unlikely for submerged wrecks.

Sites of cultural importance to Indigenous peoples include coastal middens, campsites with freshwater springs and areas linked to song lines. The documented traditional Indigenous connection with the offshore area are those of the Mirning, Wirangu, Naranggga, Kaurna and Ngarrindjeri (described in Appendix 7-3) who identify as having a dreamtime connection to whales and sea lions (totems), or responsibility over the "sea country" of the Great Australian Bight. As such, impacts to whales are already assessed under "cetaceans" above, with the focus on southern right whales which come close to the coast and are valued by the Kaurna people. Impacts to sea lions are discussed under the heading "pinnipeds" above. Issues raised in the public comment period were loss of access to areas and temporary exclusions during response, the amenity of coastal sites and health of the ocean.

Predicted effects in context of this event

The Oil Spill Modelling Study (Appendix 7-1) predicts that under an unmitigated loss of well control, plumes of elevated concentrations of entrained and dissolved do not contact the coastal areas. Sea surface oil concentrations of between 1 and 25 g/m^2 could contact sections within areas supporting commercial fishing grounds and aquaculture regions, resulting in temporary closures. Surface oil is also predicted to reach major ports and thus could pose a risk to commercial infrastructure. Entrained oil may affect offshore fisheries if largely operating deeper than the 200 m isobath. Carroll et al. (2016) provided a detailed assessment of the economic impacts to the seafood industry in the US states of Alabama, west Florida, Louisiana, Mississippi, and Texas following the Macondo spill in the Gulf of Mexico. The Macondo spill was shorter in duration which at ~780,000m^3 for 89 days is smaller and for less time than this WCD. Carroll et al. (2016) examined impacts to 10 categories of fishery: shrimp (prawns), oysters, menhaden (fish of the genera *Brevoortia* and *Ethmidium*), blue crab, reef fish, pelagic finfish, other crustaceans, bait, other shellfish and miscellaneous finfish. Overall, the oil spill led to between US$51.7 and US$952.9 million loss in total sales. This loss cost the region US$21.4–US$392.7 million in value-added services, US$21.6–US$309.8 million in income, and affected 740–9315 jobs. The harvesting sector bore the brunt of the impact. Positive impacts were reported for less affected states because of the increased price for seafoods in short supply. In some instances, impacts to fishery stocks appeared to have been very short lived. For example, the authors concluded that the shrimp (prawn) harvests had rebounded within two years following the spill. Carroll et al. (2016) also summarised seafood industry trends to better understand the effects of the spill on the seafood industry. The trend analysis highlighted the challenges in predicting the economic consequences of oil spills to seafood industries. Note too, the Macondo spill occurred 66 km from the US mainland and in the "semi-enclosed" Gulf of Mexico where oil contact with coastline was largely inevitable. In contrast, Stromlo-1 is 372 km offshore the mainland in the open ocean. So, Macondo is a worst case from numerous aspects.

Based on the modelling results, areas of southern Australia could be at risk of accumulating large volumes of shoreline oil. Some of these areas support locally, regionally and nationally important tourism activities and commercial infrastructure at risk of oiling. Section 8.0 discusses the role of dispersants applied offshore to minimise effects of oiling on nearshore and shoreline environments and infrastructure.

Shipping, ports and Defence

Shipping and vessel traffic are discussed in Section 5.6 of Appendix 7-3, with traffic in the Great Australian Bight as generally low, with higher density traffic in the Spencer and St Vincent Gulfs, around Kangaroo Island from Cape Leeuwin to Victoria, Tasmania and NSW (Figure 2.10). Department of Defence has one restricted area off Kangaroo island, one off southern Tasmania and three off the NSW coast. Adelaide is the largest port within the region but lies just outside the EMBA and well outside the moderate threshold contours.

As such, impacts at worst are damage to equipment/boat yards/ramps etc. from surface and shoreline oiling and temporary displacement during response, particularly those in South Australia. Consequences are ranked 1-3 with limited temporary impacts on local populations.

Commercial fishing - southern bluefin tuna

This section focuses on southern bluefin tuna (SBT) for the following reasons: i) this species represents a highly valuable market in the region, ii) it is ranched off Port Lincoln and iii) stakeholders expressed particular interest in this species during the public comment period. The SBT fishery covers the entire sea area around Australia out to 200 NM from the coast (Figure 2.10) (Australian Fisheries Management Authority 2018). The Blue Fin Tuna (BFT) Commonwealth Fishery has been selected as representative of the largest fishing interest in the Great Australian Bight. Fishing is mostly concentrated inshore of the 200 m isobath. SBT are wild caught in the Great Australian Bight largely from January (but can be from December) and towed in nets to near Port Lincoln where they are fed local sardines supplemented by imported feedstock till harvesting is completed around the end of August.

Whilst the sustainability status is “uncertain” (Australian Fisheries Management Authority 2018), stocks are “low” (DEE n.d.) and the SBT is now considered “conservation dependent”. All assessments of the SBT stock indicate that catches of SBT are the primary factor that has caused the decline of the stock to its current low level and which has prevented the recovery of the stock (DEE 2018). Current low stock levels are due to a combination of factors including reduced levels of spawning stock and fishing effects on spawning populations (DE, 2019). For this assessment, effects to population levels were assumed in the order of magnitude as the annual allowable catch (which for 2017–2018 was 6165 tonnes). Victorian fisheries reported catches of 2344 t for 2016–2017. PIRSA regards stocks as currently “sustainable” with the total allowable catch for 2017 as 42,750 t (Ward et al. 2017).

The Fishery Status Report (2019) for 2017–18 estimates the gross value of SBT production (combined value of catch at the point of transfer to farming pens and catch sold direct into global markets) as $39.7 million (https://www.agriculture.gov.au/abares/research-topics/fisheries/fishery-status/southern-bluefin-tuna-fishery#233-economic-status). The 8102 tonnes exported in 2016-2017 were valued at $123 million based on post-ranching exports (http://www.agriculture.gov.au/SiteCollectionDocuments/abares/publications/fsr2018.pdf). ABSTIA estimate the value at $120-280 million (ABSTIA communications, 20 March 2019).

Assessment of the potential financial and socio economic impacts of a spill on the Southern Bluefin Tuna Fishery considered the relationship between the catch value and the value of Individual Transferable Quotas, the value of the caught stock and the farmed/exported stock, and the importance of Individual Transferable Quotas as collateral for financing (due to the high value added and investment in processing facilities).

As noted under the section ‘Bony fishes and sharks’, adult and juvenile SBT could be exposed to surface, entrained and or dissolved oil following a WCD. Population-level effects are unlikely, but the economic consequences (and public perception effects) could potentially very long-term. A temporary (short-term or long-term) fisheries closure put in place by the fisheries themselves or by the regulators in combination with oil tainting (actual or perceived), would lead to financial losses to fisheries and economic losses for individual licence holders. Fisheries closures and the flow on losses from the lack of income derived from these fisheries may have widespread socio-economic consequences, such as job loss (for example in fisheries service industries in tackle and bait supplies, fuel, marine mechanical services, etc). It is noteworthy that after the Macondo oil spill, the multi-species tuna fishery landings had recovered within one-year (Carroll et al. 2016) and the shrimp (prawn) harvest rebounded only two years after the spill.

For reasons discussed above the consequences of a WCD could be long-term (restitution time >10 years) on the SBT market which has national importance and ranked as Category 7. Inaccurate negative public perceptions towards the SBT fishery following a spill could be mitigated at the time by positive marketing as was effective after Macondo.

Tourism

Coastal tourism focusses largely around the whale/sealion watching season, shark diving, scenic driving, surfing and recreational fishing. Impacts to the industry will concentrate in those areas within reach of tourist access/vessels and at the times of year when the attractions peak (e.g. whales are closer to shore).

Whale/sealion watching can be land based (e.g. in South Australia off the Head of the Bight, Bunda Cliffs and Yorke Peninsula) or sea based e.g. Kangaroo Island and Western Australia (May–September off Albany and January–March off Bremer Bay). Potential impacts to the whales and sealions themselves are discussed under “cetaceans” and “pinnipeds”.

Shark diving and swimming with SBT occurs off Port Lincoln. Point Lowly (Figure 2.9), east of Whyalla has a tourist industry based around the giant cuttlefish aggregations up the northern end of the Spencer Gulf, but this is not predicted to be impacted as modelling of a WCD forecasts the area to lie outside the Risk EMBA.

Scenic drives especially those closer to larger cities (such as Fleurieu Peninsula, Kangaroo Island and Great Ocean Road) may have beaches and sites with degraded amenity and temporary restricted access/closures.

Surfing is popular along the mainland and Tasmanian coasts, ranging from remote spots along the Bunda Cliffs and Eyre Peninsula to metropolitan sites such as Torquay. Much concern has been expressed by surfing groups through

the public comment process regarding potential spill impacts. Impacts considered are human health (e.g. temporary exclusion zones) and reduced aesthetics, while the recovery of shorelines are assessed individually under "Shorelines".

Reef fishing and near coast recreational fishing including tour boat charters may be impacted. Potential impacts are similarly ranked to the potential impacts to small pelagic fishes. Small pelagic fishes (see "Fish - Bony fish and sharks") have a predicted restitution time within a year. Potential consequences to recreational fishing take into account aesthetics, perceived tainting of catches and the on-flow of consequences to local industries catering for the recreational fishers.

With respect to human health, post-Macondo oil spill (April 2010) studies in December found of 17000 water samples, none exceeded USEPA benchmarks for protection of human health (OSAT, 2010) and a year later residual oil in nearshore and sandy shoreline areas was highly weathered and concentrations of constituents of concern were below levels of concern for human health (OSAT, 2011a).

Alaska's tourism economy took approximately two years to recover from the Exxon Valdez (BOEM, 2017).The Eastern Research Group (2014) reported that while the Macondo spill had had a significant impact on several areas of tourism in the short term and had wide-ranging impacts across the Gulf, the tourism economy has rebounded to pre-spill levels within four years. Overall, the extent of potential impacts to tourism depends largely on when the spill occurred, size and where it comes ashore. Considering the range of activities and locations, the potential for degraded amenity of areas used by coastal tourists, temporary health implications and possible closures, the consequences are ranked Category 5 (resulting in medium term impacts with 1–3 years restitution time).

Aquaculture - molluscs, fin fish

Typically, aquaculture pens are in protected bays, with some on the shore but with sea water intakes (Figure 2.11). The leases most at risk are those with nets/pens open to the ocean where surface, entrained and accumulated shoreline oil potentially exceed impact thresholds. Exposure also depends on the mollusc and finfish feeding characteristics (as filter feeders may be more vulnerable than pellet fed fish) and practicalities around temporary relocations (e.g. further upstream) and provision of booming. There is a low potential for leases in WA to be exposed to moderate and above thresholds for weathered oil ashore (after a minimum of ~59 days, low probability of 0–10%) but they are not predicted to be exposed to moderate sea surface thresholds with no impacts from elevated entrained and dissolved oil. No impacts are predicted to Tasmanian or NSW leases as they lie beyond the moderate sea surface and in water exposure threshold contours. Oil ashore along NSW (>103 days) and Tasmania (~71 days) would be highly weathered with potential exposure from resuspended shoreline accumulations.

Many of the South Australian leases lie high up the two gulfs beyond the Risk EMBA, but sites from Ceduna to Kangaroo Island may be exposed to above moderate thresholds for surface oil and accumulated shoreline oil (Figure 2.11,) with probabilities ranging from 1–30% (Figure 2.12). Similar to the SBT ranches off Port Lincoln as discussed above, tainting and perceived impacts can affect markets long after biological impacts have passed. Based on oyster aquaculture occurring in 2-year cycles from seeding to harvesting and oyster larvae being recruited from uncontaminated brood stock, the aquaculture industry was predicted to recover within three years post Macondo (Sumaila et al. 2012). As such restitution times for these South Australian leases may be medium term (0-3 years for national products) and consequences are ranked Category 6.

Historic and natural heritage sites, and Indigenous heritage values

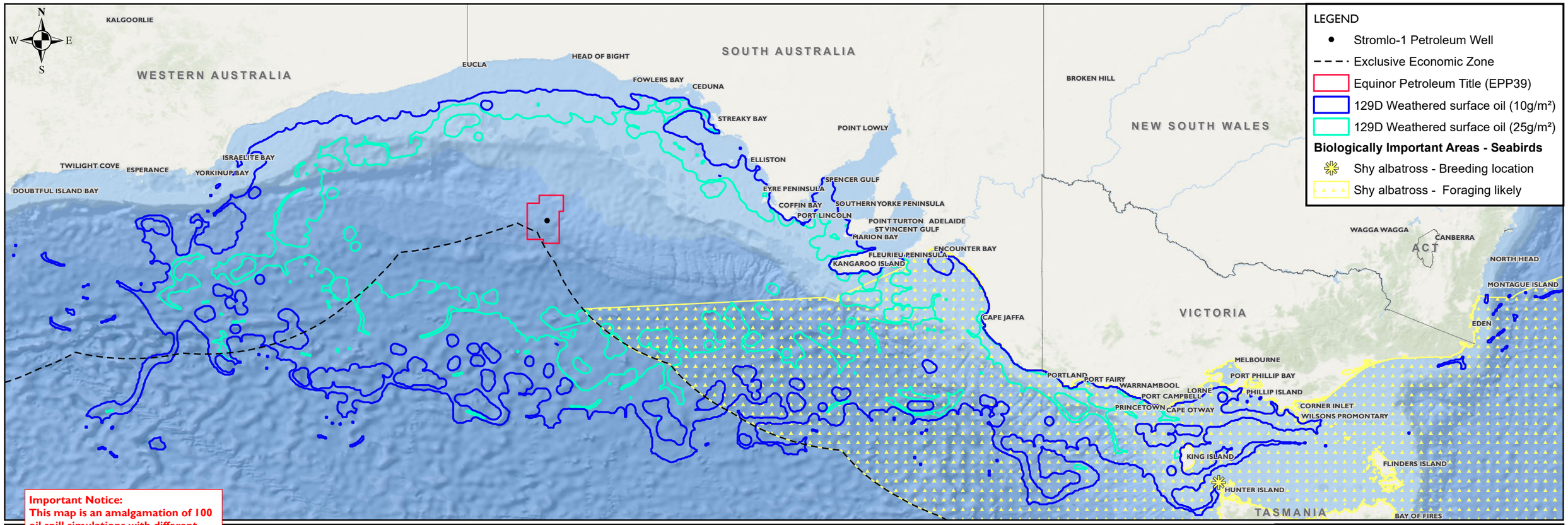
Impacts and recovery of heritage values, including that of Listed National Heritage places, are linked to beaches, coastal vegetation and towns along the coast (Figure 2.11). Many are assessed individually (e.g. shorelines, saltmarshes and coastal settlements) while impacts and recovery of sea life of Indigenous heritage significance are likewise assessed individually by receptors (e.g. 'pinnipeds and cetaceans). Impacts from degraded aesthetics of sites along the coast may take time to recover but loss of access to sites during response or for health reasons are temporary (<1 year).

The potential for consequences to heritage values due to oil spill response activities, is minimised through the application of the monitoring plan that assesses the impacts on and recovery of areas of particular heritage and Native Title importance. This plan is summarised in Table 5.2 of Section 5.0 of the OPEP (Appendix 9-1). It identifies the relevant stakeholders and registers of significant sites. It also defines activation and termination triggers to ensure timely, meaningful stakeholder consultation and data collection. Effective consultation post release, pre exposure and post exposure, will ensure the appropriate communities and agencies are involved, monitoring methods and timelines agreed, and potential disturbance minimised.

As such consequences are ranked Category 4.

Species / other	Qualitative risk assessment for unmitigated 129-day WCD
Shipping and ports	1-3
Defence	1-3
Commercial fishing - SBT	7
Aquaculture	6
Coastal tourism, whale watching, surfing, coastal drives	5
Heritage and cultural - Indigenous	4

2.0 Figures



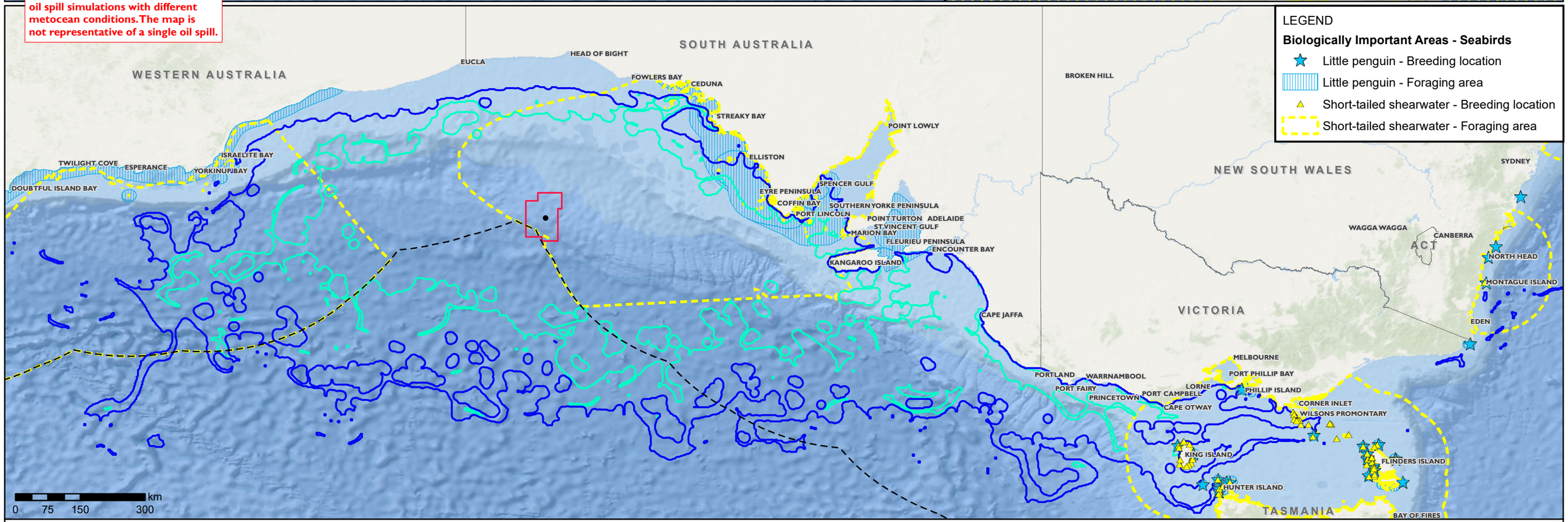


Figure 2.1
Zones of potential weathered sea surface hydrocarbon exposure (unmitigated) from 100 oil spill simulations in October to May from an average 8,943 m³/day subsea release of crude oil over 129 days, tracked for 189 days on shy albatross, little penguin and short tailed shearwater BIAs

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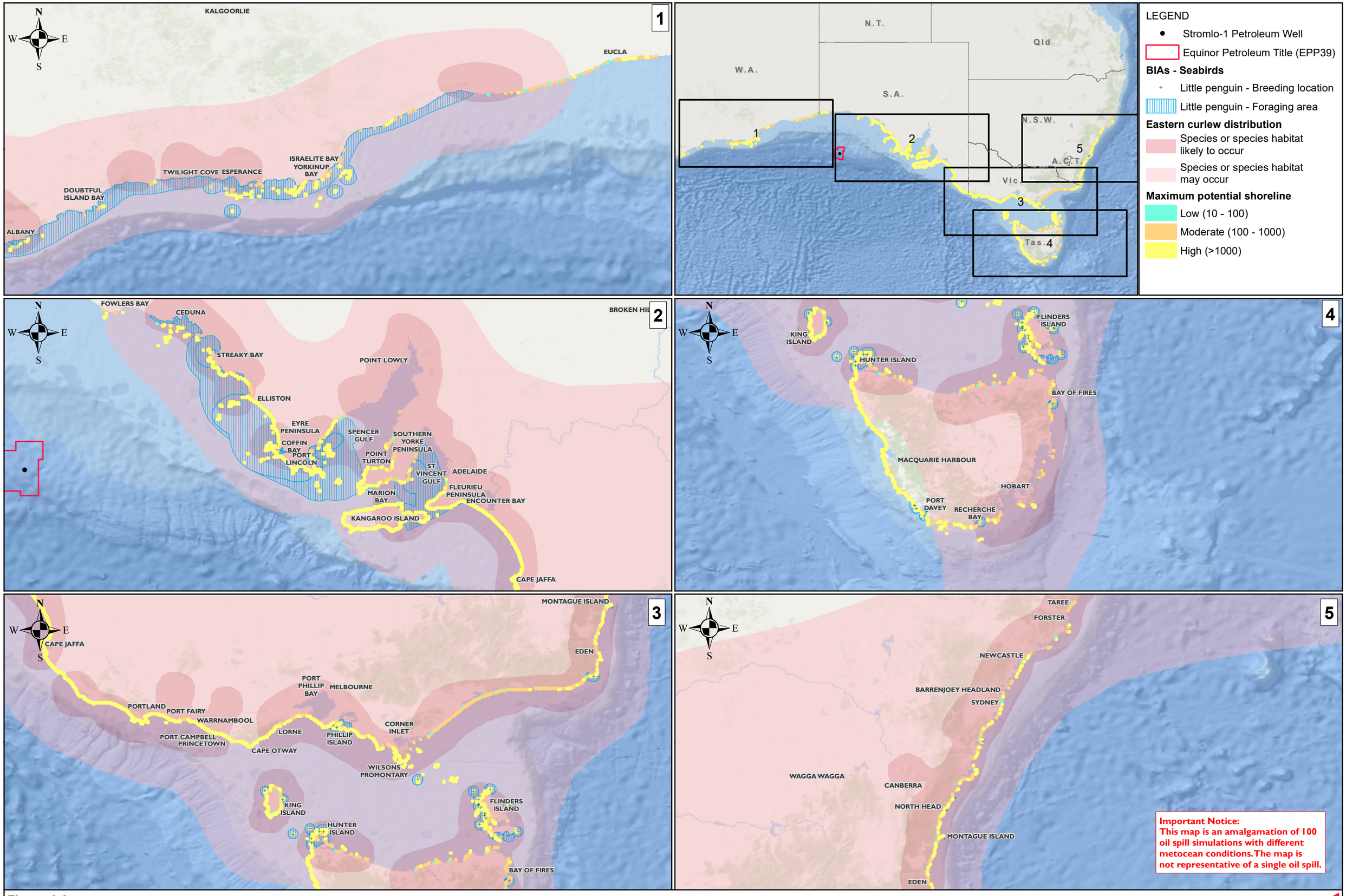

Figure 2.2
Maximum potential shoreline loading (g/m²) from weathered oil (unmitigated) from 100 oil spill simulations in October to May from an average 8,943 m³/day subsea release of crude oil over 129 days, tracked for 189 days on little penguin and eastern curlew

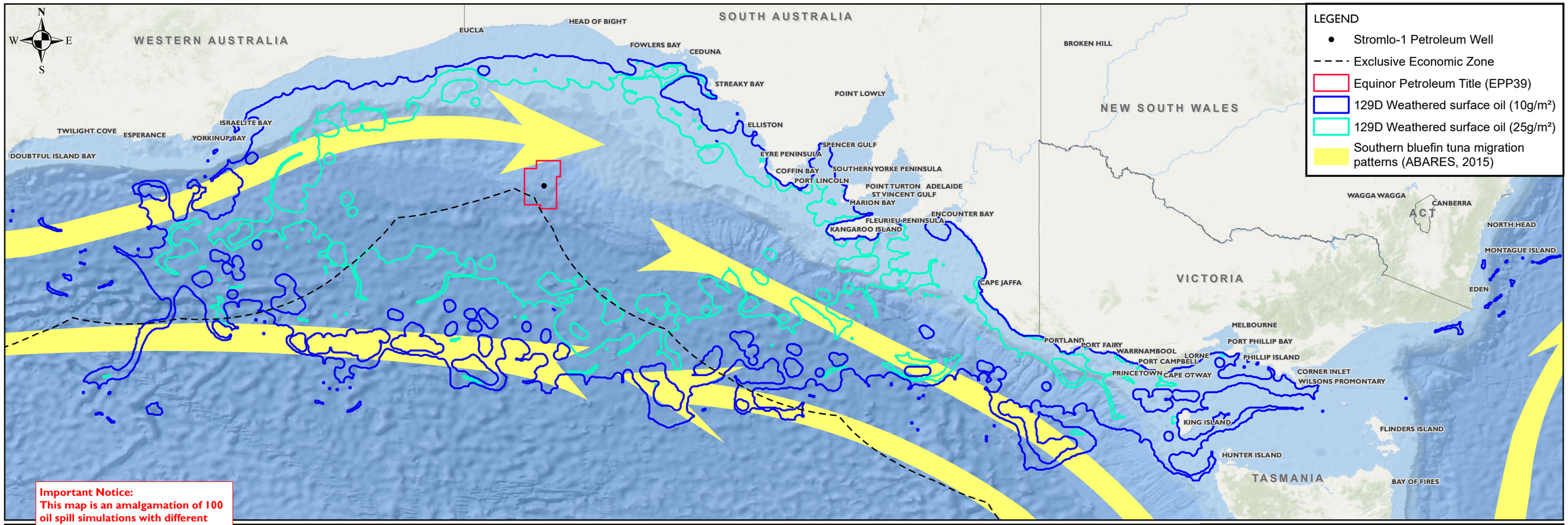

Figure 2.3
Zones of potential weathered sea surface hydrocarbon exposure (unmitigated) from 100 oil spill simulations in October to May from an average 8,943 m³/day subsea release of crude oil over 129 days, tracked for 189 days on whales BIA and SBT distribution

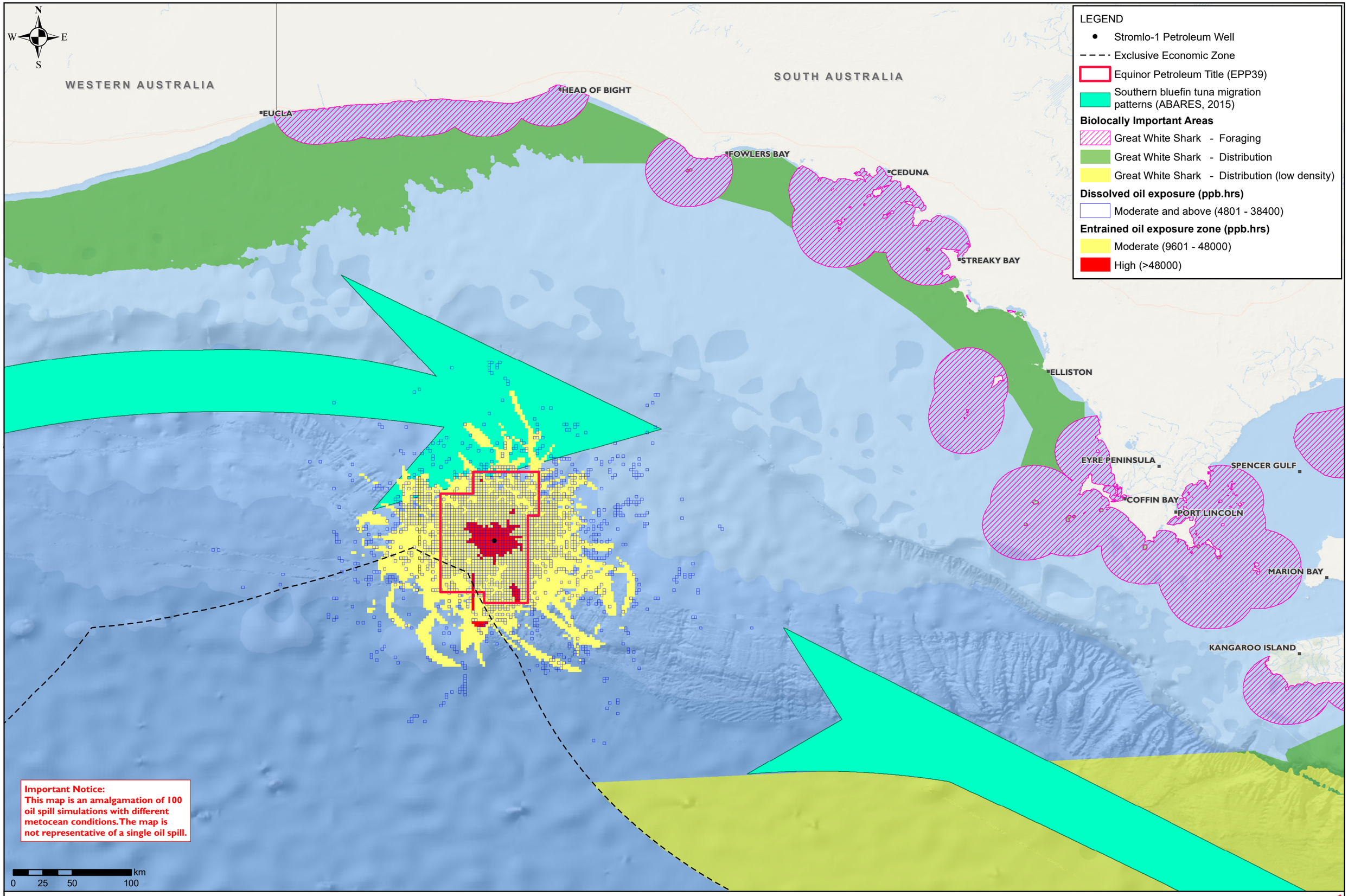

Figure 2.4
Zones of potential entrained (ppb.hours) and dissolved (ppb.hours) hydrocarbon exposure (unmitigated and dispersant mitigated scenarios) in the 0-10 m layer below the sea surface from 100 oil spill simulations in October to May from an average 8,943 m3/day subsea release of crude oil over 129 days, tracked for 189 days on SBT distribution and great white shark BIAs

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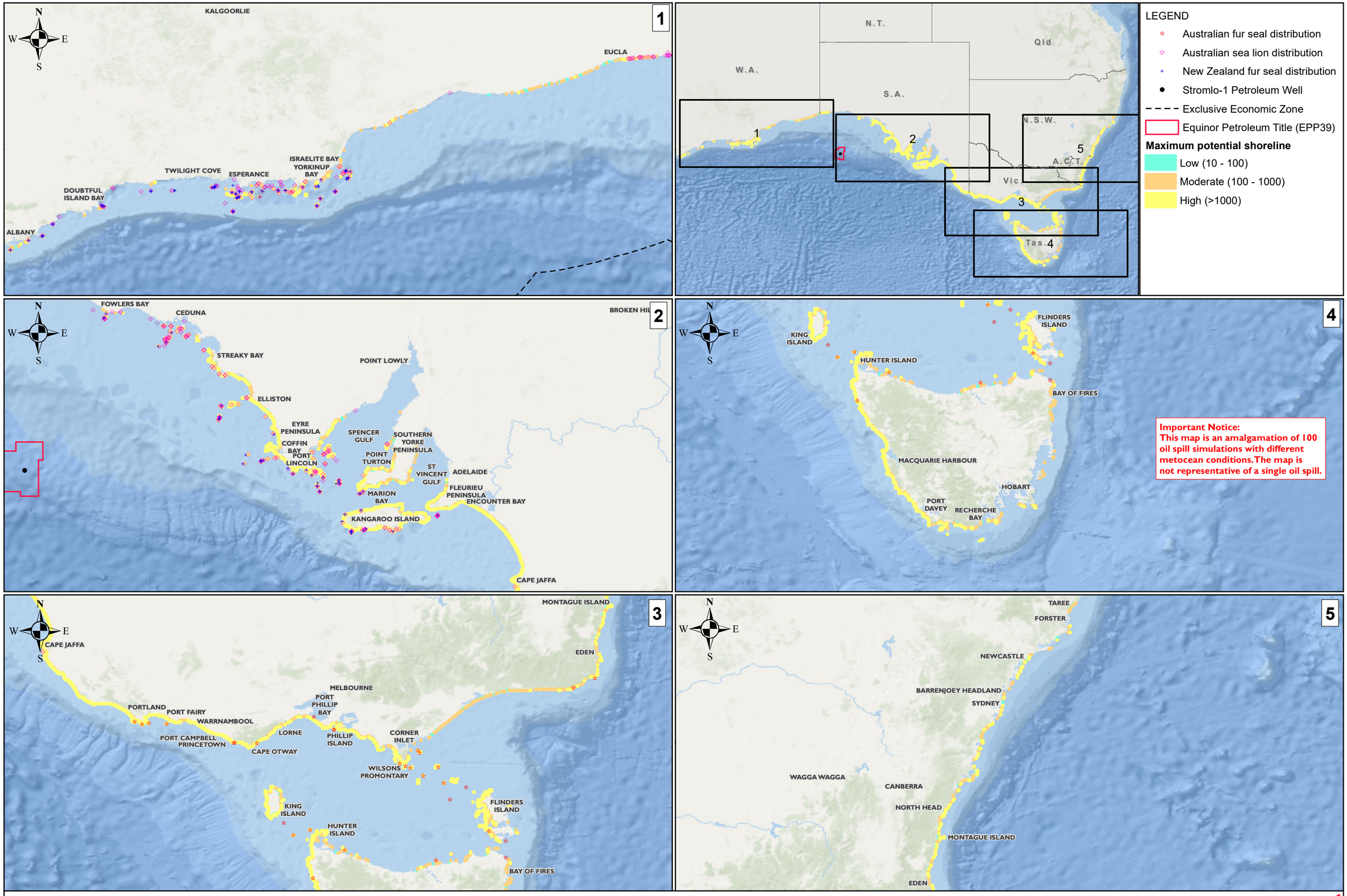


Figure 2.5
Maximum potential shoreline loading (g/m²) from weathered oil (unmitigated) from 100 oil spill simulations in October to May from an average 8,943 m³/day subsea release of crude oil over 129 days, tracked for 189 days on Australian sea lion, NZ fur seal and Australian fur seal

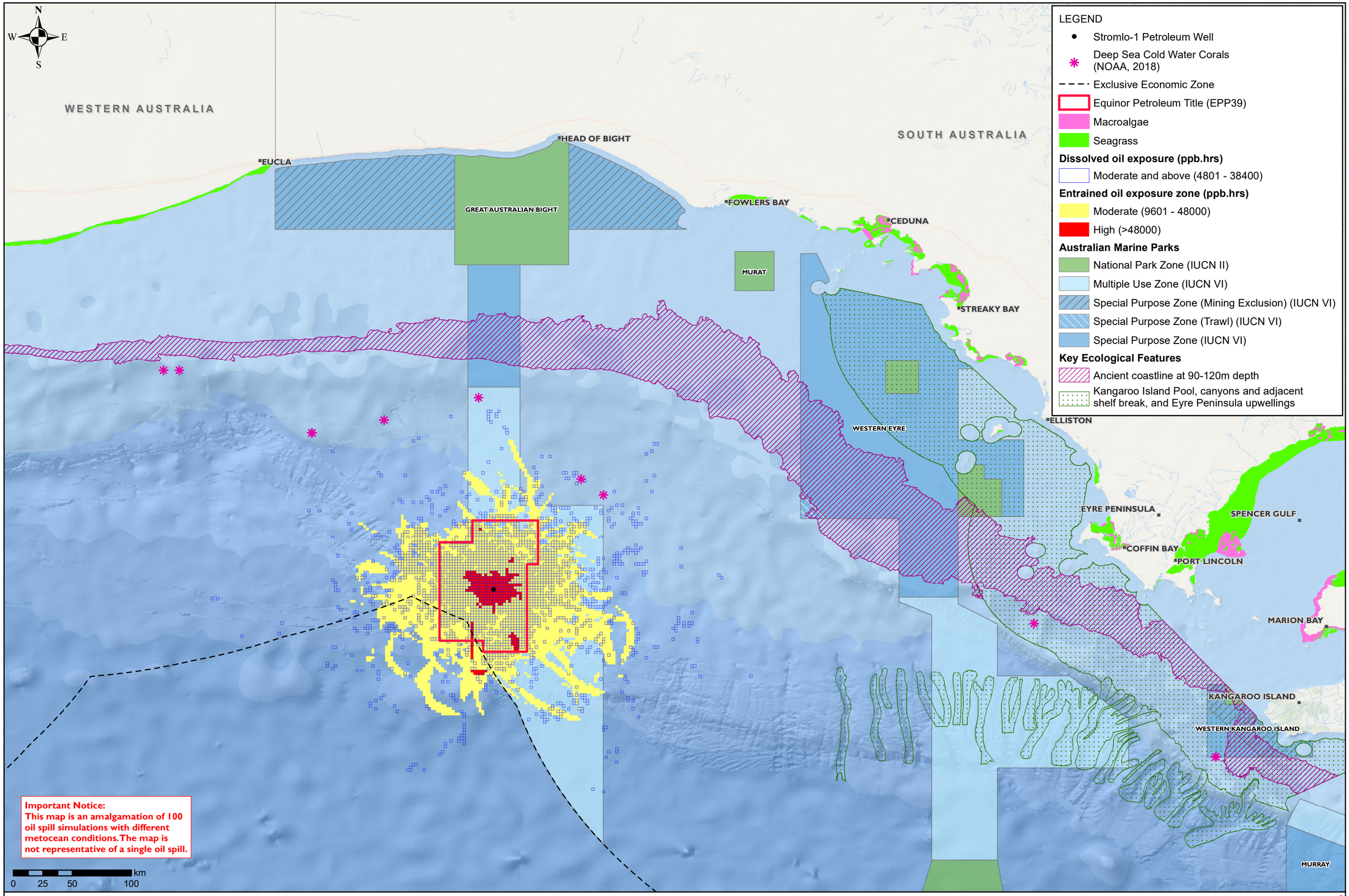
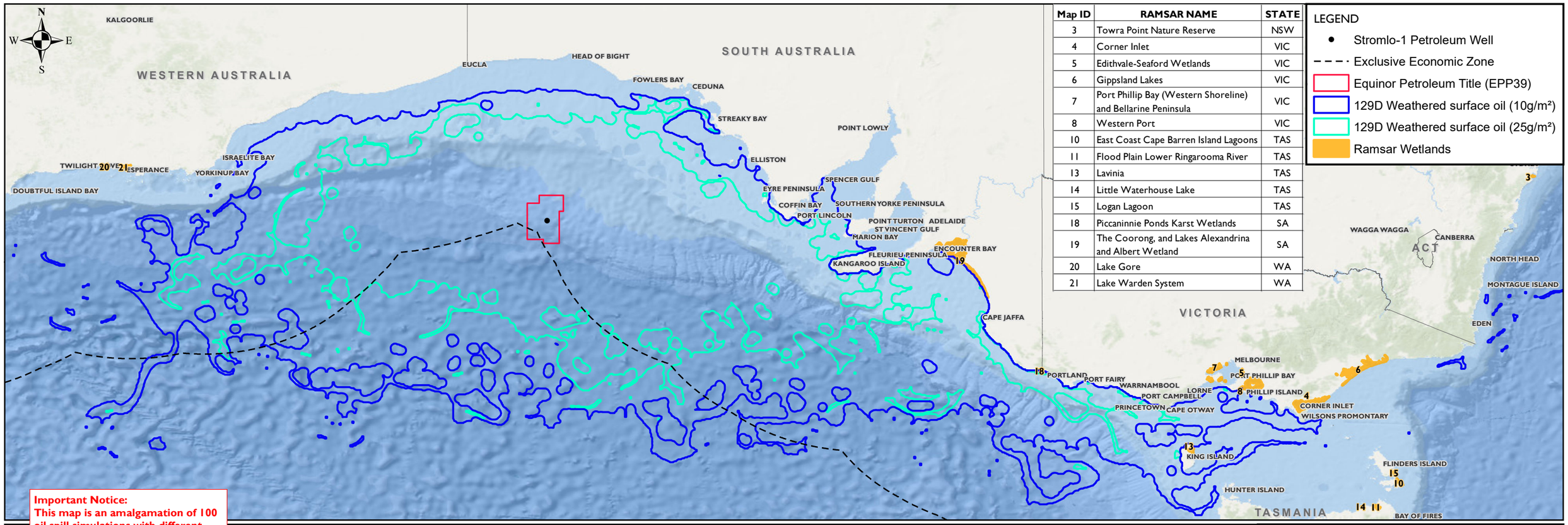


Figure 2.6

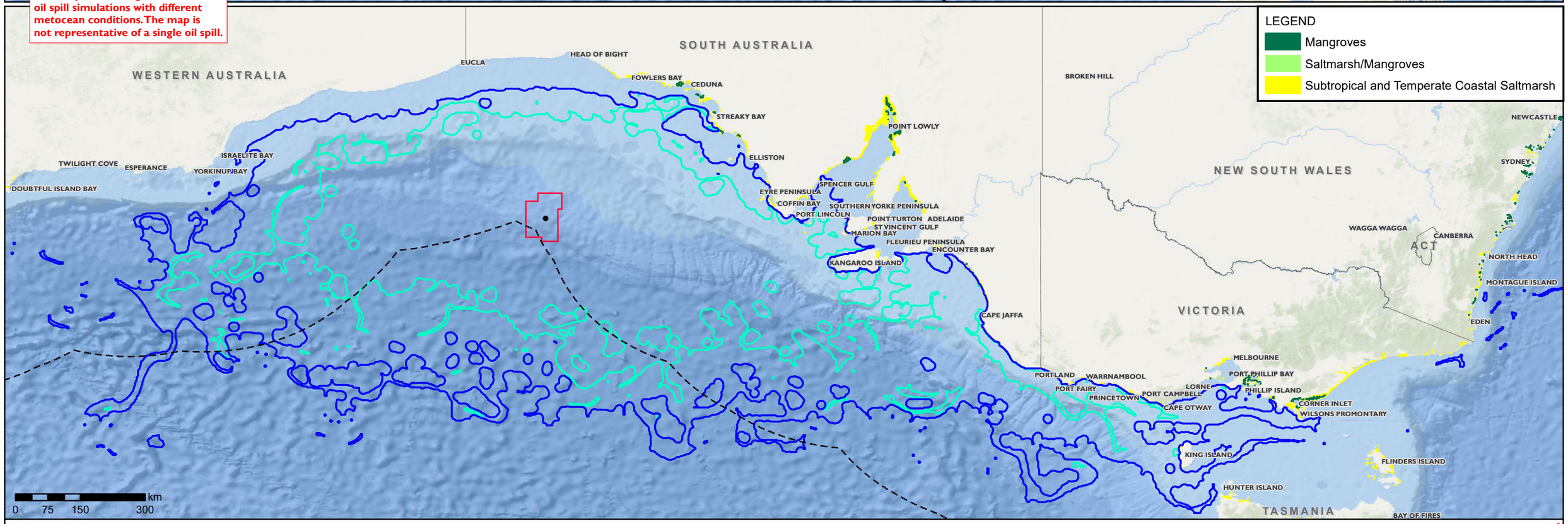
Zones of potential entrained (ppb.hours) and dissolved (ppb.hours) hydrocarbon exposure (unmitigated and dispersant mitigated scenarios) in the 0-10 m layer below the sea surface from 100 oil spill simulations in October to May from an average 8,943 m³ subsea release of crude oil over 129 days, tracked for 189 days on AMP's, KEFs, deep water coral, macroalgae, and seagrass



Map ID	RAMSAR NAME	STATE
3	Towra Point Nature Reserve	NSW
4	Corner Inlet	VIC
5	Edithvale-Seaford Wetlands	VIC
6	Gippsland Lakes	VIC
7	Port Phillip Bay (Western Shoreline) and Bellarine Peninsula	VIC
8	Western Port	VIC
10	East Coast Cape Barren Island Lagoons	TAS
11	Flood Plain Lower Ringarooma River	TAS
13	Lavinia	TAS
14	Little Waterhouse Lake	TAS
15	Logan Lagoon	TAS
18	Piccaninnie Ponds Karst Wetlands	SA
19	The Coorong, and Lakes Alexandrina and Albert Wetland	SA
20	Lake Gore	WA
21	Lake Warden System	WA

LEGEND
- Stromlo-1 Petroleum Well
- Exclusive Economic Zone
- Equinor Petroleum Title (EPP39)
- 129D Weathered surface oil (10g/m²)
- 129D Weathered surface oil (25g/m²)
- Ramsar Wetlands

Important Notice:
This map is an amalgamation of 100 oil spill simulations with different metocean conditions. The map is not representative of a single oil spill.



LEGEND
- Mangroves
- Saltmarsh/Mangroves
- Subtropical and Temperate Coastal Saltmarsh

Figure 2.7
Zones of potential weathered sea surface hydrocarbon exposure (unmitigated) from 100 oil spill simulations in October to May from an average 8,943 m³/day subsea release of crude oil over 129 days, tracked for 189 days on mangroves, saltmarshes, and Ramsar wetlands

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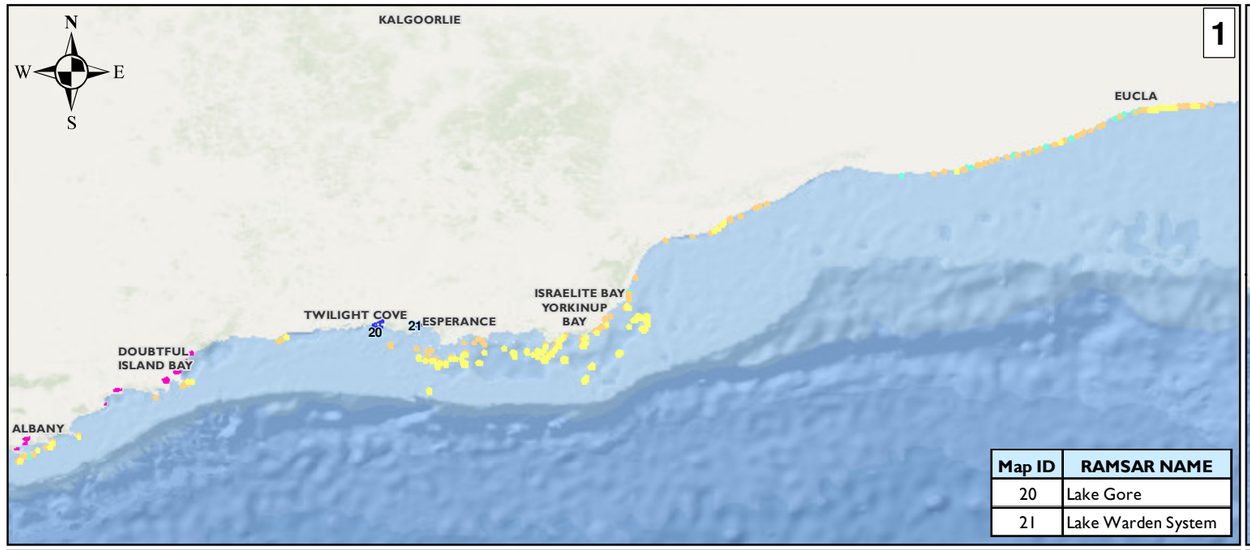
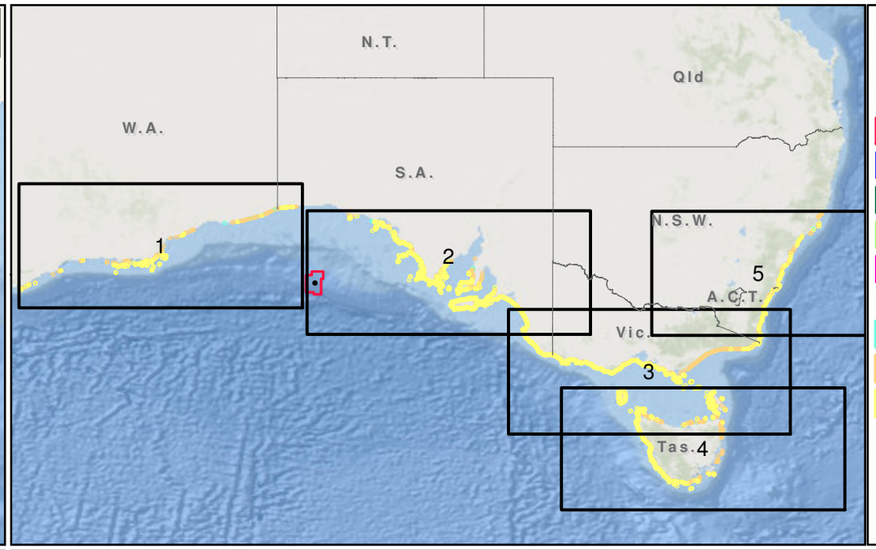


Map ID	RAMSAR NAME
20	Lake Gore
21	Lake Warden System

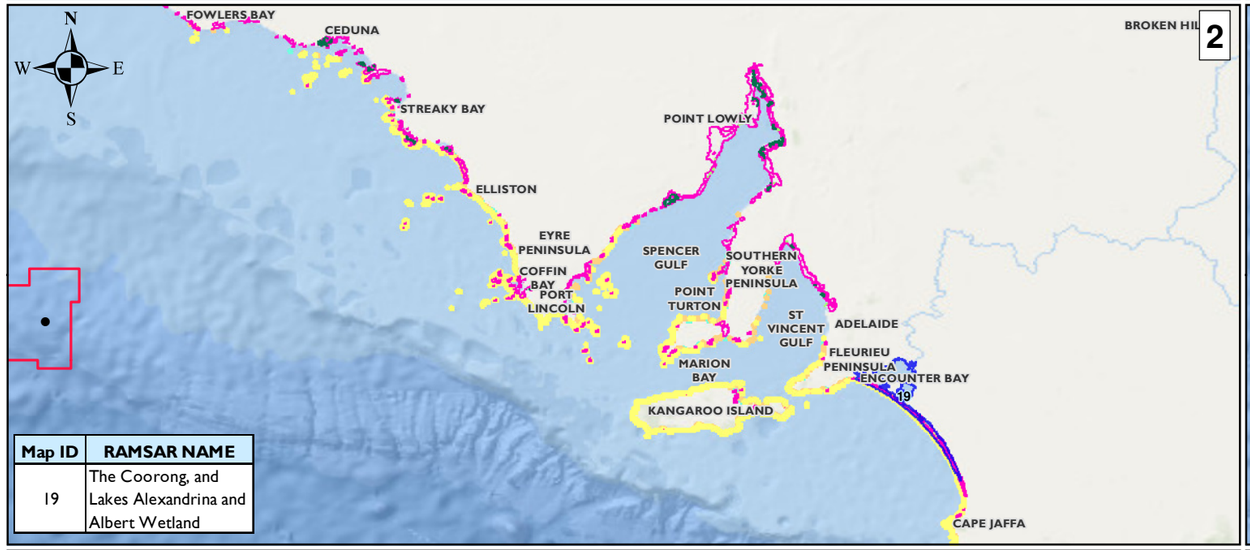


LEGEND

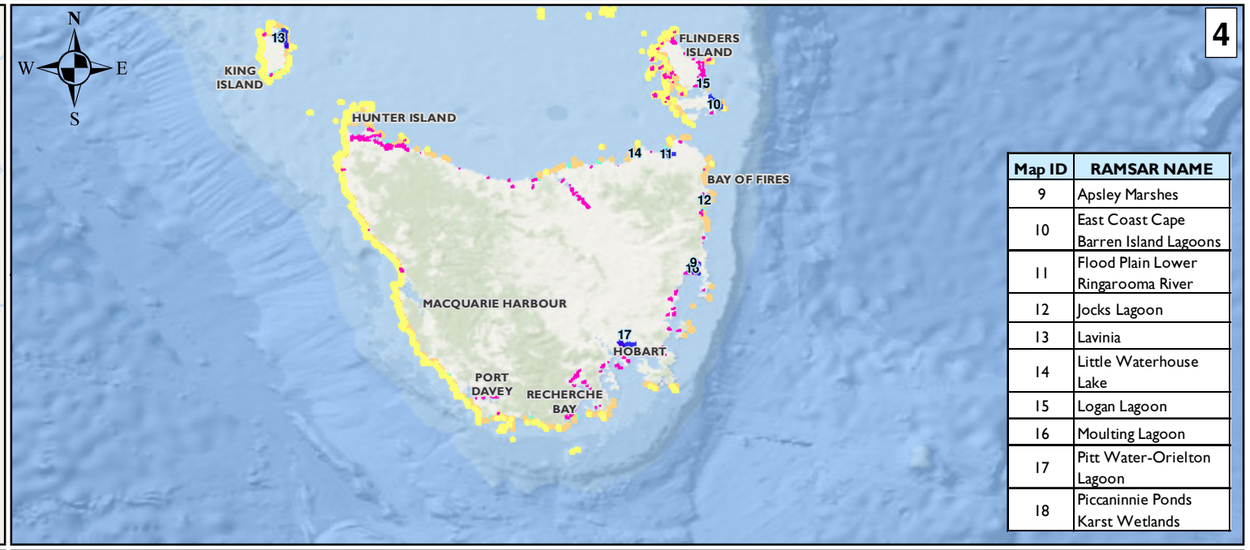
- Stromlo-1 Petroleum Well
- Exclusive Economic Zone
- Equinor Petroleum Title (EPP39)
- Ramsar Wetlands
- Mangroves (UNEP-WCMC 2017)
- Saltmarsh/Mangrove
- Coastal Saltmarsh

Maximum potential shoreline

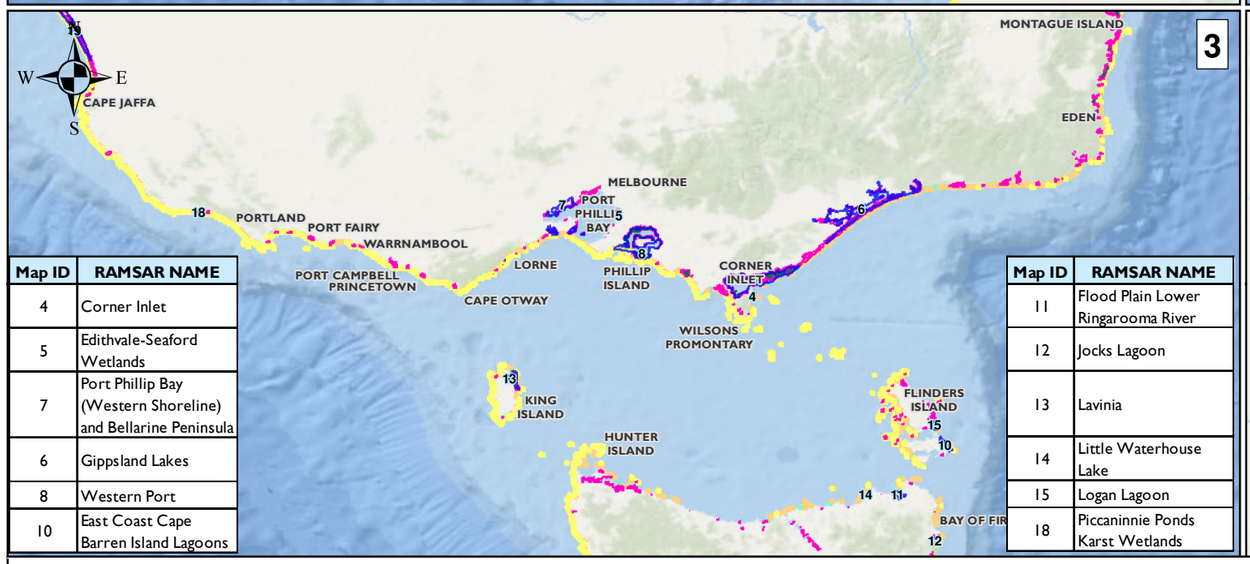
- Low (10 - 100)
- Moderate (100 - 1000)
- High (>1000)



Map ID	RAMSAR NAME
19	The Coorong, and Lakes Alexandrina and Albert Wetland

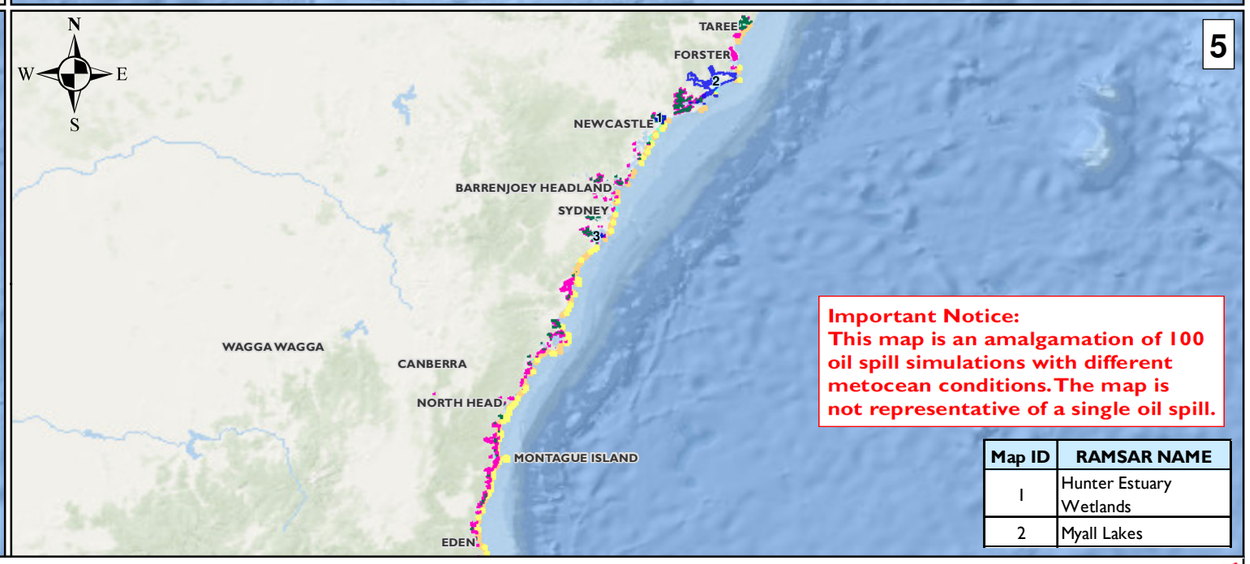


Map ID	RAMSAR NAME
9	Apsley Marshes
10	East Coast Cape Barren Island Lagoons
11	Flood Plain Lower Ringarooma River
12	Jocks Lagoon
13	Lavinia
14	Little Waterhouse Lake
15	Logan Lagoon
16	Moulting Lagoon
17	Pitt Water-Orielton Lagoon
18	Piccaninnie Ponds Karst Wetlands



Map ID	RAMSAR NAME
4	Corner Inlet
5	Edithvale-Seaford Wetlands
7	Port Phillip Bay (Western Shoreline) and Bellarine Peninsula
6	Gippsland Lakes
8	Western Port
10	East Coast Cape Barren Island Lagoons

Map ID	RAMSAR NAME
11	Flood Plain Lower Ringarooma River
12	Jocks Lagoon
13	Lavinia
14	Little Waterhouse Lake
15	Logan Lagoon
18	Piccaninnie Ponds Karst Wetlands



Important Notice:
This map is an amalgamation of 100 oil spill simulations with different metocean conditions. The map is not representative of a single oil spill.

Map ID	RAMSAR NAME
1	Hunter Estuary Wetlands
2	Myall Lakes

Figure 2.8
Maximum potential shoreline loading (g/m²) from weathered oil (unmitigated) from 100 oil spill simulations in October to May from an average 8,943 m³/day subsea release of crude oil over 129 days, tracked for 189 days on mangroves, saltmarshes and Ramsar wetlands

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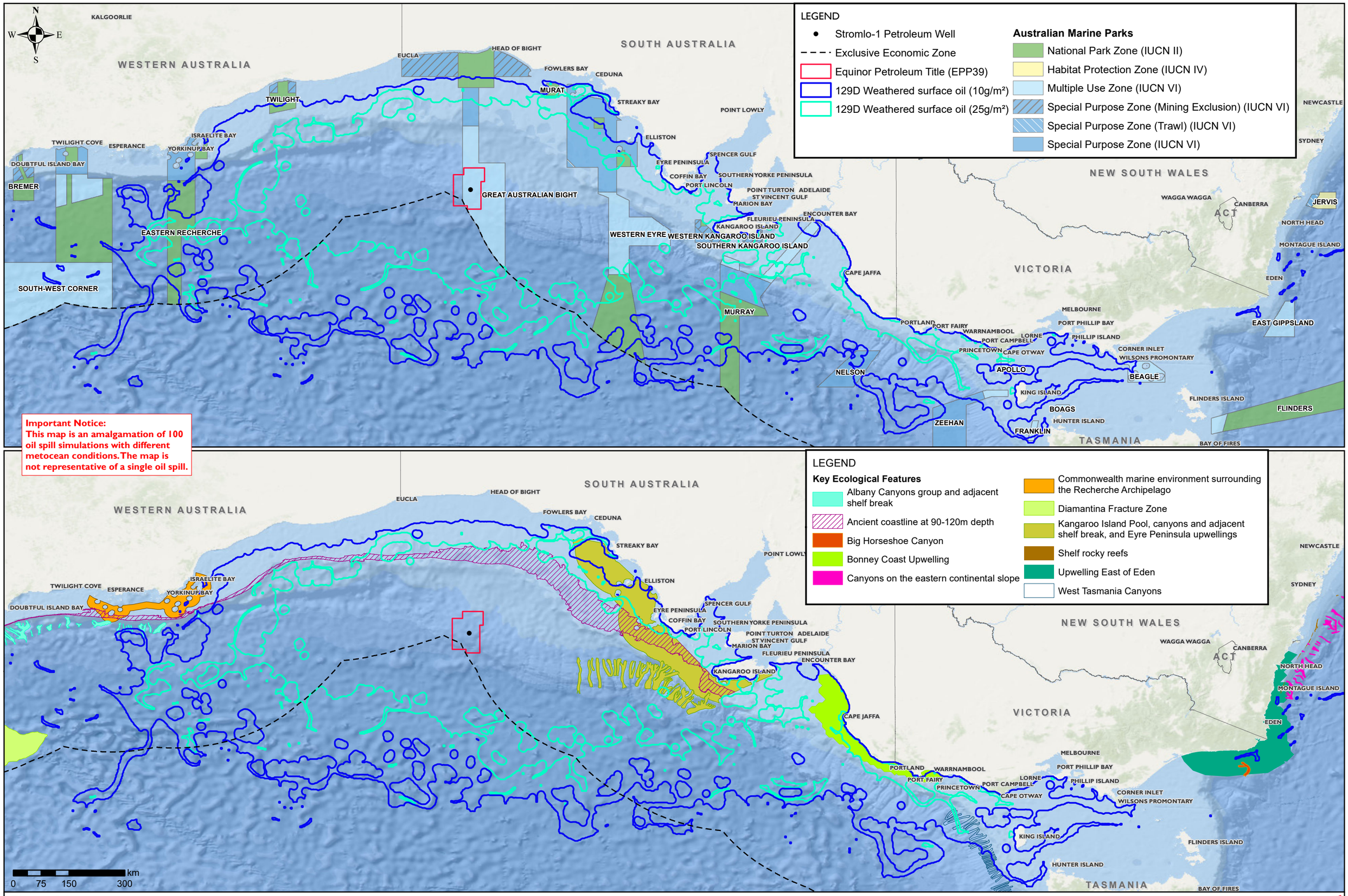

Figure 2.9
Zones of potential weathered sea surface hydrocarbon exposure (unmitigated) from 100 oil spill simulations in October to May from an average 8,943 m³/day subsea release of crude oil over 129 days, tracked for 189 days on AMPs, KEFs, and coastal settlements

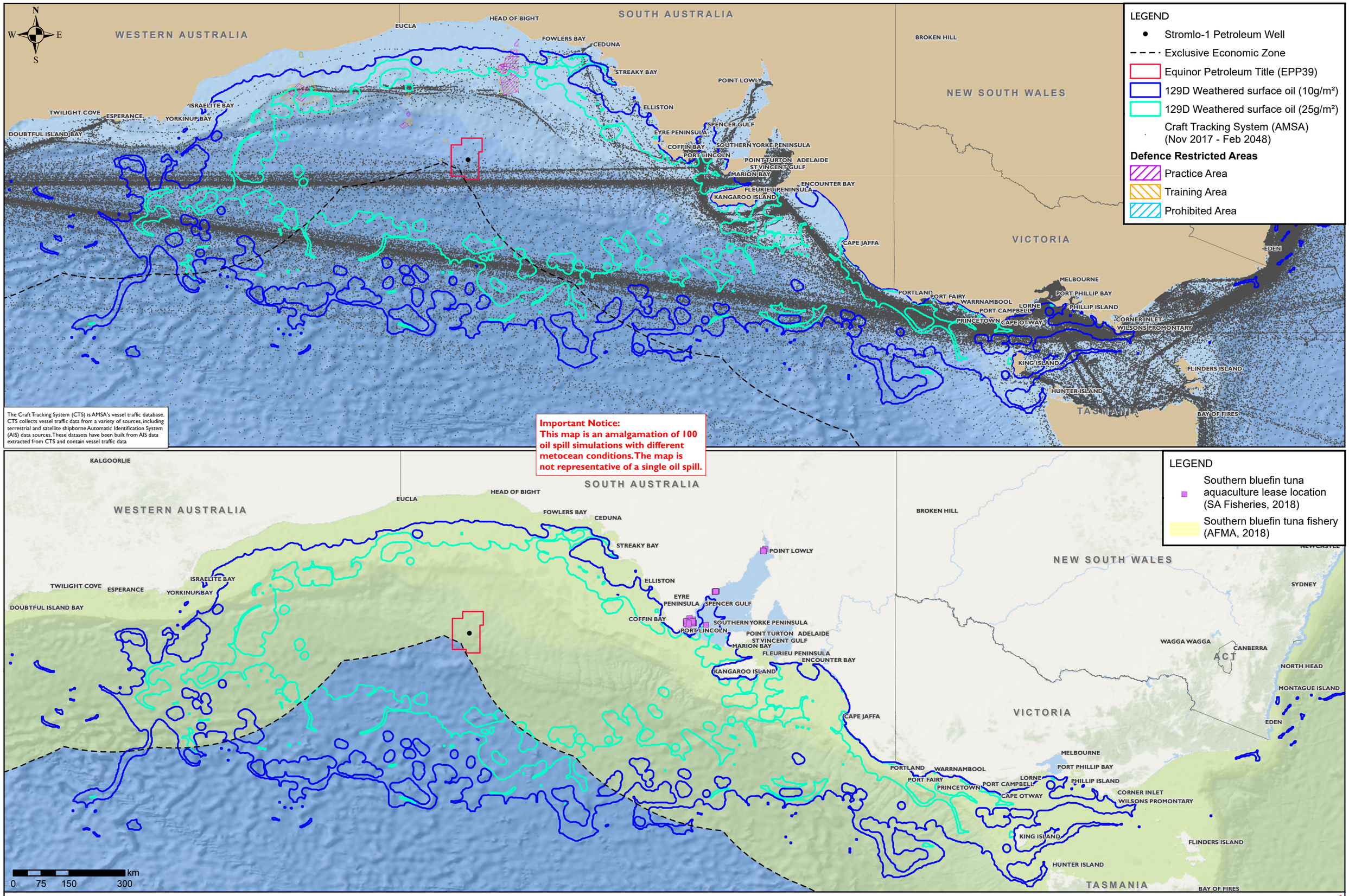

Figure 2.10
Zones of potential weathered sea surface hydrocarbon exposure (unmitigated) from 100 oil spill simulations in October to May from an average 8,943 m³/day subsea release of crude oil over 129 days, tracked for 189 days on defence areas, commercial fisheries, shipping traffic and SBT ranching

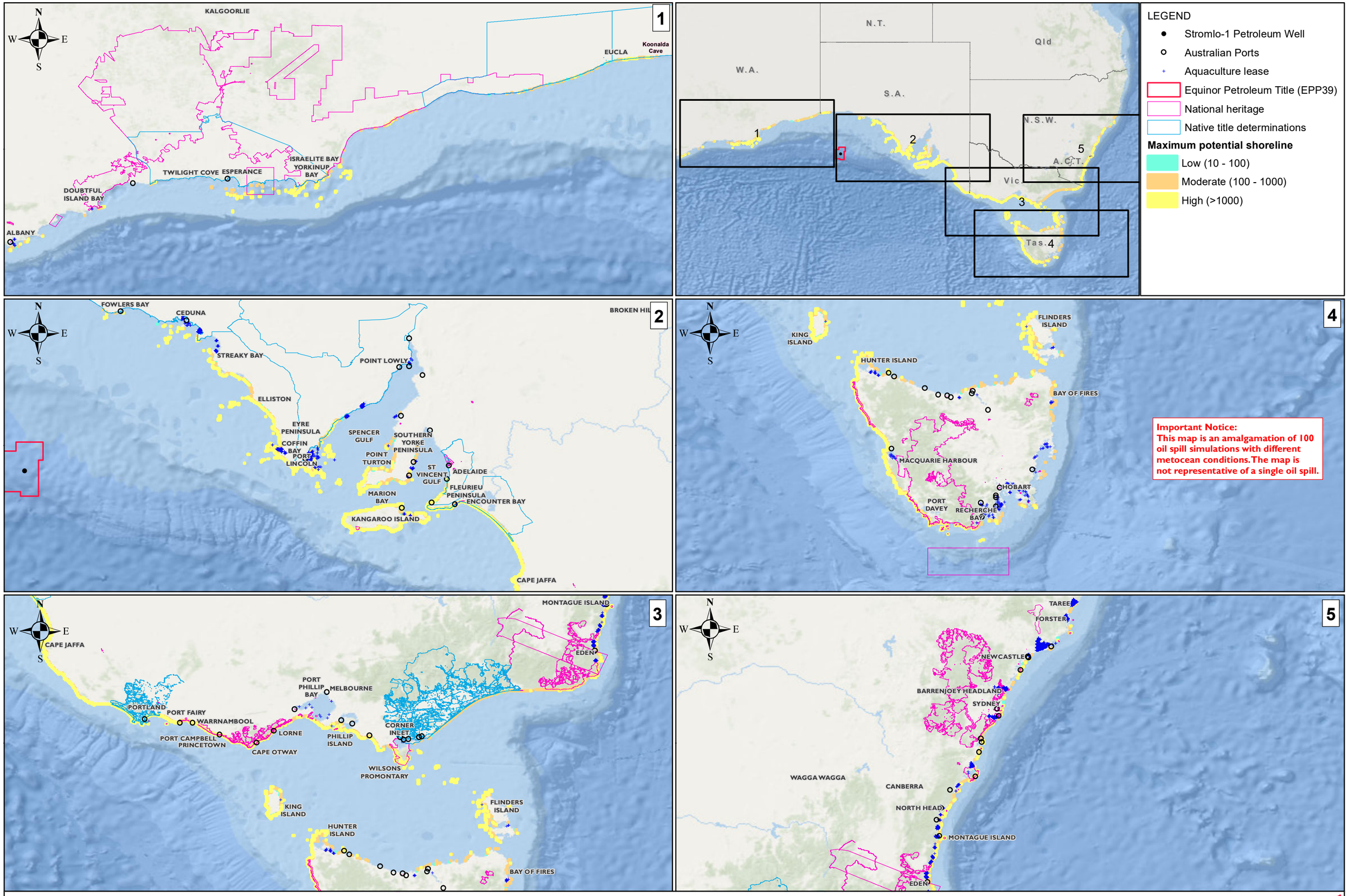

Figure 2.11
Maximum potential shoreline loading (g/m²) from weathered oil (unmitigated) from 100 oil spill simulations in October to May from an average 8,943 m³/day subsea release of crude oil over 129 days, tracked for 189 days on aquaculture leases, Heritage sites, Native Title determinations, ports

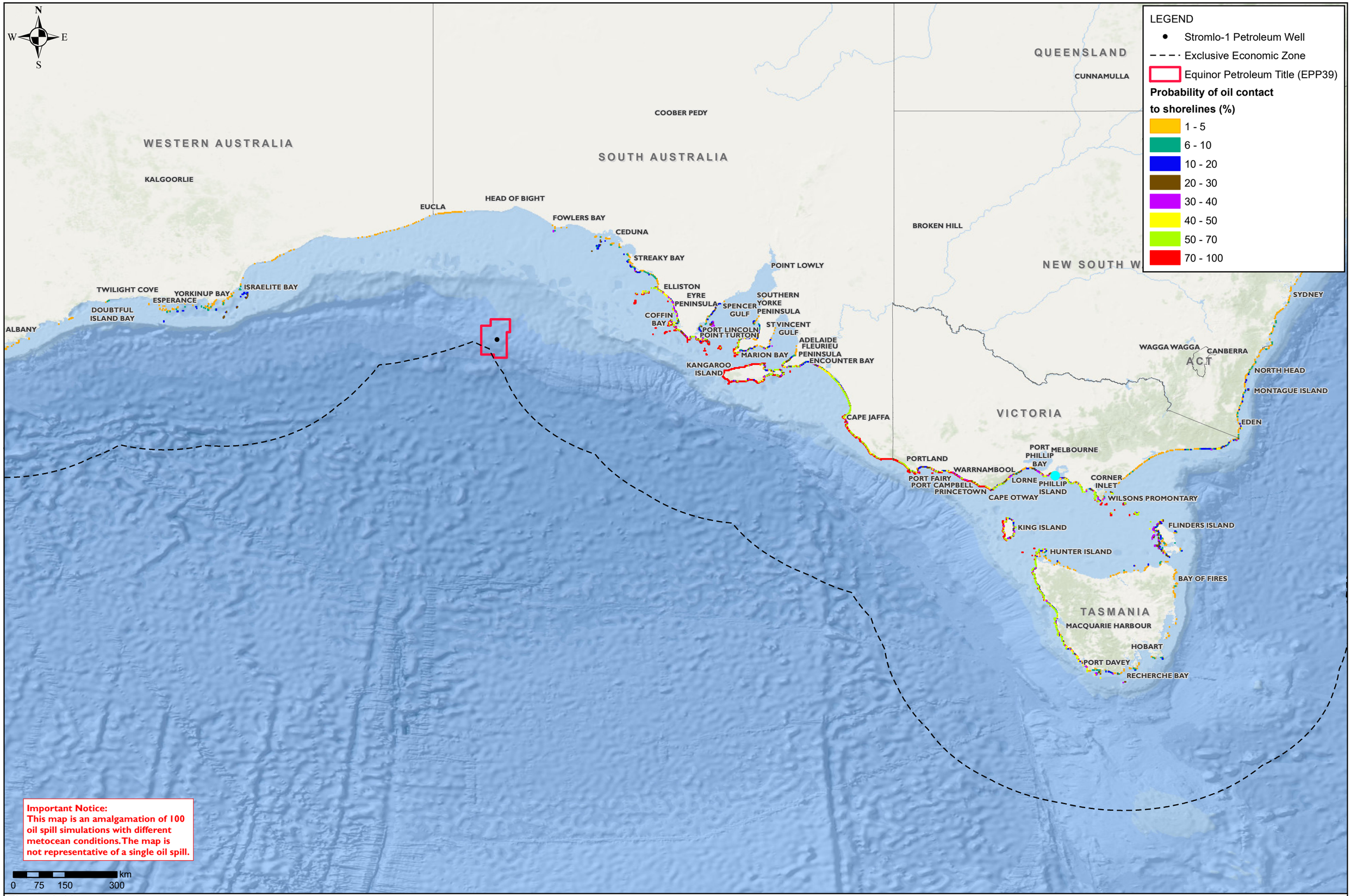

Figure 2.12
Probability of weathered oil contact to shorelines at or above the moderate threshold from 100 oil spill simulations in October to May from an average 8,943 m³/day subsea release of crude oil over 129 days, tracked for 189 days

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