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Barossa Development OPEP Addendum: Drilling and Completions

PROJECT / FACILITY	Barossa Development
REVIEW INTERVAL	No Review Required
SAFETY CRITICAL DOCUMENT	NO

Rev	Owner	Technical Reviewer(s)	Approver	Functional Endorser
2	Barossa HSE Manager	Senior Oil Spill Response Coordinator Oil Spill and Emergency Response Coordinator	Barossa Project Director	Crisis, Emergency Response and Security Manager
Signed				

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AMSA	●
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Acronyms and abbreviations

Abbreviation	Description
ALARP	as low as reasonably practicable
AMP	Australian Marine Park
EEZ	Exclusive Economic Zone
EMBA	Environment That May Be Affected
EP	Environment Plan
IAP	Incident Action Plan
IMCRA	Integrated Marine and Coastal Regionalisation of Australia
IMT	Incident Management Team
KEF	Key Ecological Feature
LOWC	loss of well control
MARPOL	International Convention for the Prevention of Pollution from Ships
MDO	Marine diesel oil
MODU	mobile offshore drilling unit
NEBA	net environmental benefit analysis
NT	Northern Territory
OIE	Offset Installation Equipment
OPEP	Oil Pollution Emergency Plan
OSC	on-scene commander
OWR	oiled wildlife response
SFRT	Subsea First Response Toolkit
SIMA	spill impact mitigation assessment
SIMAP	Spill Impact Mapping and Analysis Program
SMP	Scientific Monitoring Plan
SOPEP	Shipboard Oil Pollution Emergency Plan
SSDI	Subsea Dispersant Injection
VOC	volatile organic compound
WA	Western Australia

1 Quick reference information

<table>
<tr><th>Parameter</th><th colspan="6">Description</th><th>Further information</th></tr>
<tr><td>Petroleum Activity</td><td colspan="6">Barossa Development Drilling and Completions</td><td>Section 2 of Barossa Development Drilling and Completions Environment Plan (EP) (BAD-200 0003)</td></tr>
<tr><td>Location (Lat/Long)</td><td colspan="6">Up to 8 production wells will be drilled around three manifold locations within the Bonaparte Basin in Commonwealth waters approximately 300 km north-northwest of Darwin</td><td>Section 2.1.1 of EP</td></tr>
<tr><td>Petroleum title/s (blocks)</td><td colspan="6">NT/L1 (Production Licence)</td><td>N/A</td></tr>
<tr><td>Facilities/vessels</td><td colspan="6">MODU – semi-submersible
Light well intervention vessel
Support vessels</td><td>Section 2.2 of EP</td></tr>
<tr><td>Water Depth</td><td colspan="6">220-280 m</td><td>N/A</td></tr>
<tr><td rowspan="4">Worst-case spill scenarios</td><td colspan="2">Scenario</td><td colspan="2">Hydrocarbon</td><td colspan="2">Worst-case volume (m^3)</td><td rowspan="4">Section 3.1</td></tr>
<tr><td colspan="2">Bunkering incident</td><td colspan="2">MDO (Group II)</td><td colspan="2">10 m^3</td></tr>
<tr><td colspan="2">Vessel collision</td><td colspan="2">MDO (Group II)</td><td colspan="2">250 m^3</td></tr>
<tr><td colspan="2">Loss of well control (LOWC) (subsea)</td><td colspan="2">Barossa Condensate</td><td colspan="2">129,000 m^3</td></tr>
<tr><td>Hydrocarbon properties</td><td colspan="3">MDO:
Density at 25 °C = 829 kg/m3
Dynamic viscosity = 4 cP @ 25° C
API Gravity = 37.6°
Wax content = 1%
Pour point = -14 °C
Oil property classification = Persistent (medium)</td><td colspan="3">Barossa condensate:
Density at 16 °C = 782 kg/m3
Dynamic viscosity = 1.35 cP @ 10° C
API Gravity = 50.6°
Wax content = 3.6%
Pour point = -6 °C
Volatile components = 93%
Oil property classification = non-persistent (Group I)</td><td>Appendix A – Barossa Development OPEP</td></tr>
</table>

<table>
<tr><th>Parameter</th><th colspan="2">Description</th><th>Further information</th></tr>
<tr><td>Weathering potential</td><td>MDO is a mixture of volatile and persistent hydrocarbons with low viscosity. It will spread quickly and thin out to low thickness levels, thereby increasing the rate of evaporation. Up to 60% will generally evaporate over the first two days. Approximately 5% is considered “persistent”, which are unlikely to evaporate and will decay over time.</td><td>Barossa Condensate is a low viscosity, non-persistent hydrocarbon that if spilt on the sea surface, would rapidly spread and thin out resulting in a large surface area available for evaporation.

The fate of the condensate will depend greatly on the proportion that reaches the surface after rising through the water column. Hence, discharge conditions will have a strong influence on exposure risks for surrounding resources.</td><td>Appendix A – Barossa Development OPEP</td></tr>
<tr><td>Protection priorities</td><td colspan="2">Based on the hydrocarbon spill modelling, hydrocarbons are expected to remain in the upper water column with the probability of contact above the moderate impact exposure value decreasing with water depth.

Consequently, areas at greatest risk are the benthic habitats present on some of the shallower offshore banks and shoals, where the moderate exposure values are predicted to be exceeded, including:

+ Tassie Shoal
+ ‘Unnamed’ Shoal

The following key ecological features and Australian Marine Parks are predicted to be contacted above the moderate exposure value:

+ Oceanic Shoals Australian Marine Park
+ Carbonate bank and terrace system of the Van Diemen Rise
+ The shelf break and slope of the Arafura Shelf</td><td>Section 3.3</td></tr>
</table>

2 Introduction

2.1 Summary of proposed activity

This OPEP Addendum supports the Barossa Development OPEP (BAA-200 0314) and is applicable for drilling and completions activities associated with the Barossa Development in Commonwealth permit area NT/L1 in the Bonaparte Basin, located in the Timor Sea. The drilling and completions activities include the use of a semi-submersible MODU to drill up to eight production wells. Additional detail on the activity, project timing and duration, and equipment to be used are included are outlined in Section 2.2 of the Barossa Development Drilling and Completions Environment Plan (BAD-200 0003).

The location of the activity covered by this OPEP Addendum is shown in **Figure 2-1**. While all activities for the Barossa Development Drilling and Completions Campaign are being undertaken entirely within Commonwealth waters, a spill from the activity may enter into Indonesian and/or Timor-Leste waters. Modelling does not predict any spills entering into Northern Territory (NT) or Western Australian (WA) waters.

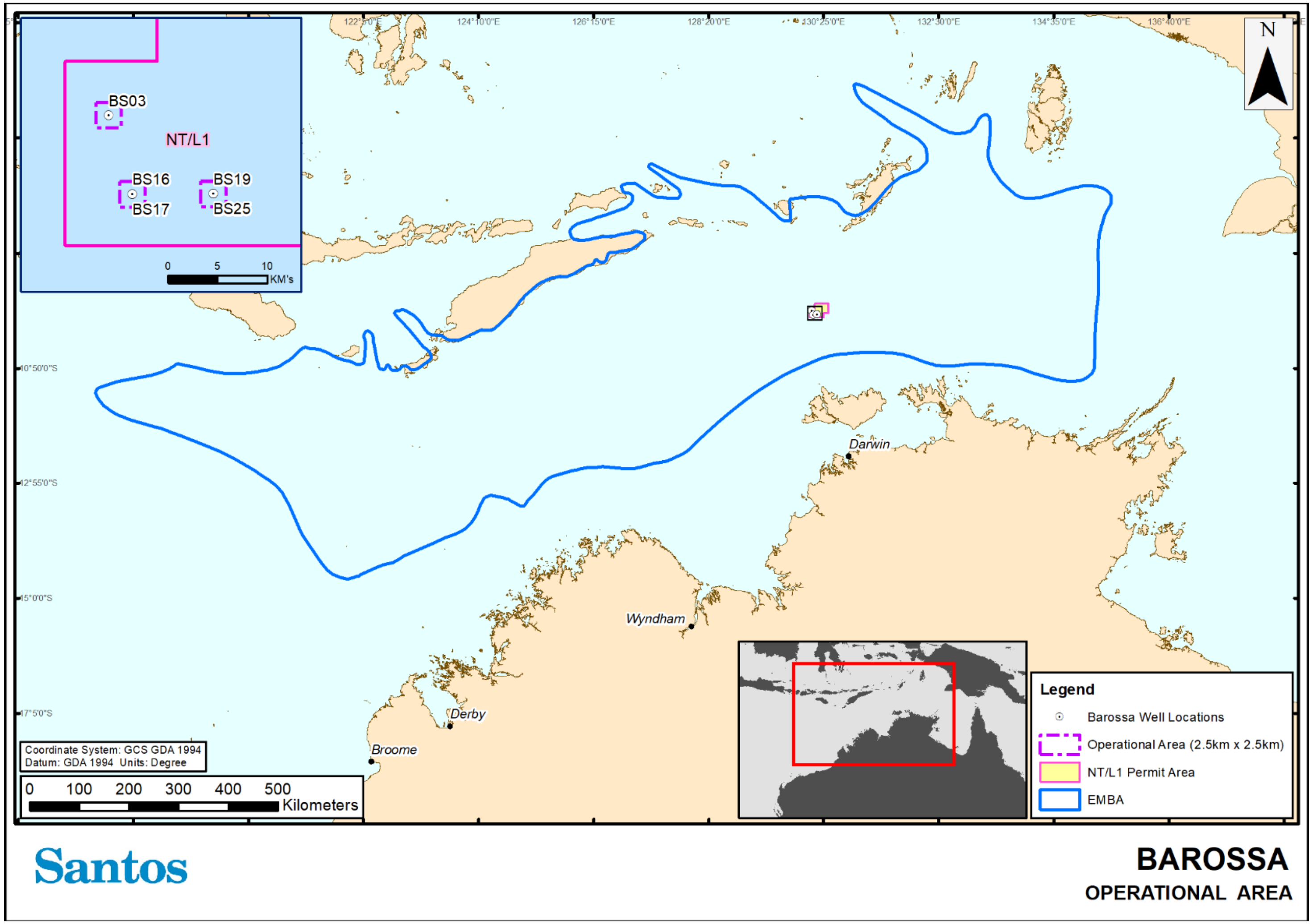

Figure 2-1: Barossa drilling and completions location map and Environment that May be Affected (EMBA) extent

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3 Description of spills and protection priorities

3.1 Spill scenarios

This OPEP Addendum outlines the credible oil spill scenarios associated with the Barossa Development Drilling and Completions activities. Of the credible spill scenarios identified in the Barossa Development Drilling and Completions EP (BAD-200 0003), all have been selected to represent worst case spills from a response perspective, taking into account the following characteristics:

+ They represent all hydrocarbon types that could be spilt during Barossa Development Drilling and Completions activities.
+ They represent maximum credible release volumes.
+ Those scenarios that represent the greatest spatial extent from a response perspective based on surface oil and shoreline accumulation as these are the key factors contributing to response.
+ Proximity to sensitive receptors, shorelines, State/Territory and Commonwealth boundaries etc.

The worst-case credible spill risks selected to inform this OPEP Addendum are presented in **Table 3-1**. Detail on the derivation of these maximum credible spills is provided within the Barossa Development Drilling and Completions EP (BAD-200 0003).

For a description of the characteristics and behaviour associated with hydrocarbons that may unintentionally be released refer to **Appendix A** of the Barossa Development OPEP (BAA-200 0314).

Table 3-1: Maximum credible spill scenarios for Barossa Development Drilling and Completions activities

Worst-case credible spill scenario	Hydrocarbon type	Maximum credible volume released (m^3)	Release duration	Maximum extent of surface hydrocarbons
Bunkering incident	MDO	10	Instantaneous	Within the extent of the worst-case spill trajectory of diesel from a vessel collision
Vessel collision	MDO	250	6 hours	Approx. 368 km (at 1 g/m^2)
LOWC – subsea release	Barossa Condensate	129,000	90 days	Approx. 370 km (at 1 g/m^2)

3.2 Spill modelling results

Spill modelling was conducted for the LOWC (subsea) (129,000 m^3 Barossa Condensate) and vessel collision scenario (250 m^3 MDO). These scenarios represent the worst-case volumes for Barossa Condensate and MDO for the Barossa Development Drilling and Completions activities and are presented in **Table 3-2**.

Stochastic oil spill modelling was performed using a three-dimensional spill trajectory and weathering model, SIMAP (Spill Impact Mapping and Analysis Program). This model is designed to simulate the drifting, spreading, weathering and fate of specific oil types under the influence of changing meteorological and oceanographic forces.

A stochastic modelling approach was followed for each of the scenarios. The stochastic model involves the repeated application of SIMAP (100 simulations for each season; summer, transitional and winter) to simulate the defined spill scenarios using different samples of current and wind data. The model results were then combined to provide a summary of each season.

The modelling outputs do not represent the potential behaviour of a single spill (which would have a much smaller area of influence) but provides an indication of the probability of any given area of the sea surface being contacted by hydrocarbons above impact exposure values.

For the purpose of spill response preparedness, outputs relating to floating oil and oil accumulated on the shoreline are most relevant (i.e. oil that can be diverted, contained, collected or dispersed through the use of spill response strategies) for the allocation and mobilisation of spill response resources. Results for the worst-case credible scenarios have only been included if there was a floating hydrocarbon concentration greater than 1 g/m^2 at >5% probability.

Modelling results for dissolved and entrained oil for the worst-case scenarios have not been included in the OPEP given there are limited response strategies that will reduce subsurface impacts. However, these modelling results inform the EMBA and are presented in Section 7.6 and 7.7 of the Barossa Development Drilling and Completions EP (BAD-200 0003).

Table 3-2: Worst-case spill modelling results for Barossa Development Drilling and Completions activities

Location	Probability (%) floating oil (>1 g/m²) on sea surface	Minimum arrival time floating oil (>1 g/m²) (days)	Probability (%) floating oil (>10 g/m²) on sea surface	Minimum arrival time floating oil (>10 g/m²) (days)	Total probability (%) shoreline oil accumulation>10 g/m²	Minimum arrival time shoreline oil accumulation >10 g/m² (days)
Scenario: Vessel collision of 250 m³ over 6 hours						
Flinders Shoal	14 (transitional)	3.5	NC	NC	N/A	N/A
Evans Shoal	22 (transitional)	2.4	NC	NC	N/A	N/A
Franklin Shoal	13 (transitional)	3.5	NC	NC	N/A	N/A
Blackwood Shoal	12 (transitional)	3.0	NC	NC	N/A	N/A
Oceanic Shoals Australian Marine Park (AMP)	6 (summer)	3.6	NC	NC	N/A	N/A
Shelf break and slope of the Arafura Shelf Key Ecological Feature (KEF)	100 (summer)	0.04	100 (summer)	0.04	N/A	N/A
Carbonate bank and terrace system of the Van Diemen Rise KEF	16 (transitional)	2.4	1 (transitional)	3.3	N/A	N/A
Scenario: Loss of well control (subsea) of 129,000 m³ over 90 days						
Oceanic Shoals IMCRA	79 (transitional)	2.6	47 (transitional)	9.1	N/A	N/A
Indonesian EEZ	98 (summer)	2.5	24 (summer)	18.3	N/A	N/A
Oceanic Shoals AMP	52 (transitional)	10.1	12 (transitional)	19.5	N/A	N/A
Shelf break and slope of the Arafura Shelf KEF	100 (all)	0.04	100 (all)	0.04	N/A	N/A
Carbonate bank and terrace system of the Van Diemen Rise KEF	74 (transitional)	2.7	39 (transitional)	10.2	N/A	N/A
Margaret Harries Bank	23 (transitional)	16	NC	NC	N/A	N/A

Location	Probability (%) floating oil (>1 g/m²) on sea surface	Minimum arrival time floating oil (>1 g/m²) (days)	Probability (%) floating oil (>10 g/m²) on sea surface	Minimum arrival time floating oil (>10 g/m²) (days)	Total probability (%) shoreline oil accumulation>10 g/m²	Minimum arrival time shoreline oil accumulation >10 g/m² (days)
'Unnamed' Shoal	66 (transitional)	4.7	17 (transitional)	12.3	N/A	N/A
Evans Shoal	67 (transitional)	2.3	NC	NC	N/A	N/A
Franklin Shoal	44 (transitional)	3.6	NC	NC	N/A	N/A
Flinders Shoal	36 (transitional)	3.8	NC	NC	N/A	N/A
Blackwood Shoal	53 (transitional)	3.0	NC	NC	N/A	N/A
Tassie Shoal	40 (transitional)	4.8	17 (transitional)	12.3	N/A	N/A
Loxton Shoal	24 (transitional)	6.8	NC	NC	N/A	N/A

3.3 Protection/monitoring priorities

When dealing with oil spills in remote environments, it is not always realistic or feasible to protect all receptors. Therefore, prioritising receptors helps identify where available resources (for response and/or monitoring) should be directed for the best effect. It enables the control agency to make informed decisions, and ultimately in the development and execution of an effective response strategy.

Results from hydrocarbon spill modelling were compared against the location of key sensitive receptors with high conservation valued habitat or species or important socio-economic/heritage value within the EMBA. Sensitive receptors within the EMBA with shortest potential timeframes to contact with hydrocarbons above the following moderate impact exposure values were identified (Note: more information on the development of the moderate impact exposure values is provided in Section 7.5.4 of the Barossa Development Drilling and Completions EP (BAD-200 0003)):

+ Floating oil: 10 g/m^2
+ Shoreline accumulation: 100 g/m^2 (note: spill modelling does not predict shoreline at any exposure value).

Based on the hydrocarbon spill modelling, hydrocarbons above these exposure values are expected to remain in the upper water column with probability of contact decreasing with water depth. Consequently, areas at greatest risk are the shallower offshore banks and shoals, while impacts are not predicted for benthic habitats in deeper waters, including in the Oceanic Shoals and Arafura Marine Parks and in the KEFs present in the EMBA.

Table 3-3 outlines the list of priority response and monitoring areas that may be impacted above these exposure values in the event of a spill associated with the drilling and completion activities.

It should be noted that the implementation of scientific monitoring is dependent upon the initiation criteria in Barossa Development OPEP (BAA-200 0314) **Appendix J** being met. In some cases, scientific monitoring will be triggered when aerial, visual or florescence observation reports submitted to the IMT show presence or likely presence of oil; or spill fate modelling predicts oil at sensitive receptors of > 1g/m^2 for surface oil, and >10 ppb for entrained and dissolved oil. This then activates the relevant Scientific Monitoring Plan (SMP), which determines if any impact has occurred based upon applicable exposure values.

Table 3-3: Priority response and monitoring areas in the EMBA

Priority protection area	Description
Offshore banks and shoals	Areas at greatest risk are the benthic habitats present on some of the shallower offshore banks and shoals, which include: + ‘Unnamed’ Shoal + Tassie Shoal. Surveys of Tassie Shoal recorded coral and algae species, filter-feeder communities, sponges, demersal fish and pelagic fish. It is expected that Unnamed Shoal would be characterised by similar communities.
Oceanic Shoals AMP	The Oceanic Shoals Marine Park is significant because it contains habitats, species and ecological communities associated with the Northwest Shelf Transition.
KEFs	Carbonate bank and terrace system of the Van Diemen Rise The shelf break and slope of the Arafura Shelf.

4 Applicable response strategies

4.1 Evaluation of applicable response strategies

Based on the nature and scale of the credible spill scenarios outlined in **Section 3.1** and spill modelling results (**Section 3.2**) the following spill response strategies have been assessed as potentially applicable for combatting a spill (**Table 4-1**).

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Table 4-1: Evaluation of applicable response strategies

OSR strategy	Tactic	Applicability and designated primary (1) or secondary (2) response strategy		Considerations/limitations
		Barossa condensate	MDO	
Source control	Spill kits	✓1	✓1	Relevant for containing spills that may arise on board a vessel or MODU.
	Secondary containment	✓1	✓1	Relevant for spills that may arise due to stored hydrocarbons, and from spills arising from machinery and equipment on board a vessel or MODU. Bunded areas will contain hydrocarbons reducing the potential for a spill escaping to marine waters. Where applicable open deck drainage will be closed to prevent hydrocarbon draining into the marine environment.
	Shipboard Oil Pollution Emergency Plan	✗	✓1	MARPOL requirement for applicable vessels. In the event a vessel hydrocarbon storage tank is ruptured, applicable strategies for reducing the volume of hydrocarbon releases will be contained within the vessel Shipboard Oil Pollution Emergency Plan (SOPEP). This may include securing cargo via transfer to another storage area on-board the vessel, transfer to another vessel, or through pumping in water to affected tank to create a water cushion (tank water bottom). Trimming the vessel may also be used to avoid further damage to intact tanks. These actions will aim to minimise the volume of fuel spilled.
	Surface well kill	✓1	✗	Considered during relief well planning but may not be possible depending upon technical and safety constraints. Surface well kill is only considered when the estimated leak rate is small enough not to generate an explosive gas cloud and access to the MODU is still preserved. This methodology would not be considered should safe access to the MODU or ability to operate a vessel alongside the MODU not be achievable.
	Blowout preventer – emergency activation	✓1	✗	A blow-out preventer (BOP) stack will be installed onto the wellhead prior to drilling of the reservoir well sections. The purpose of a BOP is to provide a secondary barrier to hydrocarbons by providing a mechanical means of shutting in the well if primary well control is lost, and hydrocarbons enter the wellbore.

OSR strategy	Tactic	Applicability and designated primary (1) or secondary (2) response strategy		Considerations/limitations
		Barossa condensate	MDO	
	Capping stack	✓ 2	✗	A Capping Stack may be a viable option for controlling a subsea well drilled using a semi-submersible drilling rig. A Capping Stack installed onto a subsea wellhead can be used to divert the flow of hydrocarbons and potentially reduce the release rate of hydrocarbons prior to well kill via a relief well. Capping stack is a secondary response measure with deployment limited to appropriate conditions (e.g., blowout rates within safe operating limits, safe vertical access) and when operating conditions permit (wind speed, wave height, current and plume radius). Debris clearance using the Subsea First Response Toolkit (SFRT) would be implemented prior to Capping Stack installation.
	Relief well drilling	✓ 1	✗	Relevant to LOWC. Relief well drilling is the primary method for killing the well if access to the MODU is not preserved. To be conducted as per the Source Control Emergency Response Plan (DR-00-OZ-20001) and Well-specific or Campaign Source Control Plan.

OSR strategy	Tactic	Applicability and designated primary (1) or secondary (2) response strategy		Considerations/limitations
		Barossa condensate	MDO	
	Subsea dispersant injection (SSDI)	✓ 2	✗	SSDI is known to reduce VOC levels at the sea surface and is shown to be effective at dispersing condensates when applied subsea (RPS, 2019), making conditions safer for responders and source control personnel. SSDI is shown to reduce surface concentrations of hydrocarbons, thereby reducing the exposure of seabirds and surfacing marine fauna to hydrocarbons. It also disperses hydrocarbons into a larger volume of water, reducing concentrations and enhances biodegradation (French McCay *et al.*, 2018). A potential drawback of this response tactic is that it will result in smaller droplet sizes and entrainment of hydrocarbons into the water column, which may affect some oceanic and benthic organisms (e.g. fish, plankton). However, this is likely to be temporary and restricted to the top ~3 m of the water column whilst SSDI is being used (RPS, 2019). This increase in entrainment is partially offset by significant increases in biodegradation rates. SSDI is only suitable for subsea LOWC scenarios. Barossa condensate is considered a Group 1 oil (non-persistent) hydrocarbon that has rapid evaporation rates (57% within a few hours to a day – refer to Barossa Development OPEP [BAA-200 0314] – Appendix A: Hydrocarbon characteristics and behaviour). There is therefore little to no direct environmental benefit from SSDI and potential drawbacks associated with the enhancement of entrainment. However SSDI would be employed as a secondary strategy and only if it was necessary to use to reduce VOCs in the atmosphere, improving the safety of response personnel working close to the well site. In this case, SSDI may have an overall environmental benefit, as enabling source control personnel access to the site to bring the release under control (e.g. for BOP intervention and/or deployment of Capping Stack) may reduce the overall volume of hydrocarbons being released into the environment.
In-Situ burning	Controlled burning of oil spill	✗	✗	Not applicable to condensate wells due to safety hazards. Not applicable to diesel spills due to inability to contain marine diesel making it very difficult to maintain necessary slick thickness for ignition and sustained burning.

OSR strategy	Tactic	Applicability and designated primary (1) or secondary (2) response strategy		Considerations/limitations
		Barossa condensate	MDO	
Monitor and evaluate plan (operational monitoring)	Vessel surveillance	✓ 1	✓ 1	Provides real-time information on spill trajectory and behaviour (e.g., weathering). Informs implementation of other response strategies. Vessel personnel may not be trained observers. Observers on leaking vessel may not have capacity to observe oil during emergency response procedure implementation. Constrained to daylight. Limited to visual range from the vessel. Limited capacity to evaluate possible interactions with sensitive receptors.
	Aerial surveillance	✓ 1	✓ 1	Provides real-time information on spill trajectory and behaviour (e.g., weathering). May identify environmental sensitivities impacted or at risk of impact (e.g., seabird aggregations, other users such as fishers). Provides information on the effectiveness of response strategies. Informs implementation of other response strategies.
	Tracking buoys	✓ 1	✓ 1	Can be implemented rapidly. Can provide indication of near-surface entrained/dissolved hydrocarbons (most other monitor and evaluate techniques rely on the hydrocarbon being on the surface or shoreline).

OSR strategy	Tactic	Applicability and designated primary (1) or secondary (2) response strategy		Considerations/limitations
		Barossa condensate	MDO	
	Trajectory modelling	✓ 1	✓ 1	Can be implemented rapidly. Predictive – provides estimate of where the oil may go, which can be used to prepare and implement other responses. No additional field personnel required. Not constrained by weather conditions. Can predict floating, entrained, dissolved and stranded hydrocarbon fractions. May not be accurate. Requires in-field calibration.
	Satellite imagery	✓ 1	✓ 1	Can work under large range of weather conditions (e.g., night time, cloud cover, etc). Mobilisation likely to be more than 24 hours. Requires processing. May return false-positives.
	Operational water quality monitoring	✓ 1	✓ 1	Fluorometry surveys are used to determine the location and distribution of the entrained oil and dissolved aromatic hydrocarbon components of a continuous subsea spill and validate the spill fate modelling predictions.
	Shoreline and coastal habitat assessment	N/A	N/A	Modelling indicates no probability of shoreline accumulation at any exposure value.

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OSR strategy	Tactic	Applicability and designated primary (1) or secondary (2) response strategy		Considerations/limitations
		Barossa condensate	MDO	
Chemical dispersion	Vessel application	✗	✗	Neither Barossa condensate or MDO are persistent hydrocarbons, both having high natural spreading, dispersion and evaporation rates in the marine environment. Surface chemical dispersants are most effective on hydrocarbons that are at a thickness of 50–100g/m^2 on the sea surface. EMSA (2010) recommends thin layers of spilled hydrocarbons should not be treated with dispersant. This includes Bonn Agreement Oil Appearance Codes (BAOAC) 1–3 (EMSA, 2010). Barossa Condensate and MDO would rapidly spread and thin out on the sea surface, so it is unlikely to reach this required thickness. Therefore, considering the rapid evaporation rates (57% within a few hours to a day – refer to Barossa Development OPEP (BAA-200 0314) – Appendix A: Hydrocarbon characteristics and behaviour) of this Group I hydrocarbon, the inability to achieve the required thicknesses for application to be effective and the remoteness of the spill location, the addition of chemical dispersants would have little to no environmental benefit.
	Aerial application	✗	✗	
Offshore containment and recovery	Use of offshore booms/skimmers or other collection techniques deployed from vessel/s to contain and collect oil	✗	✗	*Barossa condensate and MDO* Not suitable for Barossa condensate or marine diesel given their rapid weathering nature. These hydrocarbons spread quickly to a thin film, making recovery via skimmers difficult and ineffective. The ability to contain and recover rapidly weathering hydrocarbons on the sea surface is extremely limited due the very low viscosity of these hydrocarbons.

OSR strategy	Tactic	Applicability and designated primary (1) or secondary (2) response strategy		Considerations/limitations
		Barossa condensate	MDO	
Mechanical dispersion	Vessel prop-washing	✓ 2	✓ 2	Safety is a key factor and slicks with potential for high volatile organic compound (VOC) emissions are not suitable. Mechanical dispersion may be applicable for the localised entrainment of surface oil but is not considered to have a significant effect on removing oil from the surface. Mechanical dispersion will entrain surface oil into the top layer of the water column. The aim of mechanical dispersion is to reduce the concentration of oil floating at the surface which could potentially contact receptors at the sea surface (e.g., sea birds) or shoreline receptors (e.g. mangroves). Once dispersed in the water column the smaller droplet sizes enhance the biodegradation process. Marine diesel is a light oil that can be easily dispersed in the water column by running vessels through the plume and using the turbulence developed by the propellers to break up the slick. Mechanical dispersion may be considered for targeted small breakaway patches of condensate but may have limited effectiveness. The potential disadvantage of mechanical dispersion is that it could temporarily increase the concentration of entrained and dissolved oil in the vicinity of submerged shallow water receptors (e.g., corals, seagrass ad macroalgae). This is most likely in shallow water of a few metres deep. The suitability of mechanical dispersion as a response measure would consider the prevailing environmental conditions (it mimics the action of wave induced entrained so is most beneficial in calm conditions) and the type, proximity and depth (as applicable) of sensitivities in the area. Mechanical dispersion will be considered for petroleum activity sourced spills at the discretion of the On-Scene Commander (OSC)/ Incident Management Team (IMT) or by the relevant control agency. It is unlikely that vessels would be specifically allocated for mechanical dispersion but vessels undertaking primary strategies may be used opportunistically.

OSR strategy	Tactic	Applicability and designated primary (1) or secondary (2) response strategy		Considerations/limitations
		Barossa condensate	MDO	
Protection and deflection	Booming in nearshore waters and at shorelines	N/A	N/A	Modelling indicates no probability of shoreline accumulation at any exposure value.
Shoreline clean-up	Activities include physical removal, surf washing, flushing, bioremediation, natural dispersion	N/A	N/A	Modelling indicates no probability of shoreline accumulation at any exposure value.
Oiled wildlife response (OWR)	Activities include hazing, pre-emptive capture, oiled wildlife capture, cleaning and rehabilitation	✓ 1	✓ 1	Can be used to deter and protect wildlife from contact with oil. Mainly applicable for marine and coastal fauna (e.g., birds) where oil is present at the sea surface or accumulated at coastlines. Surveillance can be carried out as a part of the fauna specific operational monitoring. Wildlife may become desensitised to hazing methods. Hazing may impact upon animals (e.g., stress, disturb important behaviours such as nesting or foraging). Permitting requirements for hazing and pre-emptive capture.

OSR strategy	Tactic	Applicability and designated primary (1) or secondary (2) response strategy		Considerations/limitations
		Barossa condensate	MDO	
Scientific monitoring	The monitoring of environmental receptors to determine the level of impact and recovery form the oil spill and associated response activities	✓ 1	✓ 1	Monitoring activities include: + water and sediment quality + biota of shorelines (sandy beaches, rocky shores and intertidal mudflats) + mangrove monitoring + benthic habitat monitoring (seagrass, algae, corals, non-coral benthic filter feeders) + seabirds and shorebirds + marine megafauna (incl. whale sharks and mammals) + marine reptiles (incl. turtles) + seafood quality + fish, fisheries and aquaculture. The type and extent of scientific monitoring will depend upon the nature and scale of oil contact to sensitive receptor locations as determined through operational monitoring. Pre-defined initiation criteria exist for scientific monitoring plans associated with marine and coastal sensitivities.

4.2 Net environmental benefit analysis

The IMT uses a net environmental benefit analysis (NEBA), also referred to as a spill impact mitigation assessment (SIMA), to inform the incident action planning process (Section 8 of the Barossa Development OPEP (BAA-200 0314)), so the most effective response strategies with the least detrimental environmental impacts can be identified, documented and executed.

The Environment Unit Leader will use the information in **Section 3.3** to identify and prioritise initial response and/or monitoring priorities and apply the NEBA to identify which response strategies are preferred for the situation, oil type and behaviour, environmental conditions, direction of plume and locations.

As a component of the incident action planning process, NEBA is conducted by the control agency with responsibility for the spill response activity. Where there are different activities controlled by different IMTs, as in a cross-jurisdictional response, consultation will be required during the NEBA process so that there is consistency in the sensitivities prioritised for response across the Control Agencies.

A strategic NEBA has been developed for all response strategies identified as applicable to credible spills identified in this OPEP Addendum, with the benefit or potential impact to each sensitivity identified (refer to **Table 4-2** and **Table 4-3**).

In the event of a spill, NEBA is applied with supporting information collected as part of the Operational Monitoring Plan (Section 10 of the Barossa Development OPEP (BAA-200 0314)) to achieve the following:

+ Identify sensitivities within the area potentially affected by a spill at that time of the year (noting that the sensitivity of some key receptors, such as birdlife and turtles, varies seasonally).
+ Assist in prioritising and allocating resources to sensitivities with a higher protection and response priority.
+ Assist in determining appropriate response strategies with support of real time metocean conditions, oil spill tracking and fate modelling.

When a spill occurs, NEBA is applied to the current situation, or operationalised. Operational NEBA Templates are filed within the Environment Team Leader folder on the Santos Emergency Response Intranet site. To complete the Operational NEBA:

+ all ecological and socioeconomic sensitivities identified within the spill trajectory area are recorded
+ potential effects of response strategies on each sensitivity are assessed in terms of their benefit or otherwise to the socio-economic sensitivities
+ all persons involved and data inputs have been considered for the analysis.

The Operational NEBA Form documents the decisions behind the recommendation to the Incident Commander on which resources at risk to prioritise, and the positives and negatives of response strategies to deploy. The Operational NEBA provides guidance to the Incident Action Plan (IAPs) and is revisited each Operational Period.

Table 4-2: Strategic net environmental benefit analysis matrix – Barossa condensate loss of well control (all scenarios)

Priority for protection area	No controls	Source control	Monitor and evaluate	Mechanical dispersion	Oiled wildlife response	Scientific monitoring
Tassie and 'Unnamed' Shoal (submerged receptor)						
Coral and other subsea benthic primary producers					N/A	
Important fish communities					N/A	
Oceanic Shoals Marine Park (submerged receptor)						
Turtle habitat – flatback, olive ridley, loggerhead						
Coral and other subsea benthic primary producers					N/A	
Important fish communities					N/A	
Carbonate bank and terrace system of the Van Diemen Rise (submerged receptor)						
Coral and other subsea benthic primary producers – soft corals, sponges, epifauna					N/A	
Important fish communities					N/A	
Turtle habitat – flatback, olive ridley, loggerhead						
The shelf break and slope of the Arafura Shelf (submerged receptor)						
Phytoplankton and invertebrates					N/A	
Important fish communities					N/A	

Key:

	Beneficial impact		Possible beneficial impact depending on the situation (e.g. timeframes and metocean conditions to dilute entrained oil)		Negative impact	N/A	Not applicable for the environmental value or not applicable for hydrocarbon type

Table 4-3: Strategic net environmental benefit analysis matrix – marine diesel oil spills (all scenarios)

Priority for protection area	No controls	Source control	Monitor and evaluate	Mechanical dispersion	Oiled wildlife response	Scientific monitoring
Tassie and Unnamed Shoal (submerged receptor)						
Coral and other subsea benthic primary producers					N/A	
Important fish communities					N/A	
Oceanic Shoals Marine Park (submerged receptor)						
Turtle habitat – flatback, olive ridley, loggerhead						
Coral and other subsea benthic primary producers					N/A	
Important fish communities					N/A	
Carbonate bank and terrace system of the Van Diemen Rise (submerged receptor)						
Coral and other subsea benthic primary producers – soft corals, sponges, epifauna					N/A	
Important fish communities					N/A	
Turtle habitat – flatback, olive ridley, loggerhead						
The shelf break and slope of the Arafura Shelf (submerged receptor)						
Phytoplankton and invertebrates					N/A	
Important fish communities					N/A	

Key:

	Beneficial impact		Possible beneficial impact depending on the situation (e.g., time frames and met-ocean conditions to dilute entrained oil)		Negative impact	N/A	Not applicable for the environmental value or not applicable for hydrocarbon type

5 Spill response ALARP assessment

5.1 ALARP Assessment Summaries

ALARP assessment summary – source control (refer worksheet for further detail)
The Control Measures in place for emergency BOP activation represent industry best practice and are considered to reduce the timeframe for BOP activation to ALARP in the context of a LOWC incident. The use of a BOP is considered to be an effective source control and the emergency BOP activation procedures ensure timely activation of the BOP. No additional or alternative control measures were identified. The Control Measures in place for relief well drilling represent industry best practice and are considered to reduce the timeframe for drilling a relief well to as low as reasonably practicable in the context of the risk of an uncontrolled well leak from a production well. Potential Control Measures were identified and assessed by the Santos WA Drilling & Completions Department representatives. The drilling of a relief well is considered to be an effective control and relief well planning conducted in the area has demonstrated that relief well drilling within 90 days can be implemented using MODUs, equipment and specialist personnel that Santos has arrangements to gain access to. Santos has arrangements in place to enable access to a Capping Stack as a secondary source control strategy and would only be used where there is suitable vertical access over the wellhead. These arrangements also include trained personnel for the mobilisation, deployment and operation of the Capping Stack. Limiting factors for the deployment of a Capping Stack involve safety and technical constraints, metocean conditions, location of Capping Stacks and access to a suitable Capping Stack capable vessel. Santos assessed the feasibility of maintaining its own Capping Stack and having suitable deployment vessel/crew on standby to deploy Capping Stack. Given the low likelihood of a blowout event, the significant upfront costs involved and the presence of a more effective primary control strategy (relief well drilling) the costs are considered disproportionate to the level of risk reduction.
Fifteen potential additional Control Measures were identified and assessed.
One additional Control Measures were accepted as reasonably practicable. Accepted Control Measure was: + Pre-purchase of relief well drilling supplies.
Fourteen Control Measures were rejected as grossly disproportionate. Rejected response strategies were: + Have dedicated BOP Intervention vessel equipped with ROV tooling package in field. + Purchase and maintain own Capping Stack in Darwin. + Incentivise a vendor to set up a Capping Stack in Darwin. + Purchase and maintain own Capping Stack and have suitable deployment vessel/crew on standby with pre-approved Safety Case to deploy Capping Stack. + Transport WWC Capping Stack via air. + Use lightweight Rapid Cap to be mobilised via air from Houston, USA.

- Suitable Capping Stack deployment vessel is confirmed to be available prior to drilling
- Preposition WWC Capping Stack standby crew in Perth.
- Have MODU on standby at activity location.
- Alternative relief well design (slim hole design)
- Schedule drilling campaign to avoid cyclone season.
- Contract source control personnel through a provider in addition to existing arrangements.
- Have Wild Well Control on standby in Perth during drilling operations in order to respond immediately to a LOWC.
- Pre-drill riserless intervals for a potential relief well before drilling the main well.

Performance Standards and Measurement Criteria that have been developed for the in effect Control Measures are shown in the Barossa Development OPEP. For the Capping Stack the key areas of effectiveness for the identified Control Measures are around the maintenance of contracts for the Capping Stack equipment, deployment of personnel, and the tracking of suitable vessels. The key performance requirements for relief well drilling are the maintenance tracking, access and relief well planning arrangements (during times of maintaining preparedness) and the timely mobilisation of resources (during a response). These key areas of effectiveness are reflected in the Performance Standards.

ALARP assessment summary – subsea dispersant (refer worksheet for further detail)

For a Barossa subsea LOWC, SSDI application is considered a secondary response strategy and is included for its potential to reduce VOC exposure to response personnel working close to the well site (e.g. to deploy a Capping Stack). To assess the effectiveness of dispersant application, Santos will use the Industry Recommended Subsea Dispersant Monitoring Plan (API, 2020).

Control Measures are in place for a rapid mobilisation of the SFRT, personnel and dispersants to Darwin; it is estimated that it will be ready to commence operations by day 11 to 12. A Control Measure involving the positioning of an SFRT on standby at a regional port in order to reduce deployment time was assessed but was found to be disproportionate in terms of costs to the reduction in risk gained. Dispersant volumes available within Australia and the mobilisation of these stocks exceed worse case requirements, hence dispersant is not a limiting factor to the SSDI operation.

Seven additional potential Control Measures were identified and assessed.

No additional Control Measures were accepted as reasonably practicable.

All seven additional Control Measures were rejected as grossly disproportionate. Rejected Control Measures were:

- Purchase Santos SFRT to be located in Darwin.
- Relocate AMOSC SFRT to Darwin.
- Position subsea bladder dispersant system next to well site.
- Transport WWC SSDI system from Singapore as a back-up unit.
- Enable improved vessel access by contracting a suitable, dedicated vessel on standby.
- Gain access to additional dispersant stockpiles owned by Santos.

- Rent dispersants and position in Darwin.

Performance Standards and Measurement Criteria that have been developed for the in effect Control Measures are shown in the OPEP. The key areas of effectiveness for the identified Control Measures, during times of preparedness, are around the maintenance of contracts for the SFRT equipment, dispersants and deployment personnel and the tracking of suitable SFRT vessels. In the event of a response, the key areas for ensuring effectiveness are the mobilisation of requirements to commence subsea dispersant operations, the subsea monitoring of dispersant efficacy by ROV and the consideration of this information together with other operational monitoring information within an operational NEBA for the activity. These key areas of effectiveness are reflected in the performance standards.

ALARP assessment summary – monitor and evaluate (refer worksheet for further detail)

Various, independent inputs from multiple service providers are used to build a detailed Common Operating Picture in the event of an incident.

Eight additional potential Control Measures were identified and assessed.

Three additional Control Measures were accepted as reasonably practicable. The accepted measures were:

- Have two tracking buoys available in Darwin.
- Require that vessel specifications be included in Vessel Tracking System.
- Maintain a list of providers that could assist with fauna aerial observations.

Five Control Measures were rejected as grossly disproportionate. Rejected Control Measures were:

- Purchase oil spill modelling system and internal personnel trained to use system.
- Have trained water monitoring specialists available in Darwin.
- Have trained aerial observers based in Darwin.
- Ensure trained marine mammal/fauna observers based at strategic locations such as Darwin.
- Possibly use for surveillance purposes two vessels servicing Bayu-Undan operations in response to a spill.

Performance Standards and Measurement Criteria that have been developed for the in-effect and accepted Control Measures are shown in the OPEP. The key areas of effectiveness for the identified Control Measures, during times of preparedness, focus on maintaining access to equipment and personnel through contractual arrangements with vessel providers, aircraft providers, aerial observers, UAV providers, tracking buoys, oil spill trajectory modelling providers, satellite imagery providers, water quality monitoring providers, and spill responders. Additional key areas for effectiveness during preparedness are following relevant procedures such as the Protected Marine Fauna Interaction and Sighting Procedure, and limiting environmental impacts from response activity through personnel and vehicle management. During response, a key area for ensuring effectiveness is the mobilisation of requirements in order to commence monitor and evaluate operations. These key areas of effectiveness have been represented in Performance Standards for monitor and evaluate operations.

ALARP assessment summary – mechanical dispersion (refer worksheet for further detail)
Mechanical dispersion is a secondary strategy that could be undertaken by vessels undertaking primary response strategies without the requirement for additional equipment, and no areas of improvement were identified. The use of mechanical dispersion in a response would be assessed as part of an operational NEBA. No potential additional Control Measures were identified and assessed. Performance standards and measurement criteria that have been developed for the in-effect control measures are shown in the OPEP. The key areas of effectiveness for the identified control measures during a response are around the development of an operational NEBA to confirm suitability and environmental benefit, and the mobilisation of vessels. These key areas of effectiveness are reflected in the performance standards.

ALARP assessment summary – oiled wildlife (refer worksheet for further detail)
The worst-case scenario associated with this OPEP Addendum does not predict shoreline accumulation at any exposure value and consequently only low numbers of oiled wildlife are anticipated. Santos has developed a Santos Wildlife Framework Plan (SO-91-BI-20014) as a Control Measure to ensure that a procedure is in place for OWR, where they are the control agency or Support Organisation, in order to provide an effective and coordinated OWR. Santos has access to the indicative resource requirements for the worst-case scenario in this OPEP Addendum as per the NT Oiled Wildlife Response Plan and WA Oiled Wildlife Response Plan. Including mobilisation of AMOSC oiled wildlife equipment and industry OWR team to a forward staging area within 48 hours. AMSA also maintains an oiled wildlife washing container in Darwin. Potential Control Measures around additional responders through pre-hiring or contracts with additional service providers were investigated but were found to be not beneficial and/or the cost was grossly disproportionate to risk reduction. Three potential Control Measures were identified and assessed. All were rejected as grossly disproportionate. Rejected response strategies were: + Have additional Santos OWR trained personnel positioned in Darwin. + Pre-hire and/or preposition staging areas and responders. + Use direct contracts with service providers. Performance Standards and Measurement Criteria that have been developed for the in-effect Control Measures are shown in the Barossa Development OPEP (BAA-200 0314). The key areas of effectiveness for the identified control measures, during times of preparedness, are around maintaining access to equipment and personnel through contractual arrangements. During response, the mobilisation of requirements for initial oiled wildlife response operations and the management of the oiled wildlife response in accordance with the WA Oiled Wildlife Response Plan and NT Oiled Wildlife Response Plan are both key elements for achieving this strategy and they are represented as Performance Standards.

ALARP assessment summary – waste (refer worksheet for further detail)
The Santos contract with the waste service provider has provisions for waste management operations of the scale estimated to be required in worst case scenarios detailed in the OPEP Addendum. Further detail is captured in the Waste Management Plan – Oil Spill Response Support (QE-91-IF-10053). The waste service provider can mobilise waste receptacles to Darwin Port within 12–24 hrs. Given the waste service provider arrangements and preplanning already undertaken, waste storage facilities, road transport and logistics are not expected to be limiting factors in the response. For these components, potential Control Measures were identified and evaluated but were found to either make no improvement in capability or cost was grossly disproportionate. An area of improvement is the availability of vessels required for waste transport at sea. One potential Control Measure to address this area of improvement was identified and accepted: + Maintain contracts with multiple service providers to cover new geographic location. Two potential Control Measures were rejected as grossly disproportionate. Rejected Control Measures were: + Procure temporary waste storage for Santos stockpile. + Contract additional vessels on standby for waste transport. Performance Standards and Measurement Criteria that have been developed for the in-effect Control Measures are shown in the Barossa Development OPEP (BAA-200 0314). The key areas of effectiveness for the identified Control Measures, during times of preparedness, are around maintaining access to waste management equipment and services through contractual arrangements. During response, a key area for increasing effectiveness is the timely mobilisation of requirements for initial response operations and defining critical management and reporting services to be provided by the waste service provider. These key areas of effectiveness are captured in the Performance Standards.
ALARP assessment summary – scientific monitoring (refer worksheet for further detail)
Oil spill scientific monitoring will be conducted on behalf of Santos by a contracted monitoring service provider as detailed in the Oil Spill Scientific Monitoring Standby and Response Manual (EA-00-RI-10162) and the relevant Scientific Monitoring Programs. An area of improvement is the availability of vessels in the initial stages of response. To address this area of improvement, a potential Control Measure around more detailed vessel tracking was assessed and accepted. Additionally, three potential Control Measures were identified and assessed. One Control Measure, having trained scientific monitoring personnel and equipment on standby in Darwin was considered disproportionate. Two potential Control Measures relating to maintaining equipment and lists of monitoring providers and the provision of water quality sampling kits to be located at strategic regional locations were both found to be reasonable and practicable, both were adopted. Four additional potential Control Measures were identified and assessed. Three additional Control Measures were accepted as reasonably practicable. The accepted Control Measures were: + Maintain equipment list and list of suppliers for implementation of Scientific Monitoring Plans. + Position oil sampling kit for scientific monitoring personnel at Darwin.

- Determine required vessel specifications required for scientific monitoring implementation and improve accuracy of Vessel Tracking System.

One Control Measure was rejected as grossly disproportionate. The rejected Control Measure was:

- Have scientific monitoring personnel and equipment on standby in Darwin.

Performance Standards and Measurement criteria that have been developed for the in effect and accepted Control Measures are shown in the Barossa Development OPEP (BAA-200 0314). The key areas of effectiveness for the identified Control Measures, during times of preparedness, are around maintaining access to equipment and personnel through contractual arrangements, regular reviews of monitoring service provider capability and reviews of existing baseline data. During response, a key area for effectiveness is the mobilisation of requirements to commence scientific monitoring, and ensuring that relevant approved manuals and plans are followed. These key areas of effectiveness are reflected in the Performance Standards.

5.2 ALARP Assessment Tables

Strategy	Control Measure	Alternative, Additional, Improved	Control Measure Category	Environmental Outcomes	Effectiveness	Feasibility	Accept/ Reject
Blowout Preventer - Emergency Activation	Access to ROV capability for BOP hot-stab intervention maintained with MODU ROV contractor throughout the	In effect	Equipment	Controlling flow of hydrocarbons as quickly as possible will reduce environmental impacts. BOP closed	Provides functionality, availability, reliability, survivability, compatibility and independence.	Cost of contract	In effect
	Dedicated BOP Intervention vessel equipped with ROV tooling package in field	Alternative	Equipment	BOP closed within 1-2 days (depending upon daylight hours available) reducing release of hydrocarbons by 2-3 days.	Provides functionality, availability, reliability, survivability, compatibility and independence.	Costs associated with having an additional dedicated BOP intervention vessel on contract $50-60K USD/day.	Reject Removes limitation of having to wait 2-3 days for a suitable vessel. However, the cost of having a vessel on standby is a fixed cost, regardless of if a spill were to occur or not. The time saving of 2-3 days is not proportionate to the expense incurred.
Capping Stack	Capping Stack is applicable as a secondary strategy for subsea wells and BOPs to be used. Santos has access to two Wild Well Control Capping Stacks (Singapore and Aberdeen). Singapore Capping Stack- Assembly and ready to mobilise will take approximately 6 days + 9 days to mobilise to incident (total= 15 days)	In effect	Equipment	Controlling flow of hydrocarbons as quickly as possible will reduce environmental impacts.	Provides functionality, availability, reliability, survivability, compatibility and independence. Would only be used where there is suitable vertical access over the wellhead	Cost of contract	In effect
	Santos to purchase and maintain its own Capping Stack in Darwin	Alternative	Equipment	This is unlikely to provide any reduction in timeframes due to vessel access being the key time driver. In order for this to be effective, a suitable vessel would need to be on standby (with personnel) to realise benefit of Capping Stack in Darwin.	A Capping Stack positioned in Darwin would need to be disassembled and stored at a suitable location as there is no suitable locations to store a fully assembled Capping Stack. Unpacking the containers, assembly and testing of the Capping Stack is estimated to take 4-5 days, but the limiting factor will be the availability of a suitable vessel.	USD20 million to procure and USD 2.8 million per year to maintain	Reject Given access to the Capping Stack is in Singapore, there is no significant benefit in having a dedicated Capping Stack available in Darwin. Critical path time will most likely be sourcing and the availability of a suitable vessel, which is most likely to be in SE Asia i.e. the vessel would have to be made available and mobilised to Australia for any response regardless of Capping Stack location. Therefore, the additional cost in owning and maintaining a dedicated stack is unlikely to provide any significant environmental benefit.

	Incentivise a vendor to set up a Capping Stack Darwin	Alternative	Equipment	This is unlikely to provide any reduction in timeframes due to vessel access being the key time driver. In order for this to be effective, a suitable vessel would need to be on standby (with personnel) to realise benefit of Capping Stack in Darwin	This would result in needing to moving an existing stack away from a shared logistics hub, such as Singapore. This could potentially affect other operators sharing this contracted resource. In addition, there is no local expertise available on standby in Darwin to conduct maintenance or commence assembly operations if the Capping Stack was required.	Pay full time rental as a sole beneficiary.	Reject Critical time path will be sourcing and availability of a suitable vessel, which I most likely to be in SE Asia. Therefore, the additional cost in requesting a vendor to set up an existing Capping Stack in Singapore is unlikely to provide any significant environmental benefit.
	Purchase and maintain own Capping Stack and have suitable deployment vessel/crew on standby with pre - approved Safety Case to deploy Capping Stack	Alternative	Equipment People	Some debris removal may be required prior to Capping Stack installation. The SFRT would not be onsite until day 11-12 and then debris removal may take 1-2 days (depending on extent of damage). This option would therefore reduce Capping Stack deployment time by 1-2 days and only marginally reduce volume of oil contacting sensitive receptors.	A Capping Stack positioned in Darwin would need to be disassembled and stored at a suitable location as there is no suitable locations to store a fully assembled Capping Stack. Unpacking the containers, assembly and testing of the Capping Stack is estimated to take 4-5 days, but the limiting factor will be the availability of a suitable vessel. Purchasing a Capping Stack would also require training of personnel to maintain and install the stack, if it was required to be used. However, these personnel may not have the depth of experience that existing specialist personnel have whom are available through WWC, reducing the reliability and compatibility of this alternative.	Costs in addition to Capping Stack purchase/ maintenance costs are $80k USD per day for vessel/crew plus training costs for personnel.	Reject Based on drilling ~90 day well the costs of vessel/crew hire would be in the order of $5M additional to Capping Stack purchase/maintenance costs and not including for mobilisation costs. Capping Stack deployment is a secondary source control strategy, is contingent on safety and technical considerations, and may not be effective in controlling the source. Given the low likelihood of a blowout event, the significant upfront costs involved and the presence of a more effective primary control strategy (relief well drilling) the costs are considered disproportionate to the level of risk reduction.

	Transport WWC Capping Stack via air	Alternative	Equipment	The mobilisation time of the Capping Stack intervention system via airfreight is unlikely to provide a significant reduction in arrival time of the stack. The Capping Stack would need to be mobilised and flown into Darwin (3-5 days) and then assembled and tested (3-4 days). It would then need to be transferred and fastened on to the deployment vessel (1-2 days) and mobilised to the well site (1 day). This results in a total of 12 days. Therefore, this option is not expected to result in a significant improvement in arrival time of the Capping Stack, thus not resulting in any significant environmental benefit.	Air transportation of the Capping Stack requires it to be disassembled, which may affect the functionality of the stack if any components are damaged. The process of disassembly, packing, transport, unpacking and reassembly introduces a risk of damage to equipment, especially the metal pressure sealing surfaces associated with the high pressure connections of Capping Stacks. While the metal sealing rings have the strength to withstand very high pressures, they require a very smooth sealing surface to form a pressure seal. Mechanical handling of sealing components during Capping Stack disassembly risks damage to the smooth sealing surfaces and could result in additional time necessary to prepare the Capping Stack for deployment. Individual pressure sealing equipment elements must be packed separately. Damage to sealing surfaces may render the Capping Stack unusable until repairs can be undertaken at a certified machine shop. Therefore, air transportation adds an element of risk to the reliability of this alternative.	Cost of contracting Boeing 747 or Antonov 124 to transport the containers to Darwin.	Reject The risk associated with damaging equipment from airfreighting the Capping Stack and the minimal improvement in mobilisation time (12 days v's 15 days) is considered disproportionate to the incremental environmental benefit.
	Use of lightweight Rapid Cap to be mobilised via air from Houston, USA.	Additional	Equipment	The mobilisation time of the rapid cap would take approximately 10+ days, not resulting in any significant environmental benefit.	Airfreighting this cap in from Houston would not lead to any significant reduction in the estimated response time (10 days v's 15 days for preferred alternative of shipping Singapore stack). This is due to debris clearance taking 10+ days. Use of the Rapid Cap would only mitigate very specific cases (e.g. no debris) and industry experience indicates debris removal is likely for catastrophic failures. Although this lightweight cap only requires a lighter construction vessel with lesser specification on the crane and heave compensation, it is most likely this vessel will still need to be sourced from SE Asia.	Cost of having an additional contract for another Capping Stack.	Reject The mobilisation time of the rapid cap would take approximately 10+ days as the critical time path is likely to be debris clearance. The cost of having another contract with another equipment provider is disproportionate to the minimal environmental benefit gained.
	The location of suitable vessels (required vessel specs and Safety Case approval) for Capping Stack deployment are monitored monthly.	In effect	Procedure	Timely access to a suitable vessel could reduce mobilisation times for the Capping Stack thus reducing volume of hydrocarbon released to the environment.	Provides functionality, availability, reliability, survivability, compatibility and independence	Effort spent monitoring	In effect
	Suitable Capping Stack deployment vessel is confirmed to be available prior to drilling	Additional	Procedure	Timely access to a suitable vessel could reduce mobilisation times for the Capping Stack thus reducing volume of hydrocarbon released to the environment.	Provides functionality, availability, reliability, survivability, compatibility and independence	Effort spent monitoring	In effect

	Wild Well Control staff available via contract to assist with the mobilisation, deployment, and operation of the Capping Stack and well intervention equipment	In effect	People	Controlling flow of hydrocarbons as quickly as possible will reduce environmental impacts.	Provides functionality, availability, reliability, survivability, compatibility and independence Area of improvement; none identified	Cost of contract	In effect
	Preposition WWC Capping Stack standby crew in Perth	Additional	People	No environmental benefit as WWC personnel are available to provide support within 72 hours.	No change to effectiveness or reliability as WWC personnel available within a rapid timeframe under existing arrangements.	Significant additional costs in having WWC personnel on standby in Perth. Locating personnel with specialised expertise in Perth may also create issues for other operators, as WWC offer this service to multiple operators. Locating them in remote locations may increase travel times to other global locations if they are required.	Reject No environmental benefit in having access to personnel surplus to requirements
Relief well drilling	Santos Drilling and Completions Source Control Team mobilised within 24 hours. Well Control Specialists mobilised within 72 hours. Contract/ MOUs for source control personnel. APPEA MoU for mutual assistance for relief well drilling.	In effect	People	Controlling flow of hydrocarbons as quickly as possible will reduce environmental impacts.	This control measure provides functionality, availability, reliability, survivability, compatibility and independence Area for improvement; none identified	Cost of contracts/ MOUs	In effect
	Source Control Planning and Response Guideline (DR-00-OZ-20001).	In effect	Procedure	Provides a set process top follow in the planning and mobilisation for relief well drilling by Santos WA Source Control Team thereby reducing the timeframe and increasing the effectiveness of relief well drilling.	Provides functionality, availability, reliability, survivability, compatibility and independence	Effort in updating and maintaining document	In effect
	MODU Capability Register is monitored monthly	In effect	Procedure	By monitoring MODU, it will be possible to gain an understanding of which MODU may be rapidly available for relief well operations. This could reduce mobilisation times for MODU thus reducing volume of hydrocarbon released to the environment.	Provides functionality, availability, reliability, survivability, compatibility and independence	Effort spent monitoring	In effect

	MODU on standby at activity location	Improved	Equipment	Reduce mobilisation times of MODU to drill relief well thus reducing hydrocarbon released to the environment. Instead of base timeframe for the drilling of a relief well of 90 days, relief well potentially could be drilled in 54 days (90 days less the 36 days required for MODU to be ready to spud/commence relief well operations).	Improved availability	The cost of having a MODU on standby is approximately $600,000 per day. If adopted this cost is paid regardless if there is a loss of containment or not.	Reject Likelihood of LOWC is considered unlikely and the cost of having a second MODU on standby at location is considered grossly disproportionate to the environmental benefit.
	Alternative relief well design (slim hole design)	Alternative	Equipment	Reduced relief well drill duration, potentially reducing volume of hydrocarbon released into the environment.	The alternative Barossa relief well design considered the construction of a smaller diameter well, which takes less time to drill. However, this relief well design had an unacceptable potential risk of not enabling the required rates of kill mud to be delivered during the dynamic kill operation.	Reduced cost compared to large diameter casing design	Reject This alternative presented an unacceptable potential risk of not enabling the rates of kill mud to be delivered during the dynamic kill operations, therefore was excluded as being ALARP for technical reasons. The relief well is required to be constructed using the same large diameter casing as the Barossa development wells, which eliminates the mud rates risk in comparison to the slim hole design.
	Suitable relief well confirmed to available prior to drilling	In effect	Procedure	Identification of a suitable MODU prior to drilling would decrease the time spent searching for a suitable MODU in the event of a spill, reducing mobilisation times for MODU thus reducing volume of hydrocarbon released to the environment.	Provides functionality, availability, reliability, survivability, compatibility and independence	Effort spent monitoring	In effect
	Regular monitoring of Relief Well Availability Register to ensure preferred MODU remains available throughout the activity	In effect	Procedure	Monitoring the Register will ensure Santos are aware of any changes in availability of suitable MODUs, enabling Santos to update the Source Control Plan and identify an alternative suitable MODU if the event a MODU changes location.	Provides availability, reliability, compatibility and independence	Effort spent monitoring	In effect

	Schedule drilling campaign to avoid cyclone season	Alternative	Procedure	Drilling the well in cyclone season does not increase the likelihood of a loss of containment. This will be verified by NOPSEMA in the accepted WOMP, where the plan to suspend the well during a cyclone will be assessed.	Does not alter the effectiveness of the response strategy.	Having to mob and de-mob a MODU to guarantee the well could be drilled outside of cyclone season would be a >5MM USD cost increase.	Reject There are no additional risks associated with cyclone season on a loss of well control. The barriers installed for cyclone suspension are independent of metocean conditions. Adjusting the timing would preclude the ability to drill for 6 months of the year, materially reducing the MODUs available to do the work. Having to mobe and de-mobe a MODU to guarantee the well could be drilled outside of cyclone season would be a >5MM USD cost increase, which is disproportionate to the benefit gained.
	Pre purchase of relief well drilling supplies	Additional	Equipment	Relief well drilling supplies such as casings and well head equipment could potentially reduce relief well drilling times	Increase in availability	Cost of purchase, maintenance and storage of supplies	Accept Offshore D&C commit to having long lead equipment for a relief well at our disposal as part of WOMP commitments for each well drilled.
	Direct Surface Intervention Via Well Control Experts	In effect	Procedure	Reduce time taken to control source and reduce environmental impacts	1) Effectiveness of intervention of this type needs to be assessed at the time given that personnel safety considerations may preclude this control measure. 2) Mobilisation procedure for personnel as per SCERP 3-4) Contracts and MoUs for well control personnel (WWC)	Ability to implement and effectiveness of this control can only be determined at the time of an incident.	In effect
	Relief well design assessment to identify and screen relief well spud locations prior to drill campaign	In effect	Procedure	Reduce time taken to plan and execute relief well, and reduce environmental impacts	Improved availability and reliability	Effort required to conduct relief well assessment	In effect
	Contract source control personnel through an alternative provider in addition to existing arrangements	Alternative	People	No environmental benefit if existing service provider is adequate to fulfil requirements.	Improved availability and reliability	Significant additional cost in maintaining two contracts for the same service	Reject No environmental benefit in having an additional service provider
	Wild Well Control personnel on standby in Perth during drilling operations in order to respond immediately to a LOWC	Additional	People	No environmental benefit as WWC personnel are available to provide support within 72 hours which will coincide with starting to commence sourcing of relief well MODU	No change to effectiveness or reliability as WWC personnel available within a rapid timeframe under existing arrangements.	Significant additional costs in having WWC personnel on standby in Perth. Locating personnel with specialised expertise in Perth may also create issues for other operators, as WWC offer this service to multiple operators. Locating them in remote locations may increase travel times to other global locations if they are required	Reject No environmental benefit in having access to personnel surplus to requirements

	Pre-drill riserless intervals for a potential relief well before drilling the main well	Additional	Equipment Procedure	Could reduce relief well drill duration by 10 days. However, this activity would result in drill cuttings/discharges being released to the marine environment and noise emissions regardless if a LOWC were to occur or not.	Detailed relief well designs will be re-evaluated and revised for an actual LOWC event. There will be several locations for the relief well identified before an incident, with the optimal location selected after a LOWC incident, based on real-time information (i.e. prevailing weather). A pre-drilled relief well top-section might result in having to use a sub-optimal design and location. It is not industry practice, and such a pre-drilled riseless interval may adversely affect functionality and reliability of this response strategy.	The pre-drilling activity itself would require approximately 10 days and a complete rig move to perform, costing approximately ~7MM USD. Once the main well was completed, the partially completed relief well would need to be abandoned, at a further cost of 6-7MM USD.	Reject This option may result in a sub-optimal relief well location being used. There is minimal environmental benefit gained for the grossly disproportionate costs associated with this option.
Source Control - Vessel Collision	Vessel Spill Response Plan (SOPEP/SMPEP)	In effect	Procedure	Provides a set process to follow in the planning and mobilisation for spill response actions by the Vessel Contractor thereby reducing the timeframe and increasing the effectiveness of spill response.	Provides functionality, availability, reliability, survivability, compatibility and independence.	Effort required in contractor procedure due diligence.	In effect
No alternate, additional or improved control measures identified							

Strategy	Control Measure	Alternative, Additional, Improved	Control Measure Category	Environmental Outcomes	Effectiveness	Feasibility	Accept/ Reject
ROV survey	ROV Survey conducted at the release point to determine the nature of the release. This information will inform the applicability of subsea chemical dispersion and initial choice of dispersant injection methods (e.g., number of nozzles, nozzle sizes) and DOR.	In effect	Procedure, equipment	SSDI can break-up oil droplets forcing greater entrainment of the oil into the water column below the sea surface. Has ability to reduce volatile organic compounds in the vicinity of a spill, making the area safer for responders. It typically requires smaller volumes of dispersant to be used as it has a higher encounter rate with the hydrocarbons than surface application.	Provides functionality, availability, reliability, survivability, compatibility and independence.	Costs associated with vessel contract	In effect
No alternate, additional or improved control measures identified							
Subsea First Response Toolkit (SFRT) The SFRT includes debris clearance equipment and subsea dispersant equipment, including a dedicated dispersant stockpile (500 m³ of Dasic Slickgone NS) and ancillary equipment (e.g., pumps, flying leads, coiled tubing head, dispersant wands).	AMOSC SFRT stored at Oceaneering yard in Jandakot and can be transported to Darwin. It is estimated this would take 10 hours to arrange and up to 7 days to load and transport to Darwin, depending on the time of the year. A suitable vessel would be acquired by Santos during this timeframe and arrive in Darwin within 8 days of call-out. Once the equipment is loaded, the vessel will mobilise to site and be ready to commence operations by day 11-12 from call out.	In effect	Equipment	May improve capability to perform subsequent source control measures (e.g. capping stack) by reducing VOCs in the vicinity of the spill site. Equipment needed to clean the area around the wellhead, enable intervention and prepare for relief well drilling and safe installation of a well capping or containment device.	Provides functionality, availability, reliability, survivability, compatibility and independence. Availability - whilst the SFRT takes several days to mobilise to site and conduct initial surveys, this timeframe is considered reasonable given the technical nature of this equipment.	Cost of AMOSC membership for SFRT	In effect
	Purchase of Santos SFRT to be located in Darwin	Improved	Equipment	Reduces mobilisation time between storage and port of deployment	Improved availability however limited by vessel availability to deploy	Cost of SFRT purchase, storage and maintenance	Reject SFRT is estimated to arrive in Darwin only one day before vessel. Taking into account the significant costs of purchasing and maintaining a Santos-owned SFRT, an improvement of 2-3 days mobilisation time is not considered to provide a proportionate benefit.

	Relocate AMOSC SFRT to Darwin	Improved	Equipment	Reduces mobilisation time between storage and port of deployment (Darwin) by approx. 5 days	Improved availability however limited by vessel and personnel availability to deploy	AMOSC unable to alter storage location of SFRT as this could negatively impact other members	Reject Positioning of SFRT in Darwin in order to reduce deployment time was assessed but was found to be disproportionate in terms of costs to the reduction in risk gained and may adversely affect other SFRT members and their committed deployment times
	Subsea bladder dispersant system positioned next to well site	Alternative	Equipment	Subsea dispersant bladder system can be prepositioned and operate remotely if SSDI is determined a suitable strategy via an operational NEBA. Bladder systems are positioned in framed housings on the seafloor. Autonomous application could commence by Day 1-2, reducing application times by 7-8 days.	Possible improved availability and independence, however technical development and procurement would be required as existing components in the market would need to be combined to develop this system. Placing bladders on the seabed adjacent to the BOP exposes them to risk of damage from debris in the event of a loss of well control. Additionally, bladder systems require extensive equipment and fluid deployment/recovery operations at each wellsite, exposing personnel to significant additional HES risks. Therefore, the design and development of this technology includes a high degree of uncertainty. Subsea bladders also have limited volume capacity, meaning this alternative would offer a short term application option until SSDI arrives via the SFRT.	Purchase of bladder system on top of SFRT membership as both systems would still be required.	Reject Subsea bladder systems are a unproven technology and bring additional risks to the environment and personnel. In addition, the cost of having a subsea bladder system in place is a fixed cost, regardless of if a spill were to occur or not.
	Transport WWC SSDI system from Singapore	Additional	Equipment	No change as AMOSC SFRT system will arrive before WWC system.	Would provide a back-up system, however, the complexity of the SFRT is such that backup system is not required.	WWC SSDI system could be transported in tandem with WWC capping stack.	Reject AMOSC SFRT system is considered adequate and a back up system is not required.
No alternate, additional or improved control measures identified							
Subsea dispersant injection - planning	Source Control Planning and Response Guideline (DR-00-OZ-20001).	In effect	Procedure	Provides a detailed process to follow for the mobilisation of SFRT and suitable vessel by Santos Source Control Team thereby reducing the timeframe and increasing the effectiveness of SFRT.	Provides functionality, availability, reliability, survivability, compatibility and independence	Effort in updating and maintaining document	In effect
No alternate, additional or improved control measures identified							

Dispersant supply vessels	Level 2: Suitable vessel sourced through Santos contractors. Vessel requirements outlined in Santos Source Control Planning and Response Guideline (DR-00-ZF-1001).	In effect	Equipment	Enhance subsea dispersion and biodegradation of hydrocarbons. Consideration given to harmful impacts of chemical dispersants	Provides functionality, availability, reliability, survivability, compatibility and independence Area of improvement; early vessel availability	Cost of existing contracts with vessel providers	In effect
	Level 2: Suitable vessel sourced through any regional contractors and monitored through Santos Vessel Tracking System.	In effect	Equipment	Enhance subsea dispersion and biodegradation of hydrocarbons. Consideration given to harmful impacts of chemical dispersants	Provides functionality, availability, reliability, survivability, compatibility and independence Area of improvement; early vessel availability	Cost of vessel monitoring. Cost of contracts at the time of requirement.	In effect
	Level 3: Suitable vessel sourced as Vessels of Opportunity.	In effect	Equipment	Enhance subsea dispersion and biodegradation of hydrocarbons. Consideration given to harmful impacts of chemical dispersants	Provides functionality, availability, reliability, survivability, compatibility and independence Area of improvement; early vessel availability	Cost of contracts at the time of requirement.	In effect
	Enable improved vessel access by contracting a suitable, dedicated vessel on standby	Improved	Equipment	This alternative would result in SSDI commencing on Day 5-6, instead of Day 11-12 as vessel would be in Darwin on standby. Although this would treat released hydrocarbons for an additional 6-7 days, this would have a negligible reduction in shoreline accumulation volumes at protection priorities.	Improved availability and reliability	Costs associated with having a suitable vessel on contract and standby in Darwin - $50-60K USD/day.	Reject Removes bottleneck of having to wait for a suitable vessel. However, the cost of having a vessel on standby is a fixed cost, regardless of if a spill were to occur or not. The time saving of 6-7 days is not proportionate to the expense incurred, especially as SSDI is not anticipated to significantly reduce shoreline accumulation volumes if it were applied for an additional 6-7 days.
Subsea dispersant injection - personnel	Oceaneering personnel for the deployment of the SFRT and SSDI application	In effect	People	Enhance subsea dispersion and biodegradation of hydrocarbons. Consideration given to harmful impacts of chemical dispersants. May improve capability to perform subsequent source control measures (e.g. capping stack).	Provides functionality, availability, reliability, survivability, compatibility and independence Area of improvement; none identified	Cost of Oceaneering contract for personnel	In effect
No alternate, additional or improved control measures identified							

Subsea dispersant injection - dispersant stocks	Level 2: Dedicated SFRT dispersant stockpile stored with SFRT at Jandakot (AMOSC, 500m3 Dasic Slickgone NS). Additional dispersant stocks stored at Darwin (AMSA, 10m3 Slick Gone EW, 10m3 Slick Gone NS); Exmouth (AMOSC, 75 m3 Slickgone NS); Karratha (AMSA, 10m3 Slick Gone EW, 10m3 Slick Gone NS); Fremantle (AMOSC, 27m3 Corexit, 8 m3 Slickgone NS) (AMSA, 52 m3 Slick Gone EW, 48 m3 Slick Gone NS). Available within 24 hours.	In effect	Equipment	Enhance subsea dispersion and biodegradation of hydrocarbons. Consideration given to harmful impacts of chemical dispersants	Provides functionality, availability, reliability, survivability, compatibility and independence Availability exceeds requirements	Costs of contracts, MOU with AMOSC, access to National Plan resources through AMSA	In effect
	Level 3: Dispersant stocks stored at other national stockpiles (AMOSC, 761m^3 including 500 m3 associated with the SFRT) (AMSA, 215 m^3) OSRL dispersant stocks available in Singapore (50% of 732m^3 as SLA and 5000m3 as a subscriber to the Global Dispersant Stockpile) Mobilisation times depend on location.	In effect	Equipment	Enhance subsea dispersion and biodegradation of hydrocarbons. Consideration given to harmful impacts of chemical dispersants	Provides functionality, availability, reliability, survivability, compatibility and independence Availability exceeds requirements	Costs of contracts, MOU with AMOSC + OSRL access to National Plan resources through AMSA	In effect
	Access to additional dispersant stockpiles owned by Santos	Additional	Equipment	No additional environmental benefit if surplus to requirements	Improved availability and reliability	Additional cost for purchase and maintenance of stockpiles	Reject Analysis indicates that dispersant supplies sufficient. Santos is already subscribing to OSRL stockpiles in excess of 5,000 m^3.
	Rent dispersants and position in Darwin	Additional	Equipment	No additional environmental benefit as existing dispersant stockpiles can be relocated to Darwin and dispersant manufacture can commence in a timeframe where dispersant demand does not exceed supply.	Availability already meets requirements	Additional cost for renting dispersant stockpiles	Reject Analysis indicates that timeframes for mobilising and relocating dispersant supplies are sufficient.
Dispersant effectiveness monitoring	To assess the effectiveness of dispersant application, Santos will use the Industry Recommended Subsea Dispersant Monitoring Plan (API, 2020) to determine the efficacy of subsea dispersant application.	In effect	Procedure	The Industry Recommended Subsea Dispersant Monitoring Plan (API, 2020) to assist in characterising the nature and extent of subsea or near surface dispersed oil, aid in the validation and accuracy of plume trajectory models and allow for rapid quantification of data to enable the IMT to make decisions about continuation of dispersant application. The IMT assesses the effectiveness of continued dispersant use against an operational NEBA assessment.	Provides functionality, availability, reliability, survivability, compatibility and independence	Cost of contracts to provide monitoring capability	In effect
No alternate, additional or improved control measures identified							

Strategy	Control Measure	Alternative, Additional, Improved	Control Measure Category	Environmental Outcomes	Effectiveness	Feasibility	Accept/ Reject
Oil Spill Trajectory Modelling	Maintain contract with Oil Spill Trajectory Modelling service provider. The service provider will be contacted immediately (within 2 hours) upon notification of a level 2 or 3 spill. Upon activation, the service provider will provide trajectory models within: - 2 hours for OILMAP model for offshore and open ocean; - 4 hours for OILMAP operations for near-shore; and - Detailed modelling service is available for the duration of the incident.	In effect	System	Knowledge of the spill, provided in a short-time frame, will inform the IMT decisions with the aim of reducing and mitigating environmental impact	Provides functionality, availability, reliability, survivability, compatibility and independence Area of improvement; none identified	Cost of contract	In effect
	Access to additional spill modelling capability through OSRL	In effect	System	Knowledge of the spill, provided in a short-time frame, will inform the IMT decisions with the aim of reducing and mitigating environmental impact	An additional service provider ensures redundancy (independence) if for some reason the other service provider was unable to fulfil the function. There is also the possibility of increased functionality associated with improved certainty of the modelling results if both service providers are activated.	Cost of membership	In effect
	Purchase of oil spill modelling system and internal personnel trained to use system	Alternative	System, people	This could result in the faster generation of the initial model which may result in an environmental benefit as a consequence of the IMT making operational decisions quicker	Potentially increases availability Decrease in functionality- in house service may not be across technical advances to same extent as contracted service providers	Purchase of system, training of personnel, and on-call roster	Reject The cost of purchasing the system, training and having personnel on-call is disproportionate to any potential gains from potentially being able to deliver initial results quicker than the 2 hour turn-around currently guaranteed by the service provider
Tracking buoy	Level 1: Two tracking buoys available on MODU. Ready for deployment 24/7. Ability to deploy tracking buoys within 2 hrs.	In effect	Equipment	Tracking buoys provide real-time verification data (particularly beneficial at night and in conditions limiting aerial surveillance)	Provides functionality, availability, reliability, survivability, compatibility and independence Area of improvement; none identified	Cost of equipment	In effect
	Level 2: two tracking buoys available in Darwin during activity. Darwin to Barossa is 20 hrs pending vessel (pending vessel availability)	Additional	Equipment	Tracking buoys provide real-time verification data (particularly beneficial at night and in conditions limiting aerial surveillance)	Provides functionality, availability, reliability, survivability, compatibility and independence Area of improvement; none identified	Cost of equipment	Accept

	Level 2/3: Ten tracking buoys mobilised from Varanus Island, Dampier Supply Base or Exmouth Freight and Logistics. Mobilisation timeframe- 48-72 hrs	In effect	Equipment	Tracking buoys provide real-time verification data (particularly beneficial at night and in conditions limiting aerial surveillance)	Provides functionality, availability, reliability, survivability, compatibility and independence Area of improvement; none identified	Cost of equipment	In effect
	Level 2/3: tracking buoys available from AMOSC and through AMOSC Mutual Aid Mobilisation timeframe- 42-72 hrs	In effect	Equipment	Tracking buoys provide real-time verification data (particularly beneficial at night and in conditions limiting aerial surveillance)	Provides functionality, availability, reliability, survivability, compatibility and independence Area of improvement; none identified	Cost of membership	In effect
	Level 3: tracking buoys available from OSRL. Transit times (air) UK to Darwin = ?	In effect	Equipment	Tracker buoys provide real-time verification data (particularly beneficial at night and in conditions limiting aerial surveillance)	Provides functionality, availability, reliability, survivability, compatibility and independence Area of improvement; none identified	Cost of membership	In effect
Aerial surveillance - aircraft and crew	Maintain contract with service provider for dedicated aerial platform operating out of Darwin (Helicopter services available through Santos primary contracted suppliers. Wheels up within 1 hr for emergency response. Spill surveillance < 10 hrs (daylight dependent). Surveillance and recording using helicopter pilots is considered adequate for situational awareness.)	In effect	System	Knowledge of the spill, provided in a short-time frame, will inform the IMT decisions with the aim of reducing and mitigating environmental impact	Provides functionality, availability, reliability, survivability, compatibility and independence Area for improvement - availability - rapid mobilisation of aerial observers in initial 24 hours of incident	Cost of contract	In effect
	Level 2/3: Drones available via AMOSC. Mobilisation timeframe: < 48 hrs	In effect	System	Knowledge of the spill, provided in a short-time frame, will inform the IMT decisions with the aim of reducing and mitigating environmental impact Drones may be necessary for some sensitive environments and where personnel safety is at risk	Provides functionality, availability, reliability, survivability, compatibility and independence Area of improvement; none identified	Cost of membership	In effect

	Level 2/3: Drones available via OSRL.- Third Party provider Mobilisation timeframe: depending on the port of departure, one to two day if within Australia	In effect	System	Knowledge of the spill, provided in a short-time frame, will inform the IMT decisions with the aim of reducing and mitigating environmental impact Drones may be necessary for some sensitive environments and where personnel safety is at risk	Provides functionality, availability, reliability, survivability, compatibility and independence Area of improvement; none identified	Cost of membership	In effect
No alternate, additional or improved control measures identified							
Aerial surveillance - observers	Level 2: Trained Santos observers will be mobilised to airbase within 24 hrs, following activation	In effect	People	Knowledge of the spill, provided in a short-time frame, will inform the IMT decisions with the aim of reducing and mitigating environmental impact	Provides functionality, availability, reliability, survivability, compatibility and independence Area for improvement - availability - rapid mobilisation of aerial observers in initial 24 hours of incident	Cost of training and maintaining trained staff	In effect
	Level 2: Access to additional aerial observers through AMOSC Staff and Industry Mutual Aid Core Group Responders	In effect	People	Knowledge of the spill, provided in a short-time frame, will inform the IMT decisions with the aim of reducing and mitigating environmental impact	Provides functionality, availability, reliability, survivability, compatibility and independence Area of improvement; none identified	Cost of AMOSC membership	In effect
	Level 3 : Access to additional aerial observers through OSRL (18 people). OSRL staff initial 5 technical advisors available from 2 to 3 days of activation in Darwin, remaining personnel available from 4 to 5 days in Darwin, subject to approvals/ clearances.	In effect	People	Knowledge of the spill, provided in a short-time frame, will inform the IMT decisions with the aim of reducing and mitigating environmental impact	Provides functionality, availability, reliability, survivability, compatibility and independence Area of improvement; none identified	Cost of OSRL membership	In effect
	Level 1: Ensure trained aerial observers based at Darwin for duration of activity.	Additional	People	Current capability meets need and therefore environmental benefit would be incremental. Having trained observers living locally and on short notice to mobilise ensures trained aerial observers available from Day 2, and potentially from Day 1 (current arrangements are that the pilot would provide the initial observations and recording on Day 1).	Improved availability and reliability	Costs associated with staff employment and training	Reject Cost is considered disproportionate to the incremental benefit given surveillance on Day 1 by pilots is considered sufficient

Aerial surveillance - unmanned aerial vehicles	Level 2: Unmanned Aerial Vehicles for aerial surveillance available through AMOSC (UAVs and pilots can be accessed through AMOSC with a mobilisation time of < 48 hrs)	In effect	Equipment	Use of UAVs may provide an environmental benefit compared to alternative options (such as helicopters and fixed wing aircraft) given shorter deployment time and ability to assess difficult areas.	Provides functionality and availability Area of improvement; none identified	Cost of membership with AMOSC	In effect
	Level 3: Unmanned Aerial Vehicles for aerial surveillance available through OSRL	In effect	Equipment	Use of UAVs may provide an environmental benefit compared to alternative options (such as helicopters and fixed wing aircraft) given shorter deployment time and ability to assess difficult areas.	Provides functionality and availability Area of improvement; none identified	Cost of membership with OSRL	In effect
No alternate, additional or improved control measures identified							
Vessel surveillance	Level 1: vessels in use by Santos could be used for surveillance purposes in the event of a spill.	In effect	People	Knowledge of the spill, provided in a short-time frame, will inform the IMT decisions with the aim of reducing and mitigating environmental impact. In comparison to aerial surveillance, vessel surveillance provided limited information.	Provides functionality, availability, reliability, survivability, compatibility and independence Area of improvement; none identified	Cost of existing contracts with vessel providers	In effect
	Level 2: vessels sourced through Master Service Agreement, located in region and tracked by Santos Vessel Monitoring System.	In effect	Equipment	Knowledge of the spill, provided in a short-time frame, will inform the IMT decisions with the aim of reducing and mitigating environmental impact. In comparison to aerial surveillance, vessel surveillance provided limited information.	Improves availability and reliability Area of improvement; none identified	Cost of vessel monitoring. Cost of contracts at the time of requirement.	In effect
	Level 3: vessels sourced without existing contracts from any location	In effect	Equipment	Knowledge of the spill, provided in a short-time frame, will inform the IMT decisions with the aim of reducing and mitigating environmental impact. In comparison to aerial surveillance, vessel surveillance provided limited information.	Improves availability and reliability Area of improvement; none identified	Cost of contracts at the time of requirement.	In effect

	Two vessels are in use by Santos servicing the Bayu-Undan operations could be used for surveillance purposes in response to a spill.	Additional	Equipment	Knowledge of the spill, provided in a short-time frame, will inform the IMT decisions with the aim of reducing and mitigating environmental impact. In comparison to aerial surveillance, vessel surveillance provided limited information.	Improves availability and reliability	Cost of existing contract with vessel contractors.	Rejected One vessel is required to be on station at the Bayu-Undan facilities at all the time. The second vessel preforms critical in-field activities such as methanol bunkering and assisting with off take tanker activities. Therefore, neither vessel could be considered to be reliably available to undertake vessel surveillance activities.
No alternate, additional or improved control measures identified							
Water Quality Monitoring (operational and scientific)	Maintain monitoring service provider contract for water quality monitoring services. Water quality monitoring personnel, equipment and vessel mobilised to Darwin within 72 hrs of notification.	In effect	System	This monitoring will confirm the distribution and concentration of oil, validating spill trajectory modelling and inform the IMT decisions with the aim of reducing and mitigating environmental impact	Provides functionality, availability, reliability, survivability, compatibility and independence Area of improvement; availability of vessels	Cost of contracts	In effect
	Access to additional water quality monitoring services through OSRL	In effect	System	This monitoring will confirm the distribution and concentration of oil, validating spill trajectory modelling and inform the IMT decisions with the aim of reducing and mitigating environmental impact	Provides functionality, availability, reliability, survivability, compatibility and independence Area of improvement; availability of vessels	Cost of OSRL membership	In effect
	Required vessel specifications included in Vessel Tracking System	Improved	Procedure	Improve mobilisation time	Improved availability and reliability	Cost to maintain and operate vessel tracking system	Accept
	Trained monitoring specialists in Darwin	Additional	People	Ensure sampling is conducted correctly	Improves reliability	Costs associated with staff employment	Reject This is not necessary as a good procedure for sample collection is already in place
Satellite Imagery	Maintain membership with AMOSC provider to enable access and analysis of satellite imagery.	In effect	Systems	Satellite imagery is considered a supplementary source of information that can improve awareness but is not critical to the response and usage is at the discretion of the IMT	Provides functionality, availability, reliability, survivability, compatibility and independence Area of improvement; none identified	Cost of membership with AMOSC	In effect
	Maintain membership with OSRL to enable access to and analysis of satellite imagery	In effect	System	Satellite imagery is considered a supplementary source of information that can improve awareness but is not critical to the response and usage is at the discretion of the IMT	Provides functionality, availability, reliability, survivability, compatibility and independence Area of improvement; none identified	Cost of membership with OSRL	In effect
No alternate, additional or improved control measures identified							

Wildlife Reconnaissance (aerial/ vessel surveillance. Shoreline and coastal habitat assessment)	Maintain contract with scientific monitoring service provider for access to fauna aerial observers and personnel experienced in conducting relevant fauna surveys.	In effect	People, procedures	Wildlife reconnaissance aids the IMT to plan and make decisions for executing an oiled wildlife response and for minimising impacts to wildlife associated with the clean-up response	Provides functionality, availability and compatibility Area for improvement; availability - reduce time to mobilise personnel to strategic locations	Cost of contract	In effect
	Maintain a list of providers that could assist with fauna aerial observations	Additional	People	Wildlife reconnaissance aids the IMT to plan and make decisions for executing an oiled wildlife response and for minimising impacts to wildlife associated with the clean-up response	Improves availability and reliability Area of improvement; none identified	Cost of maintaining list	Accept
	Ensure trained marine mammal/fauna observers based in Darwin	Additional	People	Having trained marine mammal/fauna observers living locally and on short notice to mobilise would result in trained aerial observers available from Day 1	Improved availability and reliability	Costs associated with staff employment and training	Reject Maintaining trained fauna observers at location is considered grossly disproportionate as they are required only for the initial stages of the response until observers from scientific monitoring provider can be mobilised.

Strategy	Control Measure	Alternative, Additional, Improved	Control Measure Category	Environmental Outcomes	Effectiveness	Feasibility	Accept/ Reject
Mechanical Dispersion	Use of vessel crews, contract vessels and vessels of opportunity to disperse small areas of amenable hydrocarbon types such as marine diesel.	In effect	People, equipment	Enhanced dispersion and biodegradation of released hydrocarbons	Provides availability, reliability, survivability, compatibility and independence. Limited functionality as mechanical dispersion is secondary response strategy limited by weather conditions, hydrocarbon type, hydrocarbon volume.	Cost of vessel time	In effect

Strategy	Control Measure	Alternative, Additional, Improved	Control Measure Category	Environmental Outcomes	Effectiveness	Feasibility	Accept/ Reject
Oile wildlife response - planning	Level 1/2: Santos Oiled Wildlife Response Framework which will set the corporate guidance for OWR preparedness and response and define how Santos will integrate with Control Agencies to provide a coordinated response	Additional	Procedure	The framework will facilitate a rapid coordinated response, and the provision of resources by Santos in order to increase the likelihood of success of the OWR (success in terms of wildlife survivorship and rates for release back into the wild).	Improved functionality and reliability.	Cost of document maintenance	Accept
	Implementation of the Western Australian Oiled Wildlife Response Plan (WAOWRP) and Northern Territory Oiled Wildlife Response Plan (NTOWRP)	In effect	Procedure	Working within the guidelines of the WAOWRP and NTOWRP will ensure a coordinated response and that the expectations of the Control Agency are met with the overall aim to increase the likelihood of success of the OWR (success in terms of wildlife survivorship and rates for release back into the wild).	Provides functionality, availability, reliability, survivability, compatibility and independence	Effort and time involved in maintaining OWR implementation plan within OPEP	In effect
No alternate, additional or improved control measures identified							
Oiled wildlife response - equipment	Level 2: OWR kits and containers available from AMSA in Darwin	In effect	Equipment	Timely access to appropriate equipment is needed for the effective treatment of wildlife in order to increase the likelihood of success of the OWR	Provides functionality, availability, reliability, survivability, compatibility and independence Area of improvement; none identified	Cost of membership with AMOSC	In effect
	Level 3: OWR kits and containers available for AMOSC, AMSA and DoT: Broome, Fremantle, Exmouth, Geelong, Dampier, Devonport and Townsville Mobilisation to Darwin within 2-7 days	In effect	Equipment	Appropriate equipment is needed for the effective treatment of wildlife in order to increase the likelihood of success of the OWR	Provides functionality, availability, reliability, survivability, compatibility and independence Area of improvement; none identified	Cost of membership with OSRL	In effect
	Level 3 OWR equipment available from OSRL. Transit times (road/ air) Singapore to Darwin = 3–5 days of activation	In effect	Equipment	Appropriate equipment is needed for the effective treatment of wildlife in order to increase the likelihood of success of the OWR	Provides functionality, availability, reliability, survivability, compatibility and independence Area of improvement; none identified	Cost of membership with OSRL	In effect
No alternate, additional or improved control measures identified							
Oiled wildlife response - personnel	Level 1/2 Santos personnel trained in OWR. OWR trained personnel mobilised to Darwin within 48 hrs.	In effect	People	Timely access to skilled personnel will enhance the likelihood of success of an OWR.	Provides functionality, availability, reliability, survivability, compatibility and independence	Cost of training and maintaining training	In effect
	Level 2 OWR personnel from AMOSC, AMOSC-activated Wildlife Response contractors, and Industry Mutual Aid. Mobilisation of OWR personnel to Darwin will start to occur in 24-48 hours following notification of actual or imminent impact to wildlife.	In effect	People	Timely access to skilled personnel will enhance the likelihood of success of an OWR.	Provides functionality, availability, reliability, survivability, compatibility and independence Area for improvement - availability - rapid mobilisation of personnel in initial 48 hours of incident	Cost of membership with AMOSC	In effect
	Level 3 OWR personnel available through OSRL. OSRL staff initial 5 technical advisors available in Darwin from 2 to 3 days of activation, remaining personnel available from 4 to 5 days, subject to approvals/ clearances.	In effect	People	Access to skilled personnel will enhance the likelihood of success of an OWR.	Provides functionality, availability, reliability, survivability, compatibility and independence Area of improvement; none identified	Cost of membership with OSRL	In effect
	Maintain labour hire arrangements for access to untrained personnel. Untrained personnel accessed through labour-hire arrangements would receive an induction, on-the-job training and work under the supervision of an experienced supervisor.	In effect	People	During a large scale OWR the ability to access large numbers of personnel through labour hire arrangements is imperative in terms of capability for conducting an OWR.	Provides functionality, availability, reliability, survivability, compatibility and independence	Cost of labour hire at time of incident	In effect

	Additional Santos OWR trained personnel positioned in Darwin	Additional	People	Additional personnel trained in OWR will enhance the first strike capability of Santos and therefore enhance the likelihood of success of the OWR, particularly for those instances where oil is ashore within 48 hours	Improved functionality, availability, reliability and independence.	Cost of training staff	Reject Santos has recently trained additional staff for OWR. Existing OWR personnel capability meets the need.
	Prehire and/or prepositioning of staging areas and responders	Additional	System	This may enhance response times and first strike capability and hence improve the likelihood of success of the OWR. Conversely, prepositioned personnel and staging areas may result in negative impacts to the environment and wildlife.	Improved functionality, availability, reliability and independence.	Additional wildlife resources could total $1500 per operational site per day. This is a guaranteed cost regardless of whether a spill occurs or not.	Reject- the cost of setting up staging areas and having responders on standby is considered disproportionate to the environmental benefit gained. Further, prepositioned personnel and staging sites may have negative impacts on the environment and wildlife. The overall OWR capability Santos can access through Santos staff, AMOSC, AMOSC mutual aid, Santos labour force hire arrangements, DBCA and wildlife carer network are considered adequate, with further advice and international resources available through OSRL.
	Direct contracts with service providers	Alternative	System	This option duplicates the capability accessed through AMOSC and OSRL and would complete for the same resources without providing a significant environmental benefit	Does not improve effectiveness	Cost of contract	Reject- this option is not adopted as the existing capability meets the need.

Strategy	Control Measure	Alternative, Additional, Improved	Control Measure Category	Environmental Outcome	Effectiveness	Feasibility	Accept/ Reject
Waste Management	Waste management sourced through contract with waste service provider. Contract with waste service provider to be maintained and periodically reviewed. Waste service provider waste receptacles mobilised to Darwin within 12 hrs of activation for containment and recovery, protection and deflection and shoreline clean-up response strategies.	In effect	System	Timely and efficient handling of waste will reduce environmental impacts of waste and waste management. Consideration given to risks of secondary contamination.	Provides functionality, availability, reliability, survivability, compatibility and independence. Area of improvement; none identified	Cost of contract	In effect
	Maintain contracts with multiple service providers to cover new geographic location	Additional	System	Contract with existing waste service provider not sufficient to cover new geographic region (NT) as they are not located in Darwin and may not be able to service the location within the required timeframe	Improves functionality, availability, reliability, survivability, compatibility and independence.	Additional cost in maintaining two contracts for the same service	Accepted
	Temporary waste storage capacity available through waste service provider, AMOSC, AMSA, OSRL stockpiles	In effect	Equipment	Timely and efficient handling of waste will reduce environmental impacts of waste and waste management. Consideration given to risks of secondary contamination.	Provides functionality, availability, reliability, survivability, compatibility and independence. Area of improvement; none identified	Costs of contracts, MOU with waste service provider, AMOSC, OSRL, access to National Plan Resources through AMSA	In effect
	Procure temporary waste storage for Santos stockpile	Additional	Equipment	Additional storage available if required. Tanks may be stored in geographic locations that may reduce mobilisation times and allow faster collection and storage of waste. Additional storage may facilitate continuous collection operations to occur.	Provides functionality, availability, reliability, survivability, compatibility and independence	Additional cost in purchase and maintenance of tanks	Reject Purchasing this equipment for Santos stockpile is surplus to Santos requirements as AMOSC, AMSA, OSRL provides this equipment in strategic locations. Reduced mobilisation time is not an advantage, as waste storage can be mobilised at the same time as collection response strategies, and no waste needs to be stored prior to collection commenced.
	Vessels for waste transport through Santos contracted providers.	In effect	Equipment	Timely and efficient handling of waste will reduce environmental impacts of waste and waste management. Consideration given to risks of secondary contamination.	Provides functionality, availability, reliability, survivability and compatibility. Area of improvement; dependence and availability of vessels	Contract with vessel contractors to be maintained and periodically reviewed	In effect
	Contract additional vessels on standby for waste transport	Additional	Equipment	Reduce delays in transportation of wastey in the initial 2-5 days of response	Provides functionality, availability, reliability, survivability, compatibility and dependence	Cost in contracting vessels to remain on standby for incident waste requirements	Reject Expense of maintaining vessels on standby that are surplus to day to day requirements is disproportionate to environmental benefit. Santos is accustomed to coordinating logistics for tasks around finite resources. Santos monitors vessel availability through Santos Vessel Tracking System. Regularly contracted vessels could be supplemented with vessels of opportunity
	Vessel to vessel waste transfer plan to give details of waste storage requirements and procedures	In effect	Procedure	Allows effective use of available vessels and minimises vessel decontamination requirements	Provides functionality, availability, reliability, survivability, compatibility and independence.	Cost of documentation development, implementation, maintenance and exercising	In effect

Strategy	Control Measure	Alternative, Additional, Improved	Control Measure Category	Environmental Outcomes	Effectiveness	Feasibility	Accept/ Reject
Scientific Monitoring - monitoring service provider and equipment	Maintenance of Monitoring Service Provider contract for scientific monitoring services and annual review of standby manual. SMP provider and monitoring equipment mobilised to site within 72 hrs of monitoring plan approval.	In effect	System	This is the main tool for determining the extent, severity and persistence of environmental impacts from an oil spill and allows operators to determine whether their environmental protection outcomes have been met (via scientific monitoring activities). It is used to inform areas requiring rehabilitation. This strategy also evaluates the recovery from the spill.	Provides functionality, availability, reliability, survivability, compatibility and independence Area of potential improvement; none identified	Cost of contract with Scientific Monitoring Service Provider	In effect
	Regular capability reports from Monitoring Service Provider shows personnel availability and annual reviews of standby manual	In effect	System	This ensures the Monitoring Service Provider has the capability to undertake Scientific Monitoring, including, post-spill preimpact surveys within the EMBA of receptors with deficient baseline data	Improves functionality, availability and reliability	Cost of contract with Scientific Monitoring Service Provider	In effect
	Conduct periodical review of existing baseline data sources across the Santos combined EMBA	In effect	System	This ensures that receptors within the EMBA with deficient baseline data are identified	Improves functionality and provides compatibility	Cost of contract with Scientific Monitoring Service Provider	In effect
	Maintain equipment list and list of suppliers for implementation of Scientific Monitoring Plans	Improved	Procedure	Improve response time	Improved functionality, availability and reliability	Cost of contract with Scientific Monitoring Service Provider	Accept
	Purchase of oil sample kits for scientific monitoring personnel to be positioned at Darwin	Improved	Equipment	Improve response time	Improved availability and reliability	Cost associated with purchase of equipment and maintenance	Accept
Scientific Monitoring - vessels	Level 2: vessels sourced through Master Service Agreement, located in region and tracked by Santos Vessel Monitoring System. Santos to mobilise monitoring vessels to deployment location within 72 hrs.	In effect	Equipment	Improve response time	Provides availability and reliability	Effort associated with maintaining MSA	In effect
	Level 3: vessels sourced without existing contracts from any location	In effect	Equipment	Reduce the volume of surface hydrocarbons to reduce contact with protection priorities.	Provides survivability, compatibility and independence. Area of improvement; functionality, availability and reliability of tow vessels.	Cost of contracts at the time of requirement.	In effect

	Required vessel specifications included in Vessel Tracking System	Improved	Procedure	Improve mobilisation time	Improved availability and reliability	Cost to maintain and operate vessel tracking system	Accept
Scientific monitoring - personnel	Scientific monitoring personnel and equipment on standby at Darwin	Additional	Personnel, equipment	Improve mobilisation time	Improved availability and reliability	The cost of training and employing dedicated pre-positioned monitoring personnel is disproportionate to the potential benefit	Reject - Cost of permanently employing personnel is grossly disproportionate to benefits of availability in initial phase of response.
	No alternate, additional or improved control measures identified						

6 References

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