Sasanof-1 Drilling Program
Operational and Scientific Monitoring Plan

Prepared for
Western Gas Corporation Pty Ltd

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Abbreviations

Abbreviation	Definition
ALARP	As low as reasonably practicable
AIMS	Australian Institute of Marine Science
AMP	Australian Marine Park
AUV	Autonomous underwater vehicles
BIA	Biologically Important Area
DBCA	Department of Biodiversity, Conservation and Attractions
DIMT	Drilling Incident Management Team
DPIRD	Department of Primary Industries and Regional Development
DAWE	Department of Water, Agriculture and Environment
EMBA	Environment that May be Affected
EP	Environment Plan
HEA	Hydrocarbon Exposure Area
IAP	Incident Action Plan
KEF	Key Ecological Features
LC	Logistics Chief
LOWC	Loss of well control
MC	Monitoring Coordinator
MES	Monitoring, evaluation and surveillance
MODU	Mobile Offshore Drilling Unit
OC	Operations Chief
OM	Operational Monitoring
OMP	Operational Monitoring Plan
OPEP	Oil Pollution Emergency Plan
OSMP	Operational and Scientific Monitoring Plan
OST	Oil Spill Trajectory
PSZ	Petroleum Safety Zone
ROV	Remotely operated vehicles
SBRUV	Stereo-baited remote underwater video
SM	Scientific Monitoring
SMP	Scientific Monitoring Plan

Table of Contents

List of Figures

List of Tables

List of Appendices

1 Introduction

1.1 About the Operational and Scientific Monitoring Plan

Western Gas Corporation Pty Ltd (Western Gas) is planning to drill the Sasanof-1 exploration well in Exploration Permit WA-519-P. located in Commonwealth Waters in the Carnarvon Basin, offshore Western Australia (the Project). Western Gas is planning a well drilling campaign to commence in Q1/Q2 2022, however due to mobile offshore drilling unit (MODU) availability could occur any time between Q1 2022 and Q4 2023, with an approximate duration of 25 days. This Operational and Scientific Monitoring Plan (OSMP) has been designed as part of an integrated package of the environmental management documentation that includes the Environment Plan (EP) (Western Gas 2021) and the Oil Pollution Emergency Plan (OPEP). The OSMP is informed by the EP through the identification of the sensitive receptors in the field operating environment that could be impacted during an oil spill.

The OSMP covers Scenario 1 as outlined in the Equus Gas Project spill modelling (RPS Group 2020) in which there is no oil contact with shoreline. The OSMP is consistent with the requirements of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009, the Operational and Scientific Monitoring Programs Information Paper (National Offshore Petroleum Safety and Environmental Management Authority 2020) and the Oil Pollution Risk Management Guidance Note (National Offshore Petroleum Safety and Environmental Management Authority 2021). The OSMP was also developed with consideration of the Australian Petroleum Production & Exploration Association (APPEA) Draft Joint Industry Operational and Scientific Monitoring Plan Framework (Australian Petroleum Production & Exploration Association 2019).

1.2 Aims

The aims of this OSMP are to provide details that explain:

a) A description of the environmental receptors based on the spill trajectory modelling.

b) A description of operational monitoring rationale, objectives, and the initiation and termination of the individual operational monitoring plans.

c) A description of how the initiation of scientific monitoring will be informed by operational monitoring.

d) Description of best practice guidance for scientific monitoring design, sampling technique and reporting requirements, including:

    a. Monitoring objectives.

    b. Monitoring parameters.

    c. Initiation and termination criteria.

e) Resources recommended to ensure that the scientific monitoring program can be implemented and the objectives and performance outcomes can be met.

2 Operational and Scientific Monitoring

A two-class monitoring nomenclature has been developed in Australia, and is defined according to the primary objectives of the monitoring program:

- Operational monitoring (OM) provides information of direct relevance to spill response operations through the implementation of operational monitoring plans (OMPs); and
- Scientific monitoring (SM) relates to non-response objectives and includes short term environmental damage assessments, longer-term damage assessments (including recovery), purely scientific studies and all post spill monitoring activities through Scientific monitoring plans (SMPs).

The OMPs summarise generally accepted monitoring methods used to inform response operations and determine potential oil spill and response strategy impacts on habitats or species within the environment. The monitoring methods are those most appropriate given the available baseline data and based on current best practice. Methods are flexible so that a given contractor has some flexibility and can adapt to the given conditions.

Given the low likelihood and unpredictable nature of an oil spill incident, it is very unlikely that one pre-established design for SM will be appropriate for all scenarios. Instead, monitoring will require an adaptive approach which employs previous baseline monitoring, new post-spill data, spatial control sites, and wherever possible, post-spill pre-impact data. A framework has been described in Section 2.1 in order to execute monitoring plans, and apply methodologies which have the highest likelihood of identifying significant environmental impacts and consequent recovery where they occur. General monitoring designs are described in detail in Appendix B.

Both operational and scientific monitoring are required to best inform response activities, and allow further decisions to be made in as near as real time as possible (Hook et al. 2016). With this aim, Appendix B highlights the most important approaches to statistical analysis.

2.1 Scientific Monitoring Methods

In the event of an oil spill the monitoring design will depend upon the nature of the spill, the availability of baseline data in relation to the spill extent and the expert opinion of those brought to the field. In order to ensure the application of robust designs and sampling approaches which have the highest likelihood of detecting an environmental impact while allowing suitable flexibility, this plan provides a set of Guiding Principles for monitoring design and sampling (Table 1). A framework for allocating monitoring effort in both time and space is described in Figure 1. In an ideal design sampling would occur across a gradient of exposure rather than “impact” and “control” per se.

Table 1: Guiding principles for hydrocarbon spill monitoring design and methodologies.

Principle	Explanation	Key guiding references
Match baseline	Designs and methodologies should follow those used in appropriate baseline studies wherever possible.	N/A
Comprehensive sampling	Sampling methods should seek to sample the full range of taxa within each assemblage. This may require the use of several complimentary techniques. (The exception is if indicator taxa are employed; see below)	N/A

Principle	Explanation	Key guiding references
Reliable indicator taxa	If indicator taxa are targeted then the choice of indicator should be defensible, and a link to the response of the broader assemblage demonstrated. Indicators of ecosystem function should also be considered.	(Hilty and Merenlender 2000) (English et al. 1997)
Appropriate sample area or volume	Size of sampling unit should be determined based on the level of clustering of individuals and whether the goal is to quantify this clustering, or establish low inter-sample variability (probably more the latter for oil spill studies).	(Kenkel N.C et al. 1989)
Reduce within sample variation over time	Wherever possible repeated measures are carried out on the same sample space in order to reduce within treatment variation.	N/A
Compositing of samples	Appropriate compositing to increase statistical power should be considered	(Carey and Keough 2002)
Account for environmental gradients and partition variations	Sources of variation are considered and compartmentalised to best reduce within treatment variation, and thereby maximise power to detect an impact. This is managed through several means: 1. Environmental covariates are considered in sampling design recorded and incorporated statistically. 2. A hierarchical or stratified sampling design is used to address variation at multiple scales 3. Design is standardized, by sampling equivalent strata (e.g., level of exposure, depth etc.).	(Snedecor and Cochran 1989, English et al. 1997)
Assess statistical power	Where null-hypothesis tests are planned, statistical power of the design is assessed prior to execution.	(Toft and Shea 1982, Gerrodette 1987, Legg and Nagy 2006)
Appropriate sampling extent	Sample the range of hydrocarbon concentration (and at least the upper end).	(Skalski 1995)
Independence amongst samples.	Site selection should aim for independence amongst samples and potential spatial or temporal autocorrelation should be considered.	(Hurlbert 1984)
Reduce observation error	Observer bias and amongst observer variation should be considered.	(Thompson and Mapstone 1997)
Appropriate spatial replication	Sites are replicated. (A limitation is that there is only one spill, but control sites should be replicated and spatially Interspersed). Ideally, the design should be able to detect an impact at several possible scales.	(Underwood 1991, 1992, 1994)
Appropriate temporal replication	Sampling should account for natural temporal variation.	(Underwood 1991, 1992, 1994)

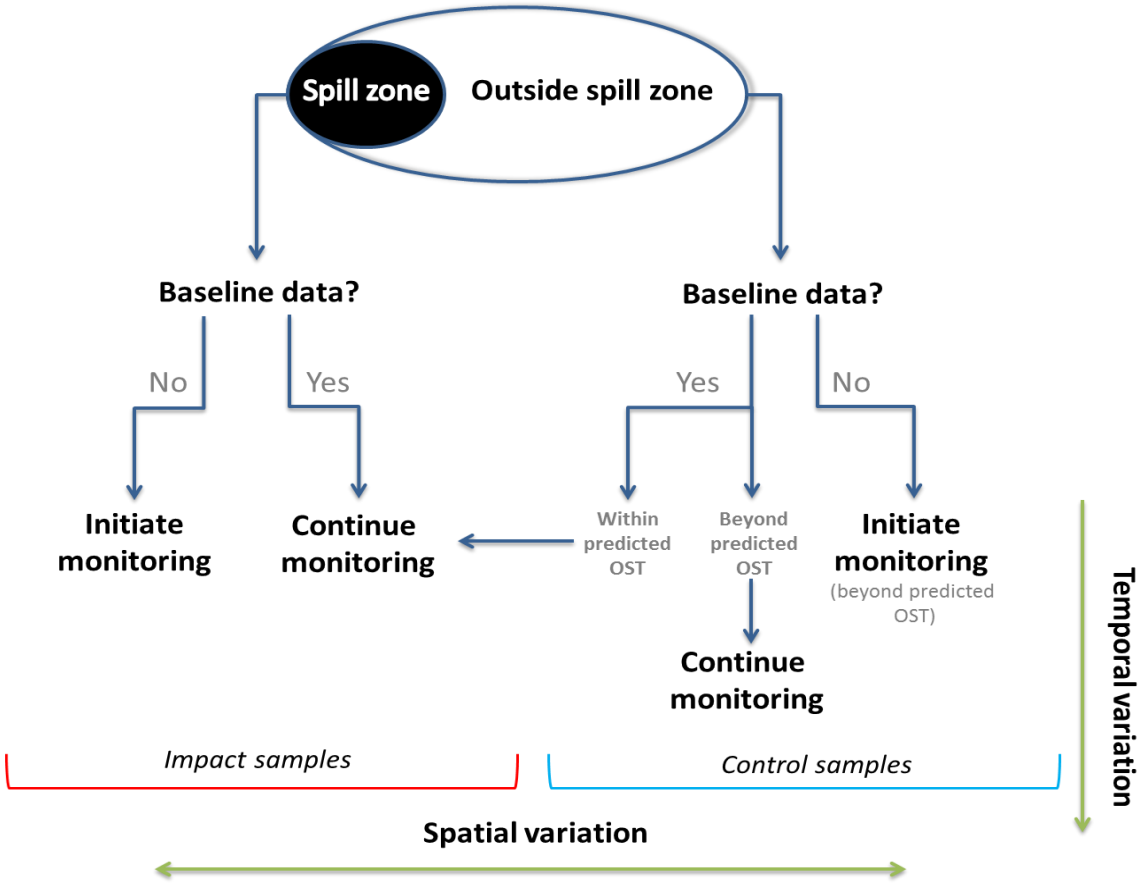

Figure 1: The decision making process in reference to monitoring programs, the availability of baseline data, and oil spill trajectory (OST).

3 Description of Activities and Sensitive Receptors

3.1 Description of Activities

The petroleum activity will be undertaken within Exploration Permit WA-519-P, in the Carnarvon Basin off Western Australia's north-west coast. One exploration well, Sasanof-1 will be drilled in Commonwealth waters, in water depth of approximately 1070 m. The Operational Area for the exploration drilling activity encompasses the 500 m petroleum safety zone (PSZ) around the MODU and support activities such as anchoring and resupply, which typically occur within 3 km of the well location. A conservation boundary of 5 km around the well location has been defined as the Operation Area. Drilling activities are planned to commence in Quarter 1 or Quarter 2 in 2022, however, due to MODU availability, drilling could occur between Quarter 1 2022 and Quarter 4 2023. Drilling activities are expected to take approximately 25 days. Further detail regarding the hydrocarbon characteristics and drilling activities are described in the EP (Western Gas 2021).

3.2 Impact and Risk Assessment Process

Project specific technical data, industry experience, modelling and published studies were used to determine the temporal and spatial characteristic of environmental aspects. This formed the basis of the environmental impact assessment. Further details of the impact and risk assessment process are described in Sections 2 of the EP (Western Gas 2021).

Western Gas identified the potential maximum credible spill scenario associated with the Sasanof-1 Exploration Drilling to the be the loss of well control (LOWC). The LOWC scenario is considered the worst-case scenario for an accidental release of reservoir hydrocarbons and is therefore representative of the greatest spatial extent of potential impacts. Therefore, the LOWC scenario is used for the purposes of impact assessment and spill modelling.

3.3 Environment that May Be Affected (EMBA)

The EP defines the following project areas (Figure 2):

- Operational Area – the area within which impacts from planned activities will occur, defined as 5 km from the well location.
- Hydrocarbon Exposure Area (HEA) – the largest area within which hydrocarbon exposure will be moderate and may result in impacts to fauna.
- Environment that May be Affected (EMBA) – the area within which a change in ambient environmental conditions could occur – this is determined by the extent of hydrocarbon exposure at low levels.

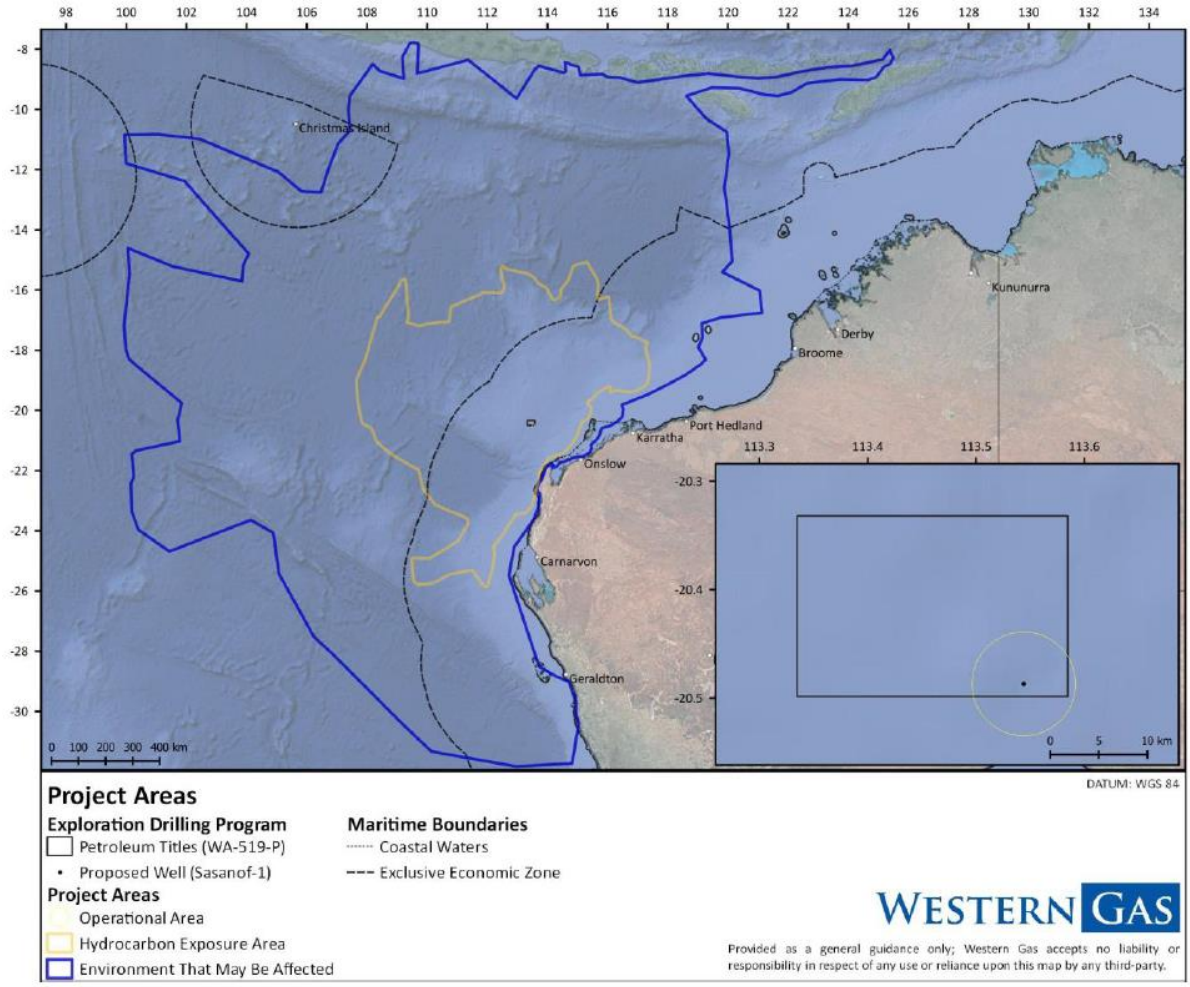

Figure 2: Project areas relevant to the Sasanof-1 Exploration Drilling.

The results of the stochastic modelling undertaken (RPS Group 2020) is presented in the EP (Western Gas 2021). In summary, no shoreline contact was predicted, consequently no shoreline contact results are presented. No dissolved hydrocarbon exposure was predicted above the low threshold (10 ppb) in the top 30 m of the water column, consequently no dissolved hydrocarbon results are presented.

3.4 Key Environmental Sensitivities

The presence of key environmental sensitivities that are potentially impacted by unplanned activities is summarised in Table 2 and the proposed OMPs and SMPs that are relevant to the drilling activities and sensitive receptors identified are provided in Table 3.

Table 2: Key environmental sensitivities in the unplanned activity project areas.

Receptor	Hydrocarbon Exposure Area	EMBA	OMP/SMP
Physical Environment			
Water quality	High quality – typical of the offshore, unpolluted tropical marine environment.	High quality – typical of the offshore, unpolluted tropical marine environment.	OMP-5 SMP-1 SMP-2
Sediment quality	High quality – typical of deep-water, offshore marine environment.		OMP-6 SMP-1 SMP-3
Ecological Environment			
Benthic habitats and communities	• Unvegetated soft sediments are a widespread habitat in both intertidal and subtidal areas, particularly in areas beyond the photic zone. • Variable biodiversity and productivity, depending upon depth, light, temperature and the type of sediment. Shallower waters contain reefs, including Ningaloo.	Not relevant	OMP-6 SMP-2 SMP-4
Coastal habitat and communities	No coastal habitats and communities within the HEA.	A range of coastal habitats exist typical of the region, including shorelines rocky, sandy and tidal flats.	n/a
Plankton	• Low/medium productivity – typical of the NWMR, however, higher productivity resulting from nutrient rich waters of the Exmouth Plateau. • Offshore phytoplankton communities characterised by smaller taxa, while shelf waters are dominated by larger taxa.	Not relevant	OMP-5 SMP-1 SMP-2
Birds	Listed Threatened (16); curlew sandpiper (Critically Endangered (CE)), Northern Siberian bar-tailed godwit (CE), eastern curlew (CE), red knot (Endangered (E)), Australian painted -snipe (E), southern giant petrel (E), Abbott's booby (E), shy albatross (E), Australian lesser noddy (Vulnerable (V)), soft-plumaged petrel (V), northern giant petrel (V), Australian fairy tern (V), Indian yellow-nosed albatross (V), white-capped albatross (V), Campbell albatross (V), black-browed albatross (V). Listed Migratory Marine (16). Listed Migratory Wetland (9). Listed Marine (30). Biologically Important Areas (BIA) (5): wedge-tailed shearwater breeding and foraging, roseate tern breeding, sooty tern foraging, fairy tern breeding, lesser crested tern breeding.	Not relevant	OMP-7 SMP-5

Receptor	Hydrocarbon Exposure Area	EMBA	OMP/SMP
Fish and sharks	Listed Threatened (5); white shark (V), whale shark (V), grey nurse shark (V), dwarf sawfish (V), green sawfish (V). Listed Migratory Marine (11). BIAs (1): whale shark foraging.	Not relevant	OMP-7 SMP-8 SMP-9
Marine mammals	Listed Threatened (5): blue whale (E), southern right whale (E), sei whale (V), humpback whale (V). Listed Migratory Marine (12). Listed Marine (33). BIAs (3): pygmy blue whale migration, humpback whale migration, dugong.	Not relevant	OMP-7 SMP-7
Marine reptiles	Listed Threatened (7): short-nosed seasnake (CE), leaf-scaled seasnake (CE), loggerhead turtle (E), leatherback turtle (E), green turtle (V), hawksbill turtle (V), flatback turtle (V). Listed Migratory Marine (5). Listed Marine (22). BIAs/habitat critical (4): loggerhead – internesting, nesting; green – aggregation, basking, foraging, internesting, nesting, mating; hawksbill – foraging, internesting, nesting, mating; flatback – aggregation, internesting, nesting, foraging, mating.	Not relevant	OMP-7 SMP-6
Socio-Economic Environment			
Key Ecological Features (KEF)	8 KEFs	16 KEFs	SMP-2 SMP-3 SMP-4 SMP-8
Australian Marine Parks (AMP)	6 AMPs	11 AMPs	SMP-4 SMP-8 SMP-9
State Protected Areas – Marine	1 State Marine Protected Area.	12 State Marine Protected Areas.	SMP-2 SMP-3 SMP-4 SMP-8 SMP-9
State Protected Area – Terrestrial	No State Terrestrial Protected Areas.	11 State Terrestrial Protected Areas.	n/a
Commercial Fisheries and Aquaculture	5 Commonwealth Commercial Fisheries permit areas. 14 State Commercial Fisheries.	5 Commonwealth Commercial Fisheries permit areas 25 State Commercial Fisheries Traditional Indonesian fishing MoU Browse Island	SMP-8 SMP-9

Receptor	Hydrocarbon Exposure Area	EMBA	OMP/SMP
Defence	Marine interface for the Learmonth Air-to-Air Weapons Range.	Marine interface for the Learmonth Air-to-Air Weapons Range.	n/a
Marine Industry (Petroleum and Shipping)	6 other petroleum facilities. Commercial shipping lanes in east portion. 2 submarine cables.	14 other petroleum facilities. Commercial shipping lanes transect east portion. 2 ports and 2 submarine cables.	n/a
Tourism and Recreation	Following activities may occur: recreational fishing, charter vessel tours, cruises, recreational diving, snorkelling, and other nature-based activities.	Following activities may occur: recreational fishing, charter vessel tours, cruises, recreational diving, snorkelling, and other nature-based activities.	SMP-4 SMP-7 SMP-8 SMP-9
Heritage and Cultural Values	1 World Heritage listed location. 1 National Heritage listed location. 1 Commonwealth Heritage listed location. 2 Underwater Cultural Heritage features.	1 World Heritage listed location. 3 National Heritage listed locations. 2 Commonwealth Heritage listed locations. 2 Underwater Cultural Heritage features.	n/a

Table 3: Western Gas operational and scientific monitoring programs included in the OSMP.

Operational Monitoring Components	
OMP-1	Operational forecast modelling
OMP-2	Desktop pre-emptive assessment of receptors at risk
OMP-3	Hydrocarbon spill surveillance and tracking
OMP-4	Hydrocarbon characterisation and weathering assessment
OMP-5	Water quality assessment
OMP-6	Sediment quality assessment
OMP-7	Marine fauna surveillance
Scientific Monitoring Components	
SMP-1	Ecotoxicology assessment of hydrocarbons
SMP-2	Water quality monitoring
SMP-3	Sediment quality monitoring
SMP-4	Benthic habitat monitoring
SMP-5	Seabirds population monitoring
SMP-6	Marine mega-fauna (reptiles) monitoring
SMP-7	Marine mega-fauna (mammals) monitoring
SMP-8	Marine fish assemblage monitoring
SMP-9	Fisheries monitoring

4 Integration of Operational and Scientific Monitoring

4.1 Roles and Responsibilities

Roles and responsibilities and competency requirements of personnel involved in the OSMP implementation are described in Table 4 and Table 5.

Table 4: Roles and responsibilities of the monitoring team.

Position	Responsibilities
Western Gas Planning Section Chief (PSC)	• Overall responsibility for the OSMP. • Determines the requirements for operational and scientific monitoring in consultation with Drilling Incident Management Team (DIMT) and scientific monitoring external service providers. • Initiates monitoring based on triggering of initiation criteria. • Terminates studies where criteria met based on consultation with DIMT. • Recommendations of MC and advice of SAG as relevant.
AGR HSE Manager	• Ensures adequate resourcing of OSMP through external service providers, SAG and EA. • Oversees HSE planning for scientific monitoring studies/activities. • Ensures EUL, EA and MC have undertaken OSMP induction prior to drilling campaign.
Western Gas Environment Coordinator (EC)	• Notifies service providers to implement study if initiation criteria triggered. • Communicates to PSC monitoring outcomes, or other environmental issues as reported by MC, during incident response. • Ensures operational monitoring results or other relevant spill/response information communicated to MC.
Western Gas Environment Manager (EM)	• Assumes responsibility for scientific studies after DIMT stand-down. • Oversees initiation or refinements to studies triggered after DIMT stand down (e.g. Hindcast Modelling). • Reviews and approves Annual and Final reports. • Periodic internal review of conformance to OSMP. • Compliance interface with NOPSEMA Environment Division.
Monitoring Coordinator (MC) (external service provider)	• Oversees all the scientific monitoring studies/activities. • Ensures TL's have undertaken OSMP induction prior to drilling Campaign. • Scientific monitoring service providers' main focal point to EUL/EA. • Provides recommendations to Western Gas regarding scientific monitoring including whether termination criteria have been satisfactorily met.
Planning and Logistics Officer (PLO) (external service provider)	• Implementation of response activation under direction from the MC. • Oversees mobilisation of Monitoring Personnel (MP), equipment and plant to site upon activation. • Planning and coordination of monitoring study with assistance from TL. • Coordinate demobilisation (MP, plant, equipment) and project close-out (Final Report, archiving data).

Position	Responsibilities
Operations Officer (OO) (external service provider)	• Responsible for implementing decisions on resource allocation in consultation with the TL and PLO. • Advises on allocation of resources and the locations at which they are required. • Reports to the MC.
Technical Lead (TL) (external service provider)	• Oversees data collection and analysis of a specific monitoring study. • Planning of monitoring study particularly scientific design and preparation of monitoring action plan, including incorporation of relevant environmental controls from EP. • QA/QC of field (or modelling) activities and data analyses. • Review and approval of a study's reporting requirements. • Advise EA via the MC with respect to environmental issues as required.
Field Lead (FL) (external service provider)	• Provides support to TL on the field work component. • Leads the field MP during field surveys.
Monitoring Personnel (MP) (external service provider)	• Undertake field monitoring (or modelling) activities as advised by FL/TL. • Perform data analysis and reporting as advised by TL. • Acquire and collate baseline data as advised by TL. • Store and archive data. • Report all environmental incidents during field monitoring activities.
Scientific Advisory Group (SAG)	• External review of scientific monitoring reports. • Provide guidance to Western Gas regarding scientific monitoring including whether termination criteria have been satisfactorily met.

Table 5: Position competency requirements for external service provider personnel.

Position	Minimum Competency Requirement
MC	• Post-graduate qualification in relevant discipline, or Bachelor degree and >15 year's experience in relevant discipline. • Demonstrated capability in coordinating multi-disciplinary scientific monitoring programs.
PLO	• Bachelor degree in relevant discipline >5 years professional environmental experience. • Demonstrated capability in planning and coordinating multi-disciplinary scientific monitoring programs.
OO	• Bachelor degree in relevant discipline >10 years professional environmental experience. • Demonstrated capability in planning and coordinating multi-disciplinary scientific monitoring programs.
TL	• Post-graduate qualification in relevant discipline, or Bachelor degree and >15 year's experience in relevant discipline >10 years professional environmental experience. • Experience in planning and coordination of environmental monitoring programs.
FL	• Bachelor degree in relevant discipline >5 years professional environmental experience. • Experience leading environmental field studies.

Position	Minimum Competency Requirement
MP	• Bachelor degree in relevant discipline. • Environmental field study and/or data collation/analysis experience. • Specific training/certification as applicable to assigned tasks (e.g. marine mammal identification).

4.2 The Monitoring Team Structure

Both OM and SM are completely integrated into the Western Gas Drilling Incident Management Team (DIMT) to ensure data generated is used either in the response decision-making process for OM or to gauge the impact of the spill/response strategies for SM. Figure 3 shows where the monitoring service provider team sits in the Environment Unit, within the Planning Section of the Western Gas DIMT. The monitoring tasks are undertaken by the Field Monitoring Teams which will fit into the relevant functions in operations as required. This ensures that resources in high demand from Logistics such as vessels and aircraft are used to their full capability wherever possible.

The Astron/BMT (monitoring service provider) organisational structure that will oversee the monitoring response, from pre-planning to recovery phases, is displayed in Figure 4. Roles include:

- A Monitoring Coordinator (MC) oversees all activities at all stages with respect to standby and any response that may be required. A critical function of the MC is to be the single point of contact between the Western Gas DIMT and the Monitoring team.
- An Operations Officer, reporting to the MC, responsible for liaison with the Western Gas DIMT Operations Chief (OC) in the event of an incident; specifically to ensure the monitoring tasks can be conducted with the resources available and can integrate wherever possible with response operations.
- A Planning and Logistics Officer, reporting to the MC and liaising closely with the Operations Officer and the Western Gas DIMT Logistics Chief (LC). Key responsibilities include training coordination, communications (inter and intra organisational) and the practicalities of mobilisation and demobilisation of the monitoring team and their resources to and from site.

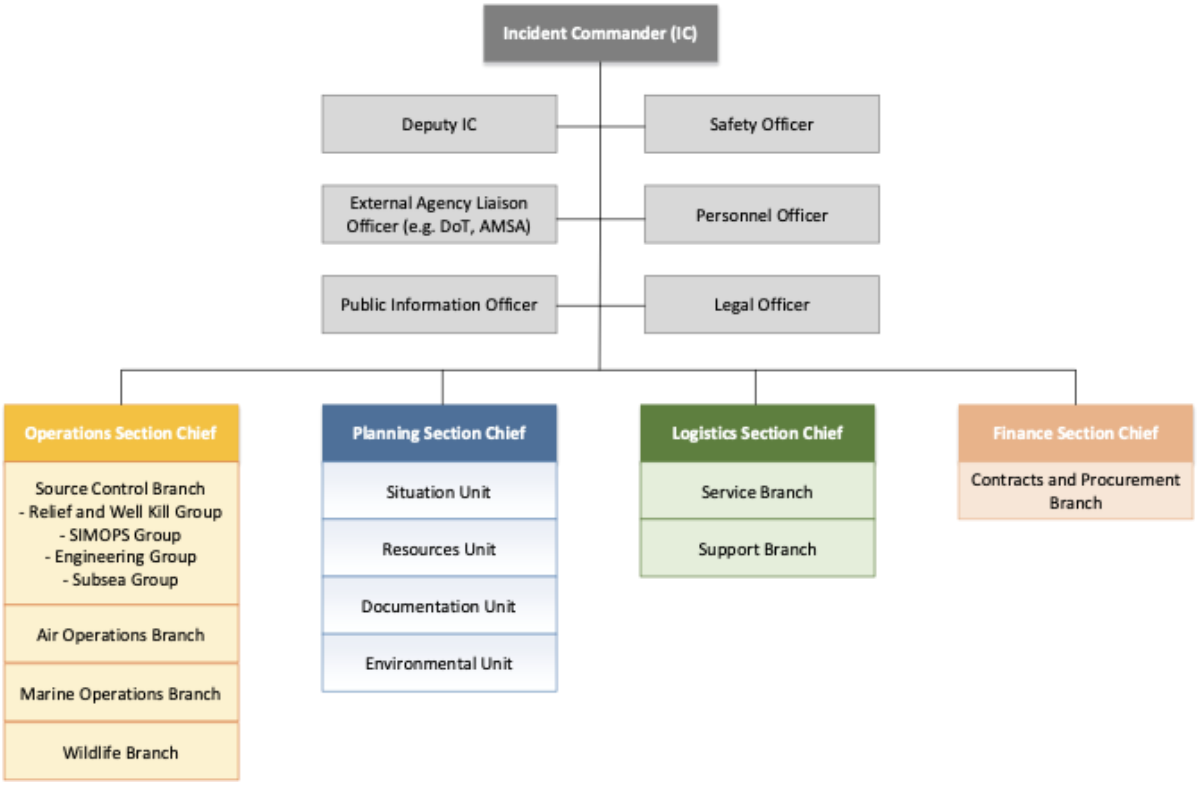

Figure 3: The Western Gas DIMT displaying how monitoring integrates into planning and operations.

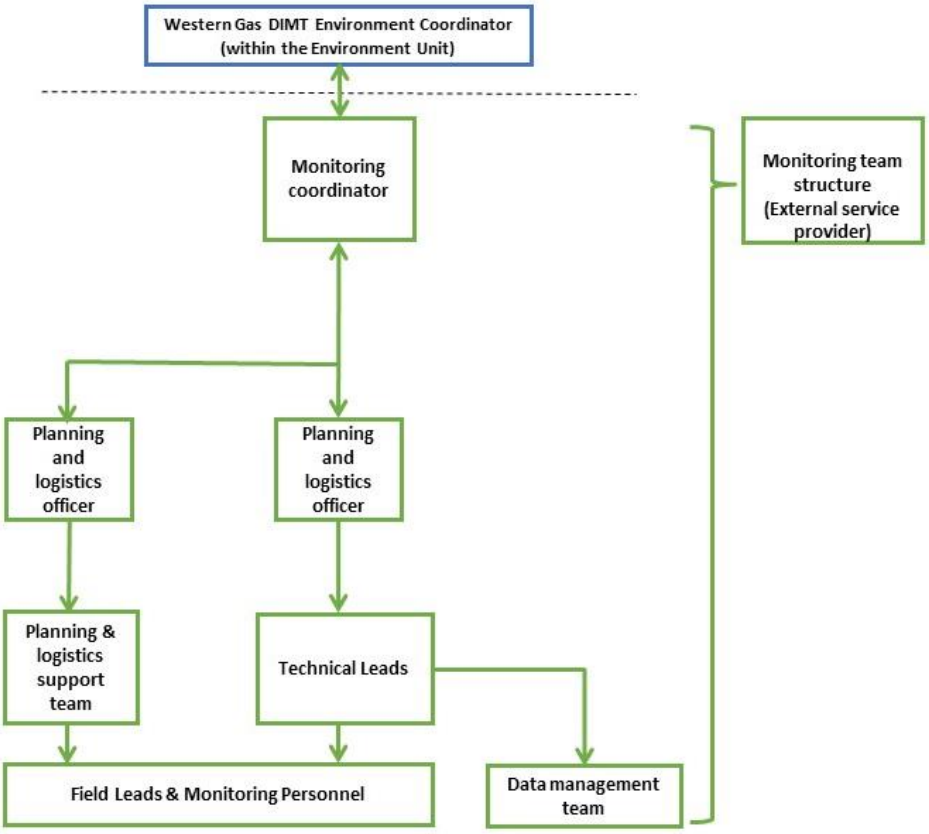

Figure 4: Structure for the monitoring section.

Several teams will be assembled to assist the functions of the key roles listed above or to provide essential resources related to monitoring in the event of a spill. These teams should comprise experienced and qualified personnel. The teams assembled could include:

- The Technical Leads are individuals who oversee and monitor within their area of expertise in the event of a spill.
- The Field Monitoring Team who will be compiled from a pool of trained, experienced and field-ready individuals available to conduct monitoring.
- The Data Management Team, responsible for data management and governance with respect to data collected by the monitoring team, as well as data that needs to be sourced from repositories of existing data that need to be accessed in the event of an oil spill. An additional function of the data management team is to commence analyses, provide results and interpretation.

4.3 Operational Monitoring Informing Response Strategies

The accepted response strategies initiated (Table 7-1 of EP) (Western Gas 2021) require operational monitoring to inform effectiveness and ultimately termination. Table 6 is a matrix showing which OMPs are activated for each oil spill response strategy. Arrangements for in field operational monitoring to inform spill response strategies rely on the effective use of the Western Gas DIMT structure.

The Western Gas DIMT will, as part of the Incident Action Planning (IAP) process, provide for the implementation of OMPs. Data collected through the implementation of the OMPs is communicated back to the Western Gas DIMT via reporting forms, debriefs and reports (such as laboratory or OSTM reports). It is then the responsibility of the Western Gas DIMT to evaluate the information collected to determine if the response strategies can be terminated or if controls need to be put in place to manage impacts of the response activities.

Table 6: Matrix of OMPs activated for each acceptable response strategy.

Response strategy	OMP-1	OMP-2	OMP-3	OMP-4	OMP-5	OMP-6	OMP-7
Source control (Tier 3 spill)	x		x	x	x	x	
Monitor and evaluate (Tier 2 & 3 spill)	x		x	x	x	x	x
Oiled wildlife response (Tier 3 spill)	x	x	x			x	x
Waste management (Tier 3 spill)	x		x	x	x	x	x
OMP-1 – Operational forecast modelling *OMP-2 – Desktop pre-emptive assessment of sensitive receptors at risk* *OMP-3 - Hydrocarbon spill surveillance and tracking* *OMP-4 – Hydrocarbon characterisation and weathering assessment* *OMP-5 – Water quality assessment* *OMP-6 – Sediment quality assessment* *OMP-7 – Marine fauna surveillance*							

4.4 Operational Monitoring Initiating and Informing Scientific Monitoring

Direction of information flow is primarily from operational to scientific monitoring. OM inform the SM receptor studies in terms of their initiation criteria and provision of essential information to guide their deployment. Key information is the location and extent of hydrocarbons (OMP-1, OMP-3, OMP-4), and location and extent of impacted receptors (OMP-2, OMP-5, OMP-6, OMP-7).

OM will also provide the location of non-impacted receptors, where spill impact is imminent (>= 3 days to impact) in order to establish post spill pre impact control samples and location of sites and receptors predicted to remain un-impacted which would form spatial controls. SM is used to quantify the effectiveness of associated response strategies. This information will also be provided by the Monitoring Coordinator (MC) to the Western Gas DIMT.

Figure 5 shows how the information from OM that is used for operational decision-making, can trigger the termination of response strategies and also potentially activates SM. The tables throughout this plan reference the specific triggers for each response strategy, OM and SM values in more detail, and include how they are informed by one another.

Appendix A provides an example of the timeframe in which OM and SM activities may be implemented and the subsequent links between the two activities.

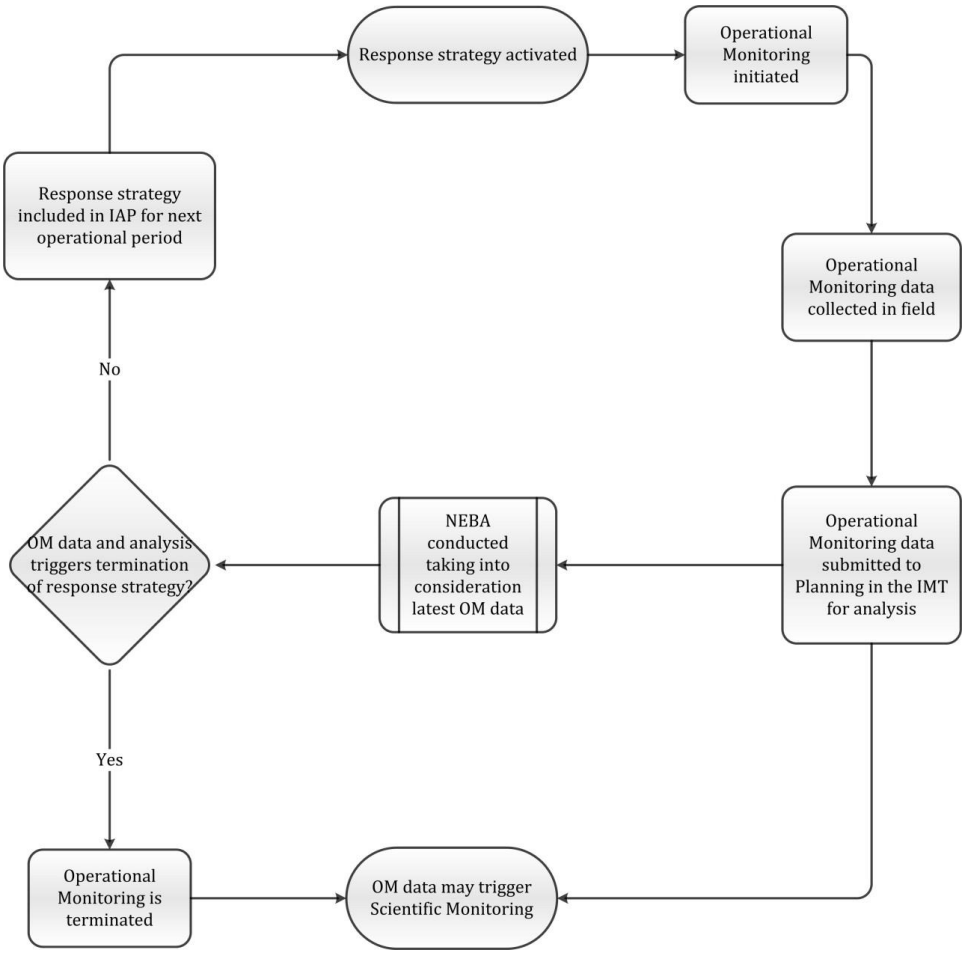

Figure 5: The information flow for operational and scientific monitoring in the planning process.

5 Logistics

5.1 Plant and Equipment

Monitoring personnel will carry out field activities from aircraft and vessels in the vicinity of the hydrocarbon source/spill during a Tier 2 or 3 incident. Aircraft and vessels will be arranged and contracted by Western Gas.

Generally, the recommended specifications for the vessels include:

- Accommodate a minimum of 6 people
- GPS unit for locating the survey locations with 2 m accuracy
- Accurate depth sounder/sonar
- Reliable communication devices suitable for areas of operation including facility for data transmission (e.g. satellite if offshore)
- Minimum cruising speed of 15 knots
- Minimum fuel capacity of 48 hours at 15 knots
- Minimum freshwater capacity of 2,000 L.

Additional specifications are detailed in the OMPs (Section 6) and SMPs (Section 7).

The aircraft to be used for aerial surveys should be able provide good downward visibility (e.g. fixed wing aircraft with an over-fuselage wing or helicopters).

5.2 Field Logistics

All field logistics in regards to survey timing, scheduling and scope are subject to safe operating conditions in accordance with Western Gas (and/or their contractors) environment, health and safety policies.

Survey scheduling (in terms of locations and sampling order) will be at the discretion of the Western Gas PSC in consultation with the external monitoring provider, taking into account existing and predicted hydrocarbon distributions, proximity to environmental sensitivities, baseline data availability, logistics and forecasted weather/sea state conditions.

An indicative logistics plan and survey schedule based on deterministic modelling undertaken by RPS (2020) is provided in Table 7 to facilitate rapid mobilisation of the OSMP in the event of an unplanned hydrocarbon release.

Table 7: Indicative logistics plan and survey schedule for the first year.

Study ID			OMP-4	OMP-5	OMP-6	OMP-7	SMP-1	SMP-2	SMP-3	SMP-4	SMP-5	SMP-6 and SMP-7	SMP-8	SMP-9
Study Descriptor			Hydrocarbon characterisation/ weathering	Water quality	Sediment quality	Marine Fauna	Ecotoxicology	Water quality	Sediment quality	Benthic habitat	Seabirds	Marine mega-fauna (reptiles and mammals)	Marine fish assemblage	Fisheries
Service Provider			BMT	BMT	BMT	Astron	BMT	BMT	BMT	BMT	Astron	Astron	BMT	BMT
Field Team Composition			1 x FL & 1-2 x MP (Scientists with Water quality sampling experience)	2 Teams: 1 x FL & 1-2 x MP (Scientists with Water & Sediment quality sampling experience)	2 Teams: 1 x FL & 1-2 x MP (Scientists with Water & Sediment quality sampling experience)	1 x aerial survey team of 1 FL and 1 MP (experienced wildlife observers). 1 x vessel survey team of 1 FL and 1 MP (experienced wildlife observers).	1 x FL & 1-2 x MP (Scientists with Water quality sampling experience)	2 Teams: 1 x FL & 1-2 x MP (Scientists with Water & Sediment quality sampling experience)	2 Teams: 1 x FL & 1-2 x MP (Scientists with Water & Sediment quality sampling experience)	1x FL& 1-3 MP (with experience in Benthic Habitat assessment.)	1 x FL (experienced ornithologist) 1 x MP (scientist with seabird experience)	1 x aerial survey team of 1 FL and 1 MP (experienced wildlife observers). 1 x vessel survey team of 1 FL and 1 MP (experienced wildlife observers).	1 x FL, 1-2 MP (Experience with SBRUV, fish identification and necropsy)	1 x FL, 1-2 MP (Experience with SBRUV, fish identification and necropsy)
Monitoring Plant			Vessel 1	Vessel 2&3	vessel 2&3	Aircraft 1 + Vessel 6	Vessel 1	Vessel 2&3	Vessel 2&3	Vessel 4	Vessel 5	Aircraft 1 + Vessel 6	Vessel 7	Vessel 8
Day	Week													
0	0	Loss of Well control	Mob	Mob	Mob	Mob	Mob	Mob	Mob	Mob	Mob	Mob	Mob	Mob
7	1													
14	2													
21	3													
28	4													
35	5													
42	6													
49	7													
56	8													
63	9													
70	10													
77	11													
84	12													
91	13													
98	14													
105	15													
112	16													
119	17													
126	18	Impact Surveys (Well Controlled)												
133	19													
140	20													
147	21													
154	22													
161	23													
168	24													
175	25													
182	26													
189	27													
196	28													
203	29													
210	30													
217	31													
224	32													
231	33													
238	34													
245	35													
252	36													
259	37													
266	38													
273	39													
280	40													
287	41													
294	42													
301	43													
308	44													
315	45													
322	46													
329	47													
336	48													
343	49													
350	50													
357	51													

Legend
Vessel 1
Vessel 2
Vessel 3
Vessel 4
Vessel 5
Aircraft 1 + Vessel
Vessel 7

6 Operational Monitoring Plans

6.1 OMP-1 Operational Forecast Modelling

OMP-1 – Operational forecast modelling		
Rationale	Focuses on hydrocarbon spill modelling using computer-based modelling principals, however, both computer based and first principal approaches to predicting movement and weathering of hydrocarbons, lead to effective and timely spill trajectory and weathering, which in turn leads to: • Rapid and often reliable prediction of the speed and direction of movement of hydrocarbons in three dimensions, including their weathering fate; • An indication where hydrocarbons are most likely to occur, providing a focus for on-scene surveillance activities, aerial reconnaissance and other operational monitoring activities; • Guidance on the locations that could be affected by hydrocarbons in the immediate future; • Assistance in the identification of the ecological and socioeconomic resources at risk from the spill and potential environmental impact assessment over the whole area of incident from the first few hours of the incident and throughout the response; and • The selection and ongoing evaluation of response options.	
Objectives	To utilise computer-based and first principal forecasting methods to predict spill movement and guide the management and execution of spill response operations to maximise the protection of environmental and other resources at risk.	
Baseline	• Pre-spill trajectory modelling and analysis (RPS Group 2020). • Met ocean data.	
Initiation criteria	The DIMT has determined that Level 2 or 3 hydrocarbon spill to marine or coastal waters has occurred.	
Termination criteria	This OMP will be terminated when: • Hydrocarbon spill modelling is no longer beneficial to predict spill trajectory and concentrations; or • Agreement has been reached with the Jurisdictional Authority relevant to the spill to terminate the response.	
Tactics	• Visual observation from vessel or facility; • Aerial observation; • Deploy satellite tracking buoy; • Real-time oil spill trajectory modelling; • Satellite imagery; and • Analysis of all surveillance data.	
Indication of resources required	• Suitable aircraft for aerial observation; • Aerial observers (4-5 for rotation work); • Satellite tracking buoy (2 minimum); • OSTM contractor; and • Satellite imagery contractor.	
Possible provider(s) & competencies	• DIMT contracted helicopters. • APASA. • Landgate (Satellite imagery – SAR).	Individuals trained or with experience in relevant tactics they are tasked with e.g. aerial observation training or experience.

OMP-1 – Operational forecast modelling		
	• CSIRO.	Satellite imagery and/or SAR must be analysed by a trained and experienced person/team.
SMP(s) triggered & associated trigger	May trigger all SMPs.	Spill surveillance and tracking identifies oil contact or real-time predicted contact (for pre-impact monitoring) to SMP(s).
Scope of works	Monitor and evaluate response activities. Scope of works prepared within 24 hours of spill having been reported.	
Design considerations	The appropriate design of this monitoring activity will vary between situations depending on: • Size of the spill; • Weathering rate of the oil; • Potential environmental and economic consequences of the spill; • Requirements to test specific response methods that may affect oil or be sensitive to the oil properties; • Requirements to inform the public or other stakeholders; • The availability of human resources, suitable vessels and other logistics; • Capacity for transporting samples from the site (e.g. by helicopter or boat); and/or • Safety considerations.	
Implementation	Implementation of this monitoring program will focus on monitoring effectiveness of the relevant response strategies, given the specifics of the spill and the real-time zone of impact, therefore allowing for any potential impacts of those response strategies complying with ALARP justifications made in the EP.	
Analysis and reporting	• All data collected for spill surveillance and tracking to be analysed within the situation unit to achieve OMP objectives; • All data collected for spill surveillance and tracking to be displayed in the DIMT CC on either status boards or electronic projections; • All data collected to be collated for the PC for integration into the IAP; and • All data collected to be made available to the MC for initiation of the SMP(s) (if applicable).	

6.2 OMP-2 Desktop Pre-emptive Assessment of Receptors at Risk

OMP-2 – Desktop pre-emptive assessment of receptors at risk	
Rationale	Desktop assessment to assist in the development of response priorities: • Sensitive areas to be identified to assess potential impact and effects; and • Potential impact to sensitive areas determines priorities for protection, response or clean-up.
Objectives	To undertake a rapid desktop-based assessment of the presence, extent and current status of sensitive receptors at risk of being affected by a hydrocarbon spill, prior to contact.

OMP-2 – Desktop pre-emptive assessment of receptors at risk		
Initiation criteria	• The DIMT has determined that Level 2 or 3 hydrocarbon spill to marine or coastal waters has occurred; and • A probable hydrocarbon impact (or impact of dispersed hydrocarbon) on a resource, habitat or shoreline is anticipated on the basis of trajectory modelling or other assessment of the incident; or • Damage to a natural resource or sensitive receptor is possible as a result of that impact.	
Termination criteria	• Agreement has been reached with the Jurisdictional Authority relevant to the spill to terminate the response; or • The assessment of sensitive receptors that were identified as being potentially impacted/contact by the hydrocarbon spill are completed. • When the OMP is no longer contributing to or influencing spill response decision making.	
Tactics	• Desktop review of sensitive receptors and locations; and • Assessment of oil spill trajectory modelling based on most recent data.	
Indication of resources required	• Specialist Assessment Team; • GIS specialists; • Computers with internet connectivity, GIS software and the Microsoft suite of products; • Activity-specific Environment Plan, Oil Pollution Emergency Plan; and • Access to baseline data and regional response information e.g. State Oil Spill Response Atlas.	
Possible provider(s) & competencies	• Astron/BMT. • CSIRO.	Individuals with knowledge of marine ecology and socio-economic receptors of region. GIS specialists with experience in the use of GIS software and developing spatial layers.
Scope of works	Prepared within 24 hours of spill having been reported.	
Design considerations	The following points should be considered: • The desk-based assessment is designed to be rapid, to inform response activities and other monitoring plans. Therefore, it requires a lower level of accuracy than what would be required for field-based and scientific monitoring. • It shall rely on existing baseline data within the predicted zone of exposure to the spill and data collected under surveillance and hydrocarbon spill modelling activities. • Activity-specific Environment Plans provide detailed information on the existing environment related to the activity, and describe potential impacts to key receptors. Therefore, these plans should be used as key source of baseline information. • Industry/government Environmental Meta-databases and the relevant State Oil Spill Response Atlas (OSRA should be used to help compile baseline information. Key information gaps in any existing baseline data should be identified.	
Implementation	Requires access to latest spill trajectory modelling (OMP-1) and receptor locations (OMP-7, Appendix C).	

OMP-2 – Desktop pre-emptive assessment of receptors at risk	
Analysis and reporting	The recommended reporting for this OMP includes: • Map collating hydrocarbon spill trajectory modelling, surveillance data and behaviour and weathering overlaid on the sensitive receptors map. • Report detailing the presence and distribution of sensitive receptors within the trajectory of the spill, or that have been exposed to the spill and/or response activities. • Assessment of the relative significance or conservation status of the identified sensitive receptors to assist in the determination of priority protection areas and inform spill response strategies.

6.3 OMP-3 Hydrocarbon Spill Surveillance and Tracking

OMP-3 – Hydrocarbon spill surveillance and tracking	
Rationale	Provide DIMT and regulatory authorities with reliable and timely tracking buoy location and surveillance observations to inform response planning and operations.
Objectives	Tracking buoy, satellite imagery, opportunistic and planned vessel and aerial surveillance used to determine the distribution of the slick, validate OSTM, monitor the effectiveness of response strategies on the slick, and identify the presence of marine fauna in the response area.
Baseline	• N/A
Initiation criteria	The DIMT has determined that Level 2 or 3 hydrocarbon spill to marine or coastal waters has occurred.
Termination criteria	This OMP will be terminated when: Field Study Termination: • Oil source controlled. Surface water does not have an oiled appearance, specifically 'silver/grey' as per the Bonn Agreement Oil Appearance Code (BAOAC). Study Termination: • OMP-3 Final Report describing outcomes of operational monitoring (i.e. spatial oil distribution observations) approved by the Western Gas Environmental Advisor.
Tactics	• Visual observation from vessel or facility; • Aerial observation; • Deploy satellite tracking buoy; • Real-time oil spill trajectory modelling; • Satellite imagery; and • Analysis of all surveillance data.
Indication of resources required	• Suitable aircraft for aerial observation – helicopter and fixed wing; • Aerial observers (4-5 for rotation work); • Support vessels; • Satellite tracking buoy (2 minimum); and • Satellite imagery contractor.

Possible provider(s) & competencies	• DIMT contracted helicopters / vessels. • AMOSC. • Advisian / Fastwave • Landgate (Satellite imagery – SAR).	Individuals trained or with experience in relevant tactics they are tasked with e.g. aerial observation training or experience.

6.4 OMP-4 Hydrocarbon Characterisation and Weathering Assessment

OMP-4 – Hydrocarbon characterisation and weathering assessment	
Objectives	To provide in field information on the hydrocarbon properties, behaviour and weathering of the spilled hydrocarbons to assist in spill response operations.
Rationale	Physical and/or chemical analysis undertaken in order to better predict oil behaviour, weathering and potential effects. • Guides planning of clean-up activities; • Indicates time and physical constraints to mounting a response (e.g. weathering characteristic of oil in real-time conditions); • Confirm source of spill; • Characterise the hydrocarbon by chemical fingerprinting; • Collect legally defensible samples to link source to spill or to eliminate possible alternative sources; • To characterise oil and/or receiving area to link spill with effects; and • Document/confirm weathering of oil.
Baseline	Characterisation of the physical and chemical hydrocarbon properties for all spill categories. Refer to OPEP & EP.
Initiation criteria	The DIMT has determined that Level 2 or 3 hydrocarbon spill to marine or coastal waters has occurred.
Termination criteria	• The DIMT Incident Commander (or delegate) considers that continuation of monitoring under this OMP will not result in a change to the scale or location of active response options; or • The DIMT Incident Commander (or delegate) has advised that agreement has been reached with the Jurisdictional Authority relevant to the spill to terminate the response; or • This OMP is no longer contributing to or influencing spill response decision-making; or • Relevant scientific monitoring components initiation criteria have been triggered.
Tactics	• Sampling (as outlined in Hook (2016)). • Laboratory analysis. • Visual observations. • Results to be provided back to the PC for integration into IAP development. • Record results and handover to MC for initiation of SMP.
Indication of resources required	• Sampling vessel. • Specialist team of 2-3 people.

OMP-4 – Hydrocarbon characterisation and weathering assessment		
Possible provider(s) & competencies	• Astron/BMT. • CSIRO. • ChemCentre.	Sampling led by scientist experienced in water and sediment sampling. Sampling can be performed by unsupervised technicians. Samples analysed by a National Association of Testing Authorities (NATA) accredited laboratory.
SMP(s) triggered & associated trigger	May trigger all receptors.	Oil character confirms extent of spill and determines locations for impact/control sites and un-impacted (for pre-impact monitoring) to SMP(s).
Scope of works	Prepared within 24 hours of spill having been reported. It will provide information on sampling of oil on the sea surface and throughout the water column at sufficient locations and replication to guide the response. Sufficiency will be guided by evidence for the spatial extent and variability (i.e. patchiness) of the spill and sensitivity of the response decisions to this variability.	
Design considerations	The appropriate design of this monitoring activity will vary between situations depending on: • Nature and scale of the spill (e.g. surface vs. subsea release, instantaneous vs. ongoing release); • Weathering rate of the oil; • Potential environmental and economic consequences of the spill; • Requirements to test specific response methods that may affect oil or be sensitive to the oil properties; • Requirements to inform the public or other stakeholders; • The availability of human resources, sampling equipment, suitable vessels and other logistics; • Capacity for transporting samples from the site (e.g. by helicopter or boat); and • Safety considerations.	
Implementation	Implementation of this monitoring program will focus on monitoring effectiveness of the relevant response strategies, given the specifics of the spill and the real-time zone of impact, therefore allowing for any potential impacts of those response strategies complying with ALARP justifications made in the EP.	
Analysis and reporting	• All data collected for spill surveillance and tracking to be analysed within the situation unit to achieve OMP objectives; • All data collected to be collated for the PC for integration into the IAP; and • All data collected to be made available to the MC for initiation of the SMP(s) (if applicable).	

6.5 OMP-5 Water Quality Assessment

OMP-5 – Water quality assessment	
Rationale	This OMP provides the DIMT with ongoing information on water quality, in particular the distribution of oil in the water column and depending on the duration of the spill and response options, the change in hydrocarbon concentrations over time within the response areas. This information helps verify oil spill modelling data and visual surveillance information. The outputs of this OMP should contribute to developing an understanding of the spatial extent of the environment that may be affected, which can be used to inform potential response strategies and longer term scientific monitoring. Depending on the size and nature of the spill, this OMP may need to be ongoing during the spill. The frequency of implementation of this OMP should be based on the data needs of the DIMT.
Objectives	To provide a rapid assessment of the presence, type, concentrations and character of hydrocarbons in marine water to assess the extent of spill contact and verify impact predictions for other monitoring plans
Baseline	• Background hydrocarbon levels: • Baseline Water Quality Study - Field Survey Report - Hess Equus Project Environmental Impact Assessment – DRAFT (EQ1-ENV-RPT-01010-B).
Initiation criteria	The DIMT has determined that Level 2 or 3 hydrocarbon spill to marine or coastal waters has occurred.
Termination criteria	• The DIMT Incident Commander (or delegate) considers that continuation of monitoring under this OMP will not result in a change to the scale or location of active response options; or • The DIMT Incident Commander (or delegate) has advised that agreement has been reached with the Jurisdictional Authority relevant to the spill to terminate the response; or • The spill is or is likely to be below visible criteria for surface oil (0.5g/m2), and low thresholds for entrained (10ppb) and dissolved (10ppb) oil concentrations; or • The Monitoring Coordinator (or delegate) considers that continuation of monitoring under this OMP is likely to increase overall environmental impact; or • Relevant scientific monitoring components initiation triggers have been assessed.
Tactics	Tactics will depend on the response strategies being undertaken and may include: • Sub-surface water quality profiling (CTD/fluorometry); • Vessel-based surface water quality sampling; • Vessel-based sub-surface water quality sampling; and • Shore-based surface water sampling Sample collection and handling will align with standard operating procedures found in the Oil Spill Monitoring Handbook (Hook et al., 2016), specifically the following sections: • Appendix A & B hydrocarbon analysis; • Appendix C Volatile Organic Compounds Analysis; • Appendix D Surface Oil Analysis; and • Appendix F use of sensors for oil spill monitoring.

<table>
<tr><th colspan="3">OMP-5 – Water quality assessment</th></tr>
<tr><td>Indication of resources required</td><td colspan="2">• 1x sampling vessel per team.
• Specialist teams of 2-3 people
• Sampling equipment appropriate for planned operational depths
• Logistics in place for collection and transport of samples from field team to receiving laboratories as fast as practicable.
• Vessel requirements specific to scope:
  ○ Lifting equipment (winch, davit/crane/A-frame) sufficient for safe deployment of proposed equipment
  ○ 240V power supply to rear deck amy be required
  ○ Refrigerator/freezers sufficient for expected sampling volumes (e.g. 1 week of sampling effort) or space to install.
  ○ Area suitable for sample processing (lab or workshop) away from potential contamination sources or space to install lab container
  ○ Ability to maintain station in expected conditions for duration of expected sampling times
• Sufficient access to the sea surface if expected to deploy instrumentation/sampling devices through oil slick, or sampling sea surface. E.g. low (<2m) freeboard or stairway.</td></tr>
<tr><td>Possible provider(s) & competencies</td><td>• Astron/BMT.
• CSIRO.
• Australian Institute of Marine Science (AIMS).</td><td>Sampling led by scientist experienced in water sampling. Sampling can be performed by unsupervised technicians.</td></tr>
<tr><td>Scope of works</td><td colspan="2">Prepared within 24 hours of spill having been reported. Inputs include the estimated rate of flow, metocean conditions and predicted spill trajectory (real-time reports at least daily). Prepared once an understanding of the spill extent and response strategies to be employed is understood.</td></tr>
</table>

OMP-5 – Water quality assessment	
Design considerations	The key components of this monitoring program are collection of data on the effects of the spill and response strategies on water quality. The assessment will include the following: • Nature and scale of the spill (e.g. surface vs. subsea release, instantaneous vs. ongoing release). • The environment which may be affected (e.g. depth, presence of other sensitive receptors etc.). • Availability of current baseline dataset to inform design (e.g. are reference sites required). • Program design aims, which may include but, not limited to the determination of the: a) Delineating the extent of hydrocarbons in water. b) Spatial and temporal distribution of the hydrocarbons in water. c) Change in hydrocarbon concentrations over time. d) Site selection and sample size considerations. • The number of sites and samples to be collected should be spill-specific taking into account level of effort, potential logistical limitations, weather conditions, sample holding times, freight/transport options etc. that if not properly managed can compromise sample integrity. • Site selection should be based on results from surveillance (e.g. visual observations of the slick location) and the results of spill trajectory modelling. • Samples should also be collected at the leading edge of a surface slick, as this is typically the thickest part of the slick. • Appropriate QA/QC samples should be collected to allow assessment of local variability and ascertain potential for introduction of sample contamination throughout the collection and analysis process. • At each location, sampling should be conducted along a depth profile, which captures the three-dimensional distribution of the hydrocarbon. For a subsea release or where surface hydrocarbon is present in shallow water (<5 m) this should involve a depth profile from the seabed to surface waters. Profiles should ensure that the full gradient of hydrocarbon in water concentration can be determined. • Monitoring frequency should consider weathering of the spilled hydrocarbon, with frequency decreasing as the rate of change in the spilled hydrocarbon decreases. • Appropriate QA/QC protocols for sample handling, storage and transport should be included to limit the potential for contamination and ensure sample integrity meets laboratory requirements. • The sampling plan should have flexibility to be adjusted based on conditions in the field. • This survey may be undertaken individually or in conjunction with the OMP: Sediment Quality Assessment. • Health and safety factors associated with working in a range of environments with consideration of prevailing weather.

OMP-5 – Water quality assessment	
Implementation	Samples will be taken in shallow water along shorelines, and in deeper off-shore sites. This will require a marine vessel and ability to approach shorelines. Sediment and water quality samples should be taken concurrently. In the first instance, other operational monitoring tasked vessels and teams can be used for this task; however, if the response is relying on the results of this program for decision-making for the next operational period/IAP then a vessel and team dedicated to this task will be engaged as they become available. Implementation of this monitoring program will focus on rapid determination of water quality, given the specifics of the spill and the zone of actual impact, therefore allowing for response strategies to continue accordingly.
Analysis and reporting	• All relevant data collected should be provided in spreadsheets (including GPS location, depth of sampling, timing, on water observations, in-situ readings and water sample label details) to DIMT on a regular basis during spill response operations; • Regular field reports of results provided to the DIMT for integration into IAP development; • Analytical results of samples following laboratory evaluation by NATA accredited laboratory; • Final report detailing all data collected throughout the monitoring program including relevant interpretation; • All electronic data should be backed up onto external hard drives each day; and • Original hardcopies of datasheets should be transferred to a project folder and kept in a secure location (e.g. wheelhouse or vessel survey laboratory).

6.6 OMP-6 Sediment Quality Assessment

OMP-6 – Sediment quality assessment	
Rationale	This OMP provides the DIMT with information on sediment quality, in particular the distribution of hydrocarbons in sediments and depending on the duration of the spill, the change in hydrocarbon concentrations over time within the response areas. The outputs of this OMP should contribute to developing an understanding of the spatial extent of the environment that may be affected, which can be used to inform potential response strategies and longer-term scientific monitoring. Depending on the size and nature of the spill, this OMP may need to be ongoing during the spill. The frequency of implementation of this OMP will be based on the data needs of the DIMT.
Objectives	To provide a rapid assessment of the presence, type, concentrations and character of hydrocarbons in marine sediments to assess the extent of spill contact and verify impact predictions for other monitoring plans.
Baseline	• Benthic Habitats, Benthic Biota and Sediment Quality Technical Report – Hess Equus Project Environmental Impact Assessment (EQ1-ENV-RPT-01012-0). • Sediment and Infauna - Field Survey Report Hess Equus Project Environmental Impact Assessment - Draft B (July 2012) (EQ1-SAF-RPT-01016-B).
Initiation criteria	• The DIMT has determined that Level 2 or 3 hydrocarbon spill to marine or coastal waters has occurred; and • Modelling and/or analysis of data from monitoring, evaluation and surveillance (MES) predicts an exposure of hydrocarbons to marine and/or coastal sediment.

OMP-6 – Sediment quality assessment		
Termination criteria	• The DIMT Incident Commander (or delegate) considers that continuation of monitoring under this OMP will not result in a change to the scale or location of active response options; or • The DIMT Incident Commander (or delegate) has advised that agreement has been reached with the Jurisdictional Authority relevant to the spill to terminate the response; or • The Monitoring Coordinator (or delegate) considers that continuation of monitoring under this OMP is likely to increase overall environmental impact; or • Relevant scientific monitoring components initiation triggers have been assessed.	
Tactics	• Sediment sampling (as outlined in Hook (2016), S.8 and/or M.9, "Obtaining sediment samples", “Guideline for sampling of seabed sediments”). • Laboratory analysis.	

Indication of resources required	• Sampling vessel/vehicle.
	• Specialist team of 2-3 people.
	• Sampling equipment (dependant on availability, suitability for substrate and planned operational depths).
	• Logistics in place for collection and transport of samples from field team to receiving laboratories as fast as practicable.
	• Vessel requirements specific to scope:
	  ○ Lifting equipment (winch, davit/crane/A-frame) sufficient for safe deployment of proposed equipment;
	  ○ 240V power supply to rear deck;
	  ○ Refrigerator/freezers sufficient for expected sampling volumes (e.g. 1 week of sampling effort) or space to install;
	  ○ Area suitable for sample processing (lab or workshop) away from potential contamination sources or space to install lab container;
	  ○ Ability to maintain station in expected conditions for duration of expected sampling times (e.g. if deploying grabs to seabed then vessel must be able to maintain station via bow thrusters or DP)
	• Sufficient access to the sea surface if expected to deploy instrumentation/sampling devices through oil slick, or sampling sea surface. E.g. low (<2m) freeboard or stairway.	

Possible Provider(s) & competencies	• Astron/BMT. • AIMS. • CSIRO.	Sampling lead by Scientist experience in water and sediment sampling. Sampling can be performed by unsupervised technicians. Samples analysed by NATA accredited laboratory. Water and sediment quality samples should be taken concurrently.
SMP(s) triggered & associated trigger.	May trigger: • SMP1 - Sediment quality. • SMP5 - Macroalgal and seagrass communities. • SMP6 - Subtidal soft-bottom communities. • SMP12 – Invertebrates.	• Oil has impacted receptors; • Oil has the potential to impact receptors (pre-impact/control sites); • Oil concentrations exceed natural background levels for the receptors impacted; and/or • Oil concentrations exceed those identified in marine management plans and specific project EP conditions for receptors impacted.
Scope of works	Prepared within 48-72 hours of spill having been reported. Inputs include the estimated rate of flow, met ocean conditions and predicted spill trajectory (real-time reports at least daily). Prepared once an understanding of the spill extent, response	

OMP-6 – Sediment quality assessment	
	strategies to be employed and therefore possible sediment impact areas/pathways are identified.
Design considerations	The appropriate design of this monitoring activity will vary between situations depending on: • Nature and scale of the spill (e.g. surface vs. subsea release, instantaneous vs. ongoing release); • The environment which may be affected (e.g. subtidal vs. intertidal, depth, presence of other sensitive receptors etc.); • Availability of current baseline dataset to inform design (e.g. are reference sites required); • Program design aims, which may include but, not limited to the determination of the: • Presence and concentrations of hydrocarbons in sediment; • Spatial and temporal distribution of the hydrocarbons in sediment; • Change in hydrocarbon concentrations over time; and • Site selection based on visual observations of the slick location and the results of spill trajectory modelling. • The number of sites and samples to be collected should be spill-specific, taking into account level of effort, potential logistical limitations, weather conditions, sample holding times, freight/transport options etc.; • Appropriate QA/QC samples should be collected to allow assessment of local variability and ascertain potential for introduction of sample contamination throughout the collection and analysis process; • Equipment selection should be based on the sediment characteristics (e.g. particle size), depth, sample size requirements and the sampling platform; • Subsea sampling in the vicinity of project infrastructure should be designed to avoid damage to or entanglement with this infrastructure; • Appropriate QA/QC protocols for sample handling, storage and transport should be included to limit the potential for contamination and ensure sample integrity meets laboratory requirements; • This survey may be undertaken individually or in conjunction with the OMP: Water Quality Assessment; and • Health and safety factors associated with working in a range of environments with consideration of prevailing weather.
Implementation	Implementation of this monitoring program will focus on monitoring effectiveness of the relevant response strategies, given the specifics of the spill and the real-time zone of impact, therefore allowing for any potential impacts of those response strategies complying with ALARP justifications made in the EP.
Analysis and reporting	Data from this OMP is used to gain situational awareness on sediment impacts and inform decisions within the DIMT. The recommended reporting for this OMP includes: • All relevant data collected should be provided in spreadsheets (including GPS location, depth of sampling, timing, on water observations and sample label details) to DIMT on a regular basis during spill response operations; • Regular field reports of results provided to the EMT/IMT for integration into IAP development; • Analytical results of sediment quality following laboratory evaluation; • Final report detailing all data collected on sediment quality throughout the monitoring program including relevant interpretation;

OMP-6 – Sediment quality assessment	
	• All electronic data should be backed up onto external hard drives each day; and • Original hardcopies of datasheets should be transferred to a project folder and kept in a secure location. Data received from the laboratories (including backups) should be downloaded and stored on the Monitoring Provider's computer system. QA/QC'd data should be presented in spreadsheet format and then transferred to the DIMT as required.

6.7 OMP-7 Marine Fauna Surveillance

OMP-7 – Marine fauna surveillance	
Rationale	This OMP will facilitate collection of ongoing information on Marine fauna (Seabirds, shorebirds, pinnipeds, cetaceans, whale sharks, dugongs) within the area predicted to be affected by hydrocarbons. Typically, all Marine Fauna Assessments include the following components: • Determination of the presence and distribution of marine fauna affected or likely to be affected by the oil spill event; • Evaluate the impact of oil, dispersant or other response activities on marine fauna (i.e. via reporting on species oiled, degree of oiling, number of mortalities, and where possible any mortalities determined to be associated with response activities); and • Recommendations regarding the requirements for triggering scientific monitoring of marine fauna and key species and sites to target during scientific monitoring Monitoring data will assist in the decision-making process on appropriate management and response actions in order to minimise the potential impacts to marine fauna.
Objectives	To undertake a rapid assessment of marine fauna at risk to assist in decisions on appropriate management and response actions during a hydrocarbon spill event to minimise the potential impact on marine fauna.
Baseline	• OSRA WMA. • Desktop Review of Marine Fauna – Hess Equus Gas Fields Development Project Environmental Impact Assessment (EQ1-ENV-RPT-01014-1).
Initiation criteria	• The DIMT has determined that Level 2 or 3 hydrocarbon spill to marine or coastal waters has occurred; and • Modelling and/or analysis of data from MES predicts, or has reported, an exposure of hydrocarbons to known sensitive fauna habitat.
Termination criteria	• The DIMT Incident Commander (or delegate) considers that continuation of monitoring under this OMP will not result in a change to the scale or location of active response options; or • The DIMT Incident Commander (or delegate) has advised that agreement has been reached with the Jurisdictional Authority relevant to the spill to terminate the response; or • The Monitoring Coordinator (or delegate) considers that continuation of monitoring under this OMP is likely to increase overall environmental impact; or • Relevant scientific monitoring components initiation triggers have been assessed.
Tactics	• Aerial fauna surveys; • Vessel fauna surveys; • Opportunistic/Incidental observations; • Record all sightings of fauna (oiled & un-oiled) on fauna survey form;

OMP-7 – Marine fauna surveillance		
	• Collate results for use by SM teams; • Record daily progress by Wildlife facility (where applicable) e.g. no of animals cleaned/released etc.; • Carcass recording; and • Conduct necropsies on deceased fauna collected to determine cause of death (as outlined, Hook (2016), M.11, "Guideline for monitoring damage to marine megafauna"). Refer also to: • WA Oiled Wildlife Response Plan (WAOWRP); and • Pilbara Region Oil Spill Wildlife Response Plan.	
Indication of resources required	Refer to section 4.2, 4.3, & 5 of WAOWRP. Refer to sections 3 & 4 of Pilbara Region Oil Spill Wildlife Response Plan.	
Possible provider(s) & competencies	• Astron/BMT • Pendoley. • Murdoch University. • Perth Zoo. • DBCA. • Massey University.	• Team experienced in turtle monitoring procedures. • Team experienced in aerial and/or marine surveys of marine fauna. • Team experienced in handling and tissue sampling of marine mammals. • Tissue samples assessed for toxicology at experienced marine laboratory. • Team experienced in sea and shore bird surveys. • Tissue samples assessed for toxicology at experienced laboratory.
SMP receptor (s) triggered & associated trigger.	May trigger: • SMP4 – Reptiles • SMP5- Marine mammals. • SMP6 - Seabirds	• Oil has impacted receptors; and/or • Oil has the potential to impact receptors (pre-impact/control sites).
Scope of works	Prepared within 48-72 hours of spill having been reported. Inputs include the estimated rate of flow, metocean conditions and predicted spill trajectory (real-time reports at least daily). Prepared once an understanding of the spill extent and nature of spill are identified (OMP-1, OMP-3 & OMP-4).	
Design considerations	The appropriate design of this monitoring activity will vary between situations depending on: • Size of the spill; • Weathering rate of the oil; • Potential environmental and economic consequences of the spill; • Requirements to test specific response methods that may affect oil or be sensitive to the oil properties; • Requirements to inform the public or other stakeholders; • The availability of human resources, suitable vessels and other logistics; • Capacity for transporting samples from the site (e.g. by helicopter or boat); and • Safety considerations.	
Implementation	Wildlife survey teams to be deployed through the DIMT Operations Unit Wildlife Division. Information generated from the wildlife survey teams then feeds back into the	

OMP-7 – Marine fauna surveillance	
	Environment Unit (Planning) for integration into the IAP and the scientific monitoring studies for relevant receptors.
Analysis and reporting	• Collate results for use by MC to initiate SMPs (if applicable); • Record daily progress by Wildlife facility (where applicable) e.g. no of animals cleaned/released etc.; • Record all results and report to Wildlife Coordinator for integration into IAP (specifically Wildlife sub-plan) development; and • Record and report to the wildlife division instances where wildlife are disturbed by both onshore and offshore response operations, including surveillance.

7 Scientific Monitoring Plans

7.1 SMP-1 Ecotoxicology Assessment of Hydrocarbons

SMP-1 – Ecotoxicology Assessment of Hydrocarbons	
Rationale	The release of hydrocarbons at sea will pollute marine waters via floating, entrained or dissolved aromatic hydrocarbons. The Ecotoxicology SMP may also be used in conjunction with OMP1 Hydrocarbon characterisation and weathering, OMP 5 Water Quality Assessment and OMP 6 Sediment Quality Assessment to inform the sampling design of other SMPs where objectives are to evaluate impact and recovery of sensitive receptors, in relation to hydrocarbon contamination.
Aim	Undertake Eco-toxicological studies to establish hydrocarbon exposure thresholds for sensitive biotic receptors to assist with the assessment of impacts to environmental sensitivities affected by the spill. This is used to: • Define hydrocarbon eco-toxicities and subsequent contribution to changes in the marine environment from unplanned hydrocarbon releases; and • Reduce the range of uncertainty of impacts to fauna and initiation and termination criteria of other scientific monitoring strategies.
Baseline	Data from appropriate reference sites may be used as baseline values.
Initiation criteria	• Spill modelling (see OMP5: Hydrocarbon spill modelling) has indicated that contact on a sensitive resource is possible and it is considered likely that ongoing (scientific) monitoring of impacts will be required, supported by scientifically rigorous water quality monitoring; or • OMP3: Water quality assessment has identified hydrocarbon and/or dispersant concentrations exceed accepted guidelines or benchmarks; or • Chemical dispersants have been applied as part of the spill response program.
Termination criteria	• The relevant Jurisdictional Authority/ Government Agency has been consulted and has agreed that water quality monitoring can be ceased; • Laboratory toxicity testing has established the risk of environmental damage caused by the hydrocarbon release; and • Independent scientific specialists have reached agreement that the result of the testing provides a satisfactory exposure threshold for hydrocarbon. Note: This SMP may be required to input into other SMPs after the termination criteria for this SMP are reached.
Receptor impact	Impacts to specific receptors from hydrocarbons within marine waters are described in individual SMPs.

SMP-1 – Ecotoxicology Assessment of Hydrocarbons	
Methodological approach	<u>Sampling Design</u> When safe to do so (taking into consideration the volatility of hydrocarbon), collect hydrocarbon samples from the surface in proximity of the release. Sampling techniques will vary depending on the individual event and final monitoring design and may be undertaken alongside teams sampling for OMP-3. Refer to: • Water Quality, Sediment and Infauna Sampling - Field Survey Plan (EQ1-FPS-EHS-RPT-01017-A); • Scientific Monitoring Study - Sampling and environment Analysis Plan – Hydrocarbons (EQ1-ENV-ANY-01007-0); • Scientific Monitoring Study - Sampling and environment Analysis Plan - Marine Waters (S1) (EQ1-ENV-ANY-01003-0); <u>Sampling techniques</u> *Water sampling* Sampling techniques will vary depending on the individual event and final monitoring design. The following types of sampling may be implemented under SMP 1: • Surface water samples should be collected using a sampling pole and wide mouthed glass container, sampling as close to the sea surface as possible. • Subsurface water quality samples will be taken using a discrete water sampling device that allows remote opening and closing (e.g. Niskin bottle); or a suspended vertical hose using a suitable pump for water sampling (e.g. a peristaltic pump) or equivalent instrument. • Where a surface slick is present, a hydrocarbon-free area will need to be created adjacent to the vessel to reduce the risk of contamination of sampling equipment as it is lowered through the surface of the water. • Receiving laboratory(ies) will inform and supply the appropriate sample containers, storage requirements, and holding times for required analytes and the analysis required for each sample. Water sample collection and handling will align with Standard operating procedures found in the Oil Spill Monitoring Handbook (Hook et al., 2016). Sampling parameters will vary depending on the individual event and final monitoring design. The following types of parameters may be analysed under SMS1: • Oil concentrations (e.g. TRH, BTEX, PAH, MAH), • Dispersant chemicals (if applied). • Ecotoxicity values (e.g. LC50, PNEC)

7.2 SMP-2 Water Quality Monitoring

SMP-2 –Water quality monitoring	
Rationale	The release of hydrocarbons at sea will pollute marine waters via floating, entrained or dissolved aromatic hydrocarbons. The water quality SMP may also be used in conjunction with OMP1 Hydrocarbon characterisation and weathering, to inform the sampling design of other SMPs where objectives are to evaluate impact and recovery of sensitive receptors, in relation to hydrocarbon contamination.
Aim	Detect and monitor the presence, concentration and persistence of hydrocarbons in marine waters following the spill and associated response activities. The specific objectives of this SMP are as follows: • Assess and document the temporal and spatial distribution of hydrocarbons and dispersants in marine waters of sensitive receptors; • Consider the potential sources of any identified hydrocarbons; • Verify the presence and extent of hydrocarbons (both surface and throughout the water column) that may be directly linked to the source of the spill; • Assess hydrocarbon/dispersant content of water samples against accepted environmental guidelines or benchmarks to predict potential areas of impact; and • Provide information that may be used to interpret potential cause and effect drivers for environmental impacts recorded for sensitive receptors monitored under other SMPs.
Baseline	Baseline Water Quality Study - Field Survey Report - Hess Equus Project Environmental Impact Assessment – DRAFT (EQ1-ENV-RPT-01010-B) Data from appropriate reference sites may also be used as baseline values.
Initiation criteria	• Spill modelling (see OMP5: Hydrocarbon spill modelling) has indicated that contact on a sensitive resource is possible and it is considered likely that ongoing (scientific) monitoring of impacts will be required, supported by scientifically rigorous water quality monitoring; or • OMP3: Water quality assessment has identified hydrocarbon and/or dispersant concentrations exceed accepted guidelines or benchmarks; or • Chemical dispersants have been applied as part of the spill response program.
Termination criteria	• The relevant Jurisdictional Authority/ Government Agency has been consulted and has agreed that water quality monitoring can be ceased; • Concentrations of hydrocarbon contaminants, attributable to the released hydrocarbon, are not significantly higher than baseline data or similar non-impacted sites data; and • In the absence of baseline or similar non-impact sites data, concentrations of hydrocarbon contaminants, attributable to the released hydrocarbon, are below the relevant hydrocarbon contaminant trigger level within the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (Australian and New Zealand Governments 2018), or the relevant regulatory site-specific trigger level (where these exist). Note: This SMP may be required to input into other SMPs after the termination criteria for this SMP are reached.
Receptor impact	Impacts to specific receptors from hydrocarbons within marine waters are described in individual SMPs.

Methodological approach	<u>Sampling Design</u> Refer to: • Water Quality, Sediment and Infauna Sampling - Field Survey Plan (EQ1-FPS-EHS-RPT-01017-A); • Scientific Monitoring Study - Sampling and environment Analysis Plan – Hydrocarbons (EQ1-ENV-ANY-01007-0); • Scientific Monitoring Study - Sampling and environment Analysis Plan - Marine Waters (S1) (EQ1-ENV-ANY-01003-0); Overall sampling design approach will be enacted according to the availability of baseline data guided as follows: • If sites are contacted in which long-term baseline data is available, a control chart (time-series) design will be applied; • If insufficient long-term baseline data is available, where appropriately matched baseline data sites are impacted and non-impacted, a before-after-control-impact (BACI) approach to monitoring will be applied; and • Where no baseline data sites are involved, a gradient approach to quantifying impacts will be applied. The selection of potentially impacted and non-impacted sites will be informed by Operational Monitoring, including operational water quality monitoring and spill trajectory modelling. Sampling frequency will be dictated by the spatial extent of the spill, the number and location of sampling sites and the philosophy of the sampling design. <u>Sampling techniques</u> *Water profiling* • To validate modelling and determine the presence, location and depth of entrained hydrocarbons for water sampling, an in-situ fluorometer/water quality profiler may be used. This may include a CTD mounted fluorometer, flow-through fluorometer, subsurface glider with built-in fluorometer, or towed fluorometer. • The parameters and settings of the fluorometers shall depend on the target hydrocarbon type. The fluorometer should be calibrated against oil in water (OIW) content using samples of known concentrations of entrained hydrocarbons. The calibration series will be made up by adding various volumes of hydrocarbons to seawater in a jar and obtaining fluorometric readings corresponding to the expected entrained hydrocarbon concentrations (as a ppb of OIW). • Sampling methods will be aligned with the recommended standard operating procedures for the use of sensors for oil spill monitoring found in Appendix F of the Oil Spill Monitoring Handbook (Hook et al. 2016). • Sub-surface water profiling depths should aim to sample throughout the water column to as close to seabed as practicable. *Water sampling* • Surface water samples should be collected using a sampling pole and wide mouthed glass container, sampling as close to the sea surface as possible. • Subsurface water quality samples will be taken using a discrete water sampling device that allows remote opening and closing (e.g. Niskin bottle); or a suspended vertical hose using a suitable pump for water sampling (e.g. a peristaltic pump) or equivalent instrument.

SMP-2 –Water quality monitoring	
	• Sub-surface water sampling depths should be based on hydrocarbon detection from water column profiling) but should also involve representative samples from throughout the water column as fluorometers used in profiling may not effectively detect dissolved components. • Where a surface slick is present, a hydrocarbon-free area will need to be created adjacent to the vessel to reduce the risk of contamination of sampling equipment as it is lowered through the surface of the water. • Receiving laboratory(ies) will inform and supply the appropriate sample containers, storage requirements, holding times, detection limits/limit of reporting for required analytes and the analysis required for each sample. Water samples shall be analysed for key contaminants of concern including Total recoverable hydrocarbons (TRH), polycyclic aromatic hydrocarbons (PAHs), monocyclic aromatic hydrocarbons (including benzene, toluene, ethylbenzene, xylene), and nutrients, metals and chlorophyll-a. At each site, replicate water samples (at least three samples) will be collected to allow appropriate statistical analyses to be made including samples for quality assurance and quality control (QA/QC) purposes (i.e. split sample, triplicate sample, field blanks, transport blanks). Water sample collection and handling will align with Standard operating procedures found in the Oil Spill Monitoring Handbook (Hook et al., 2016), specifically the following sections: • Appendix A & B hydrocarbon analysis; • Appendix C Volatile Organic Compounds Analysis; and • Appendix D Surface Oil Analysis. Environmental DNA (eDNA) may be collected to detect for the presence of marine species in the water column. Water samples will be collected in Nalgene bottles and sent to an appropriate laboratory for analysis. Sample processing will depend on holding times required (<8 hours ideal) and may involve filtering and freezing of each sample (Grochowsi and Stat 2017).
Scope of works	Prepared by monitoring provider for issue within 24 hours of SMP having been activated.

SMP-2 –Water quality monitoring	

Resources	• Marine scientists (2-3) with experience in water quality sampling;
	• Input from Geographic Information Systems (GIS) specialists;
	• National Association of Testing Authorities (NATA) accredited laboratories for water sample analysis;
	• Sample containers and preservative, insulated containers and COC forms;
	• Decontamination/washing facilities;
	• Sampling equipment appropriate to survey the entire water column at planned operational depths – e.g. if sampling sites over 100m depth teams will use SBE19V2 CTDs or equivalent;
	• Logistics in place for collection and transport of samples from field team to receiving laboratories within recommended sample holding times.
	• Vessel requirements specific to scope:
	  ○ Lifting equipment (winch, davit/crane/A-frame) sufficient for safe deployment of proposed equipment;
	  ○ 240V power supply to rear deck may be required;
	  ○ Refrigerator/freezers sufficient for expected sampling volumes (e.g. 1 week of sampling effort) or space to install;
	  ○ Area suitable for sample processing (lab or workshop) away from potential contamination sources or space to install lab container; and
	  ○ Ability to maintain station in expected conditions for duration of expected sampling times.
	• Sufficient access to the sea surface if expected to deploy instrumentation/sampling devices through oil slick, or sampling sea surface. E.g. low (<2m) freeboard or stairway.

Implementation	Service provider able to mobilise within 72 hours of the SoW following approval by Western Gas (this time allows for costing, preparation of equipment and disposables and travel time to site).
Analysis and reporting	• Chemical analysis will be carried out by NATA-accredited laboratories. • A government endorsed laboratory for forensic fingerprinting (GS/MS) will be used. • Data will be stored securely. • Laboratory results should be used to quantify the temporal and spatial distribution of hydrocarbons and dispersants in marine waters to provide data to assist in the assessment of whether spilled hydrocarbons are likely to be the cause of any identified impacts to sensitive receptors. • All sample results should be compared to the relevant Australian toxicant default guideline values. Where guideline values are either not available or have been exceeded, results should be compared to other benchmark levels which can be defined as 1) relevant regulatory site-specific trigger level (where these exist); or 2) baseline levels; or 3) reference site values (whichever is applicable). • For samples where analytical data indicate the concentration levels exceed the individual guideline/ or benchmark, further investigations should occur to assess the likelihood that the exceedance resulted from the spill and poses an environmental impact. • Interpretation of results should also be presented spatially to identify patterns of hydrocarbon contamination and environmental factors at local and regional scales. Comparisons should also be made within and between sites over time following repeated sampling. • Final draft report to be prepared within one month of monitoring completion; external peer review of final draft within two weeks of report provision to reviewer; finalise report within two weeks of peer review having been completed.

7.3 SMP-3 Sediment Quality Monitoring

SMP-3 – Sediment quality monitoring	
Rationale	Hydrocarbons released during a spill scenario may contact, settle and/or accumulate in marine sediments. Toxic substances found in accumulated hydrocarbons may lead to impacts to ecosystem processes associated with this primary producer habitat. The outputs of this SMP should contribute to developing an understanding of the short and long-term impacts on the biota of the offshore environment as well as to inform the assessment of impact, remediation / clean-up strategies that may need to be deployed and the need for any long-term monitoring programs.
Aim	Detect and monitor the presence, concentration and persistence of hydrocarbons in marine sediments following the spill and associated response activities. The specific objectives of this SMP are as follows: • Assess and document the temporal and spatial distribution of hydrocarbons and dispersants in marine sediments of sensitive receptors; • Consider the potential sources of any identified hydrocarbons; • Verify the presence and extent of hydrocarbons that may be directly linked to the source of the spill; and • Assess hydrocarbon content of sediment samples against accepted environmental guidelines or benchmarks to predict potential areas of impact.
Baseline	• Sediment and Infauna - Field Survey Report Hess Equus Project Environmental Impact Assessment - Draft B (July 2012) (EQ1-SAF-RPT-01016-B). • Benthic Habitats, Benthic Biota and Sediment Quality Technical Report – Hess Equus Project Environmental Impact Assessment (EQ1-ENV-RPT-01012-0). • Relevant industry-governmental meta-databases will also be reviewed for applicable marine baseline sediment quality and infauna data. • In the absence of baseline sediment quality data, hydrocarbon contaminant trigger values for marine sediments as listed in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (Australian and New Zealand Governments 2018) will be used as a proxy for baseline levels. • Where other regulatory site-specific trigger levels exist, the lower of these levels and the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (Australian and New Zealand Governments 2018) levels will be used as proxy baseline levels.
Initiation criteria	• OMP-6: Sediment quality assessment has identified hydrocarbon concentrations exceed accepted guidelines and benchmarks; or • Spill modelling has indicated that an impact on a sensitive resource that is closely linked to marine sediments is possible, and it is considered likely that ongoing (scientific) monitoring of a biological parameter will be required that supported by scientifically rigorous sediment quality monitoring.
Termination criteria	• The relevant Jurisdictional Authority/ Government Agency has been consulted and has agreed that water quality monitoring can be ceased; • Concentrations of hydrocarbons in marine benthic and shoreline sediments, attributable to the released hydrocarbon, are not significantly higher than baseline or similar non-impact sites; and • In the absence of baseline or similar non-impact sites data, concentrations are below marine sediment quality interim guideline levels within the ANZG (2018), or the relevant regulatory site-specific trigger level (where these exist), if this is lower.
Receptor impact	Impact to sediment quality is measured through change in hydrocarbon content and concentration.

SMP-3 – Sediment quality monitoring	
Methodological approach	Refer to: Scientific Monitoring Study - Sampling and environment Analysis Plan - Marine Sediments (S2) (EQ1-ENV-ANY-01004-1) Overall sampling design approach will be enacted according to the availability of baseline data guided by a decision-making process: • If sites are contacted in which long-term baseline data is available, a control chart (time-series) design will be applied; • If insufficient long-term baseline data is available, where appropriately matched baseline data sites are impacted and non-impacted, a before-after-control-impact (BACI) approach to monitoring will be applied; • Where no baseline data sites are involved, a gradient approach to quantifying impacts will be applied. The selection of potentially impacted and non-impacted sites will be informed by Operational Monitoring, including operational water quality monitoring and spill trajectory modelling. Sampling frequency will be dictated by the spatial extent of the spill, the number and location of sampling sites and the philosophy of the sampling design Operational Monitoring (including spill trajectory modelling) and the results of SMP1 Marine Water Quality monitoring will be used to inform the location of potentially impacted sediment sites. Sampling frequency will be dictated by the spatial extent of the spill, the number and location of sampling sites and the philosophy of the sampling design. *Sampling techniques (subtidal)* • Sampling techniques will vary depending on the objectives of the monitoring design; • At each site, replicate sediment samples will be taken including those for QA/QC purposes; • If a surface spill is still present, a hydrocarbon-free area will need to be created adjacent to the vessel to reduce the risk of contamination of sampling equipment as it is lowered through the surface of the water; • Sediment samples should be collected using a corer/grab, either from a vessel or using an ROV; • The Sediment grab (i.e. Van Veen or Box corer) or coring equipment selection will be based on water depth (offshore, inshore), substrate composition and sample size requirements; • Sediment sample collection and handling will align with Standard operating procedures found in the Oil Spill Monitoring Handbook (Hook et al. 2016), specifically the following sections according to sampling equipment utilised: • Appendix G hydrocarbon analysis (Grab samplers); • Appendix H hydrocarbon analysis (Ship borne corer); • Appendix H Manual push corer; and • Appendix O Sediment infauna. • Receiving laboratory(ies) will supply the appropriate sample containers, storage requirements, holding times, detection limits/limit of reporting for required analytes and the analysis required for each sediment sample; • Sediment samples shall be analysed for key contaminants of concern including metals, hydrocarbons, nutrients, particle size distribution, and nutrients; and

SMP-3 – Sediment quality monitoring	
	• Site selection should also consider impacts from sampling techniques on dominant biota. Forensic fingerprinting of the released hydrocarbon and sediment quality samples by way of GC/MS may be used to determine the source of contaminants where this is not otherwise clear from operational monitoring.
Scope of works	Prepared by monitoring provider for issue within 24 hours of SMP having been activated.

Resources	• Specialist sampling team of 2-3 marine scientists with field experience in sediment sampling;
	• Input from spatial GIS resources;
	• NATA accredited laboratory for sample contaminant analysis; and
	• Sampling equipment appropriate for planned operational depths
	• Logistics in place for collection and transport of samples from field team to receiving laboratories within recommended sample holding times.
	• Vessel requirements specific to scope:
	  ○ Lifting equipment (winch, davit/crane/A-frame) sufficient for safe deployment of proposed equipment;
	  ○ 240V power supply to rear deck may be required;
	  ○ Refrigerator/freezers sufficient for expected sampling volumes (e.g. 1 week of sampling effort) or space to install.
	  ○ Area suitable for sample processing (lab or workshop) away from potential contamination sources or space to install lab container
	  ○ Ability to maintain station in expected conditions for duration of expected sampling times (e.g. if deploying grabs/cameras/ROVs to the seabed then vessel must be able to maintain station via bow thrusters or DP)
	• Sufficient access to the sea surface if expected to deploy instrumentation/sampling devices through oil slick, or sampling sea surface. E.g. low (<2m) freeboard or stairway.

Implementation	Service provider to be capable of mobilising within 72 hours of the SoW having been approved by Western Gas. Actual mobilisation time will depend on the decision to adopt post-spill pre-impact monitoring and associated timing requirements.
Analysis and reporting	• Sediment samples analysed by NATA-accredited laboratories for presence and concentrations of hydrocarbons associated with the spill including full suite PAHs and total organic carbon. • A government endorsed laboratory for forensic fingerprinting (GC/MS) will be used. • Data will be stored securely and analysed statistically in order to detect significant differences among sites. • Comparisons of hydrocarbon, PSD and TOC results from exposed and reference sites should be made, including appropriate statistical comparisons. • All sample results should be compared to the relevant Australian toxicant default guideline values. Where guideline values are either not available or have been exceeded, results should be compared to other benchmark levels which can be defined as 1) relevant regulatory site-specific trigger level (where these exist); or 2) baseline levels; or 3) reference site values (whichever is applicable). • Data and conclusions will be summarised in an environmental report card. Final draft report to be prepared within one month of monitoring completion; external peer review of final draft within two weeks of report provision to reviewer; finalise report within two weeks of peer review having been completed.

7.4 SMP-4 Benthic Habitat Monitoring

SMP-4 – Benthic habitat monitoring	
Rationale	Benthic habitats are those habitats associated with the seafloor. Major benthic habitats and their associated organiSMP at risk are: • Coral reefs (likely high susceptibility to spill); • Macroalgae and seagrass (likely moderate susceptibility to spill); • Non-coral benthic filter feeders (likely moderate susceptibility to spill); • Sub-tidal pavement (likely moderate susceptibility to spill); and • Soft-substrate (likely lower susceptibility to spill). Impacts on benthic habitats vary according to the species present, oil type and response options used. As with most species, benthic species are most vulnerable during their larval and juvenile life stages. Impacts arise from direct contact via coating, smothering, absorption and/or ingestion. These impacts can be short (acute) or long (chronic) term. Indirect impacts include shading from surface oil, hydrocarbon accumulation in sediments, loss of keystone species and reduced food availability. Macroalgal and seagrass communities are important primary producers which also provide habitat, refuge areas and food for fish, turtles, dugongs and invertebrates. Seagrass and macroalgae also increase structural diversity and stabilise soft substrates. Western Australia contains the largest and most diverse assemblages of seagrasses in the world, which are found throughout the EMBA, including notably the vast meadows contained within the Shark Bay World Heritage Area. Non-coral benthic filter feeders, which include sponges, molluscs, sea whips and gorgonians, are considered indicators of disturbance due to their immobility and long life cycles. Corals are important primary producers that provide food, substrate and shelter for a diversity of marine life, including invertebrates and fish. They also protect coastlines from wave erosion and provide important substrate for algae. Undisturbed intertidal and subtidal coral reefs occur in several locations throughout the EMBA and are generally considered to be in good condition.
Aim	To assess the impact (extent, severity, and persistence) and subsequent recovery of subtidal benthic habitats and associated biological communities in response to a hydrocarbon release and associated response activities. The specific objectives of this SMP are as follows: • Collect quantitative data to determine short-term and long-term (including direct and indirect) impacts of hydrocarbon (and implementation of response options) on benthic habitats and associated biological communities, post-spill and post-response recovery. • monitor the subsequent recovery of benthic habitats and associated biological communities from the impacts of the hydrocarbon release.
Baseline	Benthic Habitats, Benthic Biota and Sediment Quality Technical Report – Hess Equus Project Environmental Impact Assessment (EQ1-ENV-RPT-01012-0). Relevant industry-governmental meta-databases will also be reviewed for applicable benthic habitat data. Pollution-induced change to benthic habitat cover and composition may take some time to be detected. Therefore, post-spill, pre-impact benthic survey data will be collected when required to have a baseline state following initial oil contact.
Initiation criteria	Operational monitoring indicates that subtidal benthic habitats or communities are contacted or are predicted to be contacted by a level 2/3 hydrocarbon spill.

SMP-4 – Benthic habitat monitoring	
Termination criteria	• There has been no impact to benthic habitats and associated biological communities (confirmation that benthic habitats were not exposed to hydrocarbons); or • Measured parameters of benthic habitats and associated biological communities impacted by hydrocarbons spills have returned to within the expected natural dynamics of baseline state (taking into account natural variability) and/or control sites; and • Agreement has been reached with the relevant stakeholders and Jurisdictional Authorities to cease monitoring this receptor.
Receptor impact	Impact to benthic habitats from pressures including hydrocarbons may be measured through change in: • Community Parameters such as: Percentage cover of taxa, diversity, distribution, dominant taxa, and percentage cover of other benthic organisms; • Population Parameters such as: abundance, shoot density (seagrass), holdfast density (macroalgae), ratio of polychaetes/ amphipods (infauna); and • Individual parameters such as signs of bleaching (corals), Colony and polyp level fecundity (corals), partial mortality (corals), Blade condition(seagrass/macroalgae).
Methodological approach	Refer to: Scientific Monitoring Study - Sampling and environment Analysis Plan - Subtidal Benthic Communities (S3) (EQ1-ENV-ANY-01005-0). Benthic habitats may support various biological communities during all, or part of, the year. To help inform scientific monitoring, it is important to first determine what benthic habitats are at risk and what biological resources inhabit these areas. This can be achieved by assessing pre-impact baseline data (if available) or inferring from reference sites that are considered comparable to impact locations. • Where long-term baseline data sites are contacted, a control chart (time-series) design will be applied. • Where appropriately matched baseline data sites are impacted and non-impacted, a BACI approach to monitoring will be applied. • Where no baseline data sites are involved, a gradient approach to quantifying impacts will be applied. <u>Sampling Techniques</u> *Physical monitoring* should be undertaken to complement biological monitoring to describe the physical environment during benthic surveys. Physical monitoring should be conducted at all biological monitoring sites, where practicable, using techniques described in SMP-2 & SMP-3. *Benthic Habitat Cover and Composition* Field survey methodology will be based upon acquiring repeat digital imagery (video or still images) of benthic habitats along random transects (preferable), using a stratified sampling approach at each site to target different habitat types and depths where clear gradients in these conditions exist. Site selection and image acquisition methodology will aim to align applicable baseline studies where these exist, such that imagery is comparable. The number of sites and frequency of sampling will depend upon the sampling design philosophy. Divers, towed video, autonomous underwater vehicles (AUV) or remotely operated vehicles (ROVs) will be employed to collect imagery considering safety aspects and the depth of water at survey locations.

SMP-4 – Benthic habitat monitoring	
	Where divers are employed, fish species will also be recorded where practicable (for example following methodologies employed by Babcock et al. (2008) to contribute to SMP7. *Fine-scale benthic surveys (Coral reef)* Finer scale surveys may be undertaken using divers or diverless techniques. Selected coral colonies may have tissue samples removed for the purpose of laboratory analysis of the concentration of accumulated hydrocarbons and for determining reproductive state, noting sampling for reproductive state will be dependent upon the timing of coral spawning. Reproductive state will be determined from measures of gamete size, stage and fecundity determined from in-field examination and laboratory analysis of histological samples. Ecotoxicology testing of the released hydrocarbon on the larval competency of representative coral species may be conducted. Settlement plates may be deployed to monitor settlement of coral recruits following spawning periods to ascertain the level of coral recruitment at impacted and non-impacted sites. *Soft sediment infauna surveys* Samples of sediment infauna will be obtained using sediment grabs or core samplers deployed from vessels, or by ROV/divers). Samples will be sieved in the field through appropriate diameter sieve (0.5mm or 1 mm) and the retained sample preserved in fixative (e.g. 10% buffered formalin or 70% ethanol) as prescribed by the receiving laboratory, and sent for identification of infauna to lowest taxonomic resolution practicable. *eDNA* eDNA may l also be collected to detect for the presence of marine infauna species in sediments. Sediment will be removed from the surface of a subset of the sediment sample and sent to an appropriate laboratory for analysis.
Scope of works	Prepared by monitoring provider for issue within 24 hours of SMP being activated.
Resources	• Specialist sampling team (2 to 4 people) including field lead/Marine Scientist with experience in benthic habitat assessment; • Additional Divers or ROV operators as required; • Input from DIMT GIS resources; • Suitable vessel; • Sampling equipment appropriate for depth (ROV/Towed video/sediment grab); • Diving equipment (shallow depths) • Lifting equipment (winch, davit/crane/A-frame) sufficient for safe deployment of proposed equipment • 240V power supply to rear deck • Refrigerator/freezers sufficient for expected sampling volumes (e.g. 1 week of sampling effort) or space to install. • Area suitable for sample processing (lab or workshop) away from potential contamination sources or space to install lab container • Ability to maintain station in expected conditions for duration of expected sampling times (e.g. if deploying grabs/cameras/ROVs to the seabed then vessel must be able to maintain station via bow thrusters or DP)

SMP-4 – Benthic habitat monitoring	
	• Deck hose • Sufficient access to the sea surface if expected to deploy instrumentation/sampling devices through oil slick, or sampling sea surface. E.g. low (<2m) freeboard or stairway. • If Divers used, then vessel must have access to sea surface sufficient for safe ingress, egress and diver recovery, or alternative lifting device (e.g. person winch or LARS)
Implementation	Service provider is to be able to mobilise within 72 hours of the SoW being approved by Western Gas (this time allowing for costing, preparation of equipment and disposables and travel to site). Actual mobilisation time will depend on the decision to adopt post-spill pre-impact monitoring and associated timing requirements.
Analysis and reporting	Digital imagery will be analysed using a point-count technique (using software such as AVTAS, Coral Point Count with Excel extensions (CPCe) or TransectMeasure (SeaGIS)) to estimate the percentage cover of biotic and abiotic categories (in line with the CATAMI classification scheme) comprising the benthic habitat. Biotic categories to include the following as applicable: corals; macroalgae and seagrass; and non-coral benthic filter feeders. Live, dead and bleached coral cover shall be recorded. The imagery collected will allow for the determination of percent cover, abundance, measurement of size (if scaling lasers are included in the image) and a visual assessment of health (Kohler and Gill 2006). NATA accredited laboratory analysis to determine the concentration of hydrocarbons within coral tissue. Reproductive output to be determined by complementary means, including in-field and laboratory analysis of gametes, including microscopic examination of histological samples preserved in the field. Coral larval competency tests to be conducted by ecotoxicological laboratory in addition to standard suite of ecotoxicological tests using released hydrocarbon. Data will be stored securely and analysed in order to determine significant differences between impacted and non-impacted assemblages. Data and conclusions will be summarised in an environmental report card provided as part of report. Final draft report to be prepared within one month of monitoring completion; external peer review of final draft within two weeks of report provision to reviewer; finalise report within two weeks of peer review having been completed.

7.5 SMP-5 Seabird Population Monitoring

SMP-5 – Seabird population monitoring	
Rationale	The region supports approximately 30 species of seabirds. Impacts to seabirds and shorebirds due to the presence of surface, entrained and dissolved hydrocarbons may include behavioural (e.g. deviation from migratory routes), physiological (e.g. disruption to digestion) or physical (e.g. matting of feathers, inability to fly). These effects may ultimately lead to death or failed breeding. For the purposes of this document, seabirds are defined as: • Seabirds – those birds associated with the sea and deriving most of their food from it, and typically breeding colonially, including the marine raptors osprey and white-bellied sea eagle. As there is no predicted shoreline contact, shorebirds are not detailed in this SMP.
Aim	Document and quantify shorebird and seabird presence; and any impacts and potential recovery from hydrocarbon exposure. The objectives are to:

SMP-5 – Seabird population monitoring	
	• Identify and quantify, if time allows, the post-spill/pre-impact presence and status of seabirds in the study area; • Observe, and if possible, quantify and assess, the impacts from exposure of seabirds to hydrocarbons (i.e. post-impact) and to the response activities, including abundance, oiling, mortality, and sub-lethal effects; and • Identify, quantify, and evaluate the post-impact status and if applicable, recovery of key behaviour and breeding activities of seabirds and with regard to control sites.
Baseline	Desktop Review of Migratory Birds and Seabirds - Hess Equus Gas Fields Development Project Environmental Impact Assessment (Document #: EQ1-ENV-RPT-01015-1). The Oil Spill Response Atlas (Department of Transport (DoT)), National Conservation Values Atlas (Department of Agriculture, Water and the Environment (DAWE). https://www.environment.gov.au/webgis-framework/apps/ncva/ncva.jsf). Desktop Review of Migratory Birds and Seabirds - Hess Equus Gas Fields Development Project Environmental Impact Assessment (EQ1-ENV-RPT-01015-1).
Initiation criteria	Operational monitoring indicates that known foraging areas for seabirds has been contacted, or are predicted to be contacted, by a hydrocarbon spill; or Operational monitoring indicates that seabirds have been contacted, or are predicted to be contacted, by a hydrocarbon spill.
Termination criteria	Detectable levels of hydrocarbons attributable to the hydrocarbon spill are not present in seabird tissues; AND Measured variables are not statistically significantly different from their baseline or pre-spill state (where these data exist) or from measured variables at non-impacted sites; AND Monitoring is terminated in consultation with the relevant environmental authority (DBCA and/or DAWE).
Receptor impact	Impact to seabirds from pressures including hydrocarbons is measured through change in: • Species diversity; • Bird abundance; • Health/condition; and • Breeding success (resident species only). Other pressures to these states are: • Physical disturbance of foraging and nesting habitat; • Accidental chemical spillage; • Entanglement in litter; • Displacement by less favourable species (e.g. Silver Gull); • Predation; and • Climate change.
Methodological approach	Refer to: Sampling and Analysis Plan – Marine Avifauna (EQ1-ENV-ANY-01009-0). Monitoring for seabirds and shorebirds will measure abundance and diversity in key foraging/roosting areas with the timing of surveys to coincide with seasonal peaks in abundance. Although shoreline contact is not predicted, monitoring of nesting (burrow) density, breeding participation and breeding success, may be necessary and informative. Bird mortality to be recorded during monitoring of seabirds with tissue samples taken from dead birds for hydrocarbon analysis in the laboratory.

SMP-5 – Seabird population monitoring	
	Necroscopies will follow the process of Gagnon and Rawson (2010).
Scope of works	Prepared by monitoring provider for issue within 24 hours of SMP being activated.
Resources	• Experienced seabird biologist; • Experienced shorebird biologist; • Personnel with pathology or veterinary skills; • NATA accredited laboratory for sample analysis and necropsy; • Available vessel and tender in operation; • Decontamination/washing facilities; and • Safety aircraft/rescue vessels on standby.
Implementation	Service provider able to mobilise within 72 hours of the scope of work having been provided to them (this time allowing for costing, preparation of equipment and disposables and travel to site). Actual mobilisation time will depend on the decision to adopt post-spill pre-impact monitoring and associated timing requirements.
Analysis and reporting	Data will be stored securely and analysed in order to determine significant differences between impacted and non-impacted assemblages. Draft annual report to be prepared within one month of monitoring completion; external peer review of final draft within two weeks of report provision to reviewer; finalise report within two weeks of peer review having been completed.

7.6 SMP-6 Marine Mega-fauna (reptiles) Monitoring

SMP-6 – Marine mega-fauna (reptiles) monitoring	
Rationale	Six species of marine turtle, 22 species of sea snake and one species of estuarine crocodile are considered to occur within the region. The presence of most species is expected to be of a transitory nature within the majority of the Project Areas. Green and loggerhead turtles nest along the North West Cape. Impacts to marine reptiles due to presence of surface oil, entrained oil and dissolved aromatic hydrocarbons may include behavioural, physiological (e.g. disruption to digestion) or physical effects. This plan is primarily focussed on marine turtles, while assessing other reptiles where encountered.
Aim	The objectives are to: • To observe and quantify the presence of marine reptiles (including life stage) within the area affected by hydrocarbons; and • Where possible, assess and quantify lethal impacts and/or sub-lethal impacts directly related to the hydrocarbon spill or other secondary spill-related impacts (including vessel strike and/or use of dispersants).
Baseline	Desktop Review of Marine Fauna – Hess Equus Gas Fields Development Project Environmental Impact Assessment (EQ1-ENV-RPT-01014-1). The Oil Spill Response Atlas (DoT), National Conservation Values Atlas (DAWE - https://www.environment.gov.au/webgis-framework/apps/ncva/ncva.jsf). Pilbara Region Oiled Wildlife Response Plan (Department of Parks and Wildlife and Australian Marine Oil Spill Centre 2014) should also be consulted.
Initiation criteria	Operational monitoring indicates that marine reptiles or nesting sites are contacted or likely to be contacted by a hydrocarbon spill; or Operational monitoring indicates that marine reptiles are contacted, or are predicted to be contacted, by a hydrocarbon spill (OMP-1, OMP-2, OMP-7).

SMP-6 – Marine mega-fauna (reptiles) monitoring	
Termination criteria	Detectable levels of hydrocarbons attributable to the hydrocarbon spill are no longer present in marine reptile tissues collected from live or dead individuals; AND In the event that an impact attributable to the hydrocarbon spill is detected on marine reptiles, the measured parameters are not statistically significantly different from their baseline or pre-spill state (where these data exist) or from measured parameters at non impacted sites; or Monitoring is terminated in consultation with the relevant environmental authority (Department of Biodiversity, Conservation and Attractions (DBCA) and/or Department of Water, Agriculture and Environment (DAWE)).
Receptor impact	Impact to marine turtles from pressures including hydrocarbons is measured through change in: • Abundance; • Health/condition; and • Nesting success. Impact to other marine reptiles from pressures including hydrocarbons is measured through change in observed injury and condition. Other pressures to these states are: • Lighting and flares causing disorientation (turtles); • Vessel strike; • Physical disturbance of nesting sites; • Predation; • Entanglement in fishing gear and litter; • Accidental chemical spillage; • Habitat loss or change due to dredging; • Climate change; and • Over-exploitation.
Methodological approach	Refer to: Scientific Monitoring Study - Sampling and environment Analysis Plan - Marine Megafauna (S7) (EQ1-ENV-ANY-01008-0). **Abundance** In-water impacts – aerial surveys. **Health/condition** In-water impacts – vessel surveys (collecting observations on animal condition and collection of tissue samples or dead specimens for analysis). Dead reptiles will be collected for autopsy following Gagnon (2009). **Reproductive success** Shoreline impacts – ground surveys (detailed tagging and/or nesting success studies). Design of ground surveys for turtles will be applied as follows: • Where long-term baseline data sites are contacted a control chart (time-series) design will be applied. • Where appropriately matched baseline data sites are impacted and non-impacted, a BACI approach to monitoring will be applied. • Where no baseline data sites are involved, and timing allows, a post spill pre-impact approach will be attempted. • If a post-spill pre-impact approach is not practicable, a gradient approach to quantifying impacts will be applied.

SMP-6 – Marine mega-fauna (reptiles) monitoring	
Scope of works	Prepared by monitoring provider for issue within 24 hours of SMP being activated.
Resources	Aerial survey: • Senior marine scientist; • Trained marine wildlife observers x 2; • Fixed wing aircraft (incl. pilot/s); and • Refuelling facilities. Vessel-based Survey: • Senior Marine Scientist; • Trained marine wildlife observers x 2; • Personnel with pathology or veterinary skills; • NATA accredited laboratory for sample analysis and necropsy; • Available vessel in operation; • Decontamination/washing facilities; • Safety aircraft/rescue vessels on standby.
Implementation	Service provider to be able to mobilise within 72 hours of the scope of work having been approved by Western Oil (this time allowing for costing, preparation of equipment and disposables and travel to site). Actual mobilisation time will depend on the decision to adopt post-spill pre-impact monitoring and spill timing requirements.
Analysis and reporting	Data will be stored securely. Turtle data will be analysed in order to test for significant differences between impacted and non-impacted assemblages. Owing to their observational nature and potentially low sample size, observed impacts to other reptile fauna will be corroborated with marine scientist(s) with expertise in relevant fauna in the north-west of Western Australia. Draft annual report to be prepared within one month of annual monitoring completion; external peer review of final draft within two weeks of report provision to reviewer; finalise report within two weeks of peer review having been completed.

7.7 SMP-7 Marine Mega-fauna (mammals) Monitoring

SMP-7 – Marine mega-fauna (mammals) monitoring	
Rationale	Forty three species of marine mammals are known to occur within the region, 32 within the HEA. These include cetaceans (whales and dolphin) and sirenians (dugong). Effects to marine megafauna due to presence of surface oil, entrained oil and dissolved aromatic hydrocarbons may include behavioural (e.g. deviation from migratory routes), physiological (e.g. disruption to digestion) or physical effects. Given large spatial variation in occurrence and broad scale movement, population estimates and associated change are not often available. This plan will focus on assessing the extent of impacts to animals within the region, and where possible, the level of recovery. This will then be used to deduce potential impacts at a population level.
Aim	To monitor short and long-term environmental effects on marine mammals that may have resulted from the hydrocarbon spill and associated response.
Baseline	Desktop Review of Marine Fauna – Hess Equus Gas Fields Development Project Environmental Impact Assessment (EQ1-ENV-RPT-01014-1). The Oil Spill Response Atlas (DoT), National Conservation Values Atlas (DAWE - www.environment.gov.au/webgis-framework/apps/ncva/ncva.jsf) and Pilbara Region Oiled Wildlife Response Plan (Department of Parks and Wildlife and Australian Marine Oil Spill Centre 2014) should also be consulted.

SMP-7 – Marine mega-fauna (mammals) monitoring	
Initiation criteria	Operational monitoring indicates that marine mammals are contacted or predicted to be contacted by a hydrocarbon spill (OMP-1, OMP-2, OMP-7).
Termination criteria	Restoration or resumption of key biological processes (e.g. abundance, distribution, breeding) necessary to ensure post-impact recovery is demonstrated. Specific criteria to be developed by Marine Scientist(s) with expertise in marine mammals in the north-west of Western Australia; and No further instances of dead marine mammals with detectable levels of hydrocarbons attributable to the hydrocarbon spill; AND Monitoring is terminated in consultation with the relevant environmental authority (DBCA and/or DAWE).
Receptor impact	Impact to marine mammals from pressures including hydrocarbons is measured through observed injury and mortality. Other pressures to these states are: • Physical disturbance; • Entanglement in fishing gear and litter; • Accidental chemical spillage; • Climate change; and • Over-exploitation.
Methodological approach	Refer to: Scientific Monitoring Study - Sampling and environment Analysis Plan - Marine Megafauna (S7) (EQ1-ENV-ANY-01008-0). Aerial and marine surveys will be implemented to identify individuals in proximity of the spill and to quantify damage. Refer to Sampling and Analysis Plan – Marine Megafauna (EQ1-ENV-ANY-01008-0) Tissue sampling of dead or injured animals will follow the protocols of: Department of Environment and Heritage (DEH) (2006) (Cetaceans); and • Eros et al. (2000) (Dugongs).
Scope of works	Prepared by monitoring provider for issue within 24 hours of SMP being activated.
Resources	Aerial survey • Senior Marine Scientist; • Trained marine wildlife observers x 2; • Fixed wing aircraft (incl. pilot/s); and • Refuelling facilities. Vessel-based survey • Senior Marine Scientist; • Trained marine wildlife observers x 2; • Personnel with pathology or veterinary skills; • NATA accredited laboratory for sample analysis and necropsy; • Available vessel in operation; • Sample container and preservative; • Decontamination/washing facilities; and • Safety aircraft/rescue vessels on standby.
Implementation	Service provider able to mobilise within 72 hours of the scope of work having been approved by Western Gas (this time allowing for costing, preparation of equipment and disposables and travel to site).

SMP-7 – Marine mega-fauna (mammals) monitoring	
	Actual mobilisation time will depend on the decision to adopt post-spill pre-impact monitoring and spill timing requirements.
Analysis and reporting	Data will be stored securely. Data and conclusions will be summarised in an environmental report card. Statistical power related to these receptors is likely to be low, due to observational data and small sample sizes. Therefore, the assessment of quantified impacts will be corroborated with marine scientist(s) with expertise in relevant fauna in the northwest of Western Australia. Draft annual report to be prepared within one month of annual monitoring completion; external peer review of final draft within two weeks of report provision to reviewer; finalise report within two weeks of peer review having been completed.

7.8 SMP-8 Marine Fish Assemblage Monitoring

SMP8 – Marine fish assemblage monitoring	
Rationale	Impacts to marine fish species due to presence of entrained hydrocarbons may include lethal and sub-lethal physiological effects (e.g. reduced growth) and physical effects that affect fish at the individual and community level. This SMP will provide information to help understand the impacts to benthic habitats from hydrocarbons and/or associated response activities and should inform any restoration or remediation activities that may need to be implemented.
Aim	To assess the impacts to and subsequent recovery of fish assemblages associated with specific benthic habitats (as identified in SMP: Benthic Habitat Assessment) in response to a hydrocarbon release and associated response activities. The specific objectives of this SMP are as follows: • Characterise the status of resident fish populations associated with habitats monitored in SMP: Benthic Habitat Assessment that are exposed/contacted by released hydrocarbons; • Quantify any impacts to species (abundance, richness and density) and resident fish population structure (representative functional trophic groups); and • Determine and monitor the impact of the released hydrocarbons and potential subsequent recovery to residual demersal fish populations.
Baseline	Baseline datasets from industry & governmental meta-databases, including: • State Fishery data; • Commonwealth fishery data; project-specific baseline data and baseline summary report/data/maps/models, where available, for the relevant study area.
Initiation criteria	Operational monitoring indicates marine fish are contacted or likely to be contacted by a hydrocarbon spill.
Termination criteria	• There has been no impact on fish and fish population structure; or • Measured parameters of fish, fish habitat, and marine fisheries locations impacted by hydrocarbon spills have returned to within the expected natural dynamics of baseline state and/or control sites; and • Agreement has been reached with the relevant stakeholders and Jurisdictional Authorities to cease monitoring this receptor.
Receptor impact	Specific impacts on marine fish from pressures associated with elevated hydrocarbon concentrations include: • Reduced sensory ability which disrupts behaviour;

SMP8 – Marine fish assemblage monitoring	
	• Lowered immune efficiency (chronic) causing secondary infections; • Impairment of the viability of fish eggs and of the survival of fish larvae; • Ulcers and bleeding in the stomach from direct ingestion of hydrocarbon droplets; • Poisoning from ingestion of contaminated food sources; • Organ damage or failure; and • Uptake of dissolved petroleum compounds through the gills or other body surfaces. Community level impacts include changes in: • Species diversity; • Abundance of indicator taxa; • Assemblage structure; and • Health. Aquatic species with high fat content have a greater ability to bio-accumulate petroleum hydrocarbons in their tissues.
Methodological approach	Refer to: Scientific Monitoring Study - Sampling and environment Analysis Plan - Hydrocarbons in Representative Commercial and Recreational Fish. (EQ1-ENV-ANY-01007-0). *Monitoring Design* Assessments of fish populations should be carried out via field studies, based on methods that relate to the particular receptors identified at risk. The monitoring approach needs to consider the data collected during surveillance and operational monitoring activities. The geographic extent of the area to be monitored should be based on the hydrocarbon distribution and predicted movement of the hydrocarbon spill, as determined through surveillance activities, and measured hydrocarbons within the water column, sediments, and habitats, as determined through the relevant OMPs and SMPs (as data becomes available). These outputs should identify potential impact areas to be sampled, which will allow comparison of results to baseline values. The number of sites that can be monitored each day depends on the travel distance between sites, number of replicates required, depth of water and weather conditions. Sampling design for fish assemblages will be as follows: • Where long-term baseline data sites are contacted a control chart (time-series) design will be applied. • Where appropriately matched baseline data sites are impacted and non-impacted, a BACI approach to monitoring will be applied. • If baseline data is not available, a gradient approach to quantifying impacts will be applied. For fish species potentially exposed to an oil spill, species will be sampled across the contamination gradient as per Gagnon and Rawson (2012). *Sampling Techniques* Fish assemblages will be assessed using a combination of techniques, including baited/non baited video and fish capture: • Stereo-baited remote underwater videos (SBRUVs); • Remotely operated Vehicle (ROV) Survey/ Towed video systems; and • Biota Tissue Sampling. If fish kills are observed, whole specimens will be obtained and preserved (frozen) for necropsy to determine the cause of death.

SMP8 – Marine fish assemblage monitoring	
Scope of works	Prepared by monitoring provider for issue within 24 hours of this SMP being activated.
Resources	• SBRUVS systems; • ROV (optional); • Towed video (optional); • Specialist team *(2-3) including: o Marine scientists with BRUV experience; o Marine scientist trained in fish identification and necropsy. • NATA accredited laboratory for sample analysis; • Suitable vessel; o Lifting equipment (winch, davit/crane/A-frame) sufficient for safe deployment of proposed equipment; o 240V power supply to rear deck may be required; o Ability to maintain station in expected conditions for duration of expected sampling times (e.g. if deploying grabs/cameras/ROVs to the seabed then vessel must be able to maintain station via bow thrusters or DP) • Sufficient access to the sea surface if expected to deploy instrumentation/sampling devices through oil slick, or sampling sea surface. E.g. low (<2m) freeboard or stairway.
Implementation	Service provider to be able to mobilise within 72 hours of the scope of work having been approved by Western Gas (this time allowing for costing, preparation of equipment and disposables and travel to site). Actual mobilisation time will depend on the decision to adopt post-spill pre-impact monitoring and spill timing requirements.
Analysis and reporting	BRUV imagery will be processed using suitable software e.g. EventMeasure (SeaGIS) software. This software should be used to view and analyse footage for measures of fish species richness, relative abundance for all species, and size structure for the ten most abundant species. All fish data and still reference images should be run through QA/QC procedures. Analysis of biota tissue samples should be completed at an accredited NATA laboratory (where relevant). Data will be entered into a database and analysed to test for statistically significant differences between non-impacted and impacted fish assemblages. A final report that includes: • Spatially explicit information on the concentrations and nature of hydrocarbons for all water samples; • Digital maps generated of hydrocarbon concentrations and associated data; • Details of the impacts and subsequent recovery of fish assemblages in response to a spill event and associated response activities as well as comparisons of exposure sites and reference sites, along with a determination of whether the termination criteria have been reached, including recommendations on the requirements of future monitoring; and • Where appropriate, data provided by this monitoring should be integrated with data from other relevant SMPs to fully understand the three-dimensional distribution of the spill; and • Any data outputs made available to other relevant SMPs.

7.9 SMP-9 Fisheries Monitoring

SMP-9 –Fisheries monitoring	
Rationale	This SMP should be initiated if Operational Monitoring has identified that commercial, aquaculture or recreational species have been, or are at high risk of being exposed to the hydrocarbon spill. This SMP would continue with the chemical analysis of the flesh and extend the chemical assessment to stomach and intestinal contents, which can help to characterise the geographical spread, temporal trends and severity of contamination. Seafood safety is an important concern associated with significant hydrocarbon spill incidents and is a primary objective of Commonwealth and State/Territory public health industries. Actual and potential contamination of seafood can substantially affect commercial and recreational fishing and subsistence seafood use, resulting in serious economic consequences. The effects of hydrocarbon spills on fisheries is related to the quantity of hydrocarbons that has affected an area, the type of hydrocarbon, its chemical composition, its degree of weathering, the duration of exposure, the sensitivity of that species to hydrocarbons and the ability of mobile species to move away from an area. The habitat utilisation, species metabolic capacity and feeding strategies (predatory, scavenger, omnivorous, grazer, filter feeder etc.) also affect the risk of exposure to, and uptake of, hydrocarbon contamination.
Aim	To monitor potential contamination and tainting of important finfish and shellfish species from commercial, aquaculture and recreational fisheries to evaluate the likelihood that a hydrocarbon spill will have an impact on the fishing and/or aquaculture industry. The specific objectives of this SMP are as follows: • Assess any physiological impacts to important fish and shellfish species and if applicable, seafood quality and safety; • Assess targeted fish and shellfish species for hydrocarbon contamination; • Provide information that can be used to make inferences on the health of fisheries and the potential magnitude of impacts to fishing industries (commercial, aquaculture and recreational).
Baseline	Available regional information on fisheries (WA and Commonwealth fisheries data). External datasets (e.g. DEE, DoF etc.), information, including access to raw data and metadata statements outlining data collection methods. Additional industry & Governmental metadata database records may identify existing baseline datasets.
Initiation criteria	• Spill trajectory modelling, surveillance or monitoring predicts contact is possible to commercial, recreational, traditional species and or aquaculture species; or • Advice has been provided to government to restrict, ban or close a fishery; or • Declarations of intent by commercial fisheries or government agencies to seek compensation for alleged or possible damage.
Termination criteria	• Agreement has been reached with the relevant Jurisdictional Authorities (e.g. Department of Primary Industries and Regional Development - DPIRD) to cease monitoring of fisheries; and • Contamination in the edible portion or in the stomach/intestinal contents attributable to the spill is no longer detected; or • No differences are detected in commercial, recreational or aquaculture fisheries from control and impact sites; or • The physiological and biochemical parameters in the studied species have returned to baseline levels; or

SMP-9 –Fisheries monitoring	
	• Evidence that catch rates, species composition, community abundance, distribution and age structure of commercial fisheries and their by-catches have returned to baseline levels.
Receptor impact	Impact to fisheries from pressures including hydrocarbon concentrations is measured through change in: • Species diversity; • Abundance of indicator taxa; • Assemblage structure; and • Health.

Methodological approach	Refer to:
	
	Scientific Monitoring Study - Sampling and environment Analysis Plan - Hydrocarbons in Representative Commercial and Recreational Fish. (EQ1-ENV-ANY-01007-0).
	
	<u>Monitoring Design</u>
	The exact nature of the monitoring activities should depend upon the area of operation, availability of baseline data and the nature and scale of the spill. The monitoring design should ensure there is sufficient statistical power to provide the information needed at the desired level of confidence to support seafood management decisions. This SMP should be administered in conjunction with relevant authorities as information collected will assist in informing appropriate management decisions, such as the closure and re-opening of fisheries.
	Species relevant to the commercial, recreational and aquaculture fisheries should be targeted. Indicator (target) fish and aquaculture species should be selected from the identified receptors at risk within the Environment that May be Affected (EMBA) to represent impact to fish health and should include demersal and/or pelagic commercial and recreational species based on the species available in sufficient abundance within the EMBA. The selection of an indicator species should be based on knowledge of which species represent the most sensitive component with reference to:
	• Presence, abundance and distribution within the EMBA;
	• Availability of baseline information; and
	• Vulnerability to the impacts of a hydrocarbon spill (e.g. finfish metabolise PAHs quickly, whereas bivalves tend to bioaccumulate contaminants).
	<u>Sampling techniques</u>
	Sampling techniques will vary depending on the objectives of the monitoring design. A summary of sampling types and techniques that may be suitable for this SMP are:
	• Fish health - Laboratory analysis of biopsies or fish carcases;
	  ○ Biomarkers (Liver detoxification enzymes (EROD activity);
	  ○ Polycyclic aromatic hydrocarbon (PAH) biliary metabolites;
	  ○ Oxidative deoxyribonucleic acid (DNA) damage;
	  ○ Serum sorbitol dehydrogenase (SDH) activity;
	  ○ Condition factor (CF);
	  ○ Liver somatic index (LSI)
	  ○ Gonado-somatic Index (GS)I;
	  ○ Gonad histology;
	  ○ Total weight;
	  ○ Total length; and

SMP-9 –Fisheries monitoring	
	○ Parasites. • Fitness for human consumption ○ Seafood taint assessment (sensory assessment); ○ Total petroleum hydrocarbons (TPH); ○ Polycyclic aromatic hydrocarbons (PAH); ○ Benzene, toluene, ethylbenzene and xylene (BTEX); ○ Paraffins, Isoparaffins, Aromatics, Napthenes, and Olefins (PIANO); and ○ Metabolites of aromatic compounds by high performance liquid chromatography (HPLC) or gas chromatography-mass spectroscopy (GC-MS). • Changes in fish resource stocks: ○ Stock assessments. Where relevant, data available from DPIRD, including catch/effort data, will be assessed to determine potential changes from baseline levels in fishing grounds potentially affected by an oil spill compared to after the event. <u>Commercial Fisheries</u> Samples of commercial fishes including shellfish may be obtained from licensed fishers, either by commissioning the licence holder to collect the fish directly (preferable), or by purchasing fish/shellfish from licensed fishers portioning in the area. If purchasing fish/shellfish, the location at which the fish/shellfish were caught must be clearly identified. The collection method should be suitable for the target species and may include baited demersal fish traps, single lure lines, baited pots and trawler nets. Samples may also be obtained from catch landing sites for operational fisheries. <u>Aquaculture Facilities</u> If particular aquaculture facilities have been contacted or are likely to be contacted by the hydrocarbon release, then targeted monitoring should occur. For example, if areas where wild stocks of Pinctada maxima are collected for the pearling industry are exposed to hydrocarbons then exposure and reference sites should be selected to monitor the impact to this fishery. <u>Recreational fisheries</u> Sampling to obtain fish targeted by recreational fishers should be undertaken via targeted fishing surveys conducted by a survey team at known recreational fishing locations. If fish kills are observed, whole specimens will be obtained and preserved (frozen) for necropsy to determine the cause of death.
Scope of works	Prepared by monitoring provider for issue within 24 hours of this SMP being activated.
Resources	• Senior marine scientist; • Specialist sampling team (2 to 3 people); • NATA accredited laboratory for sample analysis; and • Logistics in place for collection and transport of samples from field team to receiving laboratories within recommended sample holding times. • Suitable vessel, either existing commercial fisher form area or vessel with: ○ Appropriate fishing gear for target species ○ Lifting equipment (winch, davit/crane/A-frame) sufficient for safe deployment of proposed equipment; ○ 240V power supply to rear deck may be required; ○ Refrigerator/freezers sufficient for expected sampling volumes (e.g. 1 week of sampling effort) or space to install;

SMP-9 –Fisheries monitoring	
	○ Area suitable for sample processing (lab or workshop) away from potential contamination sources or space to install lab container; and • Ability to maintain station in expected conditions for duration of expected sampling times.
Implementation	Service provider to be able to mobilise within 72 hours of the scope of work having been approved by Western Gas (this time allowing for costing, preparation of equipment and disposables and travel to site). Actual mobilisation time will depend on the decision to adopt post-spill pre-impact monitoring and spill timing requirements.
Analysis and reporting	NATA-accredited laboratories will be employed for health analyses. Data will be entered to spatially explicit database and analysed to test for statistically significant differences between non-impacted and impacted fish assemblages. A final report that includes: • The impact of the spill event on commercial, recreational and aquaculture fisheries (including mortality, fish health and abundance, composition, distribution of commercial catches and of by-catches, age structure) and recovery of key process (i.e. Breeding). • Details of the impacts and subsequent recovery of fisheries in response to a spill event and associated response activities as well as comparisons of impact and reference sites, along with a determination of whether the termination criteria have been reached, including recommendations on the requirements of future monitoring. • Where appropriate, data provided by this monitoring should be integrated with data from other relevant SMPs to fully understand the three-dimensional distribution of the spill. • Any data outputs made available to other relevant SMPs.

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Appendix A: Time-based breakdown of monitoring responses to spill

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Table 1-1: Time-based breakdown of monitoring responses to spill, based on Scenario 1 as outlined in the Equus Gas Project spill modelling (RPS Group 2019).

Location	Monitoring Type	0 - 48 hrs	72 hrs	96 hrs	Seven days	> =Two weeks
Spill site and immediate waters	OM	Initiation of: OMP1 – Hydrocarbon characterisation and weathering OMP2 – Desktop pre-emptive assessment of receptors at risk OMP5 - Hydrocarbon spill modelling	Scope of works prepared for: • OMP3 – Water quality • OMP4 – Sediment quality • OMP5 – Oil encounter rate • Implementation in progress. • OMP6 - Marine fauna assessment	Results from OMPs are continuously integrated into the IAP process for the next operational period and are re-designed/re-allocated as required given the specifics of the actual spill scenario.	Results from OMPs are continuously integrated into the IAP process for the next operational period and are re-designed/re-allocated as required given the specifics of the actual spill scenario.	Results from OMPs are continuously integrated into the IAP process for the next operational period and are re-designed/re-allocated as required given the specifics of the actual spill scenario.
Spill site and immediate waters	SM	Activation	Mobilisation	Impact monitoring: SMP1 - Water Quality SMP2 - Sediment Quality SMP3- Benthic Habitat SMP4- Marine Mega-fauna (reptiles) SMP5 – Marine Mega-fauna (mammals) SMP6 – Seabirds and Shorebirds SMP7 – Marine fish assemblages SMP8 – Fisheries Gradient analysis throughout spill and non-spill zones established.	Impact monitoring continues for SMP 1-8	Impact monitoring continues for SMP 1-8 .

Location	Monitoring Type	0 - 48 hrs	72 hrs	96 hrs	Seven days	> =Two weeks
Spill extent and associated reference locations	OM	Initiation of: OMP1 – Hydrocarbon characterisation and weathering OMP2 – Desktop pre-emptive assessment of receptors at risk OMP5 - Hydrocarbon spill modelling	Scope of works prepared for: OMP3 – Water quality OMP4 – Sediment quality OMP5 – Oil encounter rate Implementation in progress. OMP6 - Marine fauna assessment	Results from OMPs are continuously integrated into the IAP process for the next operational period and are re-designed/re-allocated as required given the specifics of the actual spill scenario.	Results from OMPs are continuously integrated into the IAP process for the next operational period and are re-designed/re-allocated as required given the specifics of the actual spill scenario.	Results from OMPs are continuously integrated into the IAP process for the next operational period and are re-designed/re-allocated as required given the specifics of the actual spill scenario.

Location	Monitoring Type	0 - 48 hrs	72 hrs	96 hrs	Seven days	> =Two weeks
Spill extent and associated reference locations	SM	Activation	Mobilisation	Non-impact spatial controls established for range of monitored receptors. Gradient designs established Spatio-temporal impact monitoring: SMP1 - Water Quality SMP2 - Sediment Quality SMP3- Benthic Habitat SMP4- Marine Mega-fauna (reptiles) SMP5 – Marine Mega-fauna (mammals) SMP6 – Seabirds and Shorebirds SMP7 – Marine fish assemblages SMP8 – Fisheries	Non-impact spatial controls established for range of monitored receptors. Spatio-temporal impact/cleanup monitoring Gradient design monitoring continues. SMP1 - Water Quality SMP2 - Sediment Quality SMP3- Benthic Habitat SMP4- Marine Mega-fauna (reptiles) SMP5 – Marine Mega-fauna (mammals) SMP6 – Seabirds and Shorebirds SMP7 – Marine fish assemblages SMP8 – Fisheries	Spatio-temporal impact/cleanup monitoring: Gradient design monitoring continues. SMP1 - Water Quality SMP2 - Sediment Quality SMP3- Benthic Habitat SMP4- Marine Mega-fauna (reptiles) SMP5 – Marine Mega-fauna (mammals) SMP6 – Seabirds and Shorebirds SMP7 – Marine fish assemblages SMP8 – Fisheries

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Appendix B: Scientific Monitoring Data Analysis

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1 Data Analysis

1.1 Data Analysis

This section provides some comprehensive background to the issues that must be considered, and the design options that are available, in the event that an oil spill incident triggers scientific monitoring. The information is divided between:

- Regulator considerations – current NOPSEMA guidelines should be addressed.
- Comprehensive information on scientific monitoring designs
    - Gradient analysis
    - Control charts
    - Before After Control Impact
- A summary of the application, strengths and limitations of each design (Table 1)

According to NOPSEMA (2020), the scientific monitoring program design "must allow the impacts from the spill and response activities to be measured and to be separated from natural variation occurring in the environment". Due to their unplanned and accidental nature, hydrocarbon spills represent particular challenges in terms of statistical design and analysis (Skalski 1995). True replication and randomisation are generally limited. Unpredictability also precludes an ideal set of baseline at anticipated control and impact sites. However, the spatially fixed nature of an oil platform and oil spill trajectory modelling allows for some planning for likely baseline, impact and control data, but still with the proviso that any spill will largely be unpredictable before its initiation. It is in this environment that monitoring designs and analysis call for creative, flexible, pragmatic yet justifiable and reliable approaches.

Ideally, monitoring and analysis would incorporate the most comprehensive set of spatial and temporal variation possible. Incorporating both spatial and temporal data allows for a broad range of statistical and graphical approaches, such as generalised additive mixed models and control charts. For simplicity three separate methodologies which are used to detect environmental change, while accounting for natural variation in the environment are described here. Ideally, these approaches are integrated to optimize clarity, statistical power and robustness. The precise analytical approach will depend upon the variation in sites available and the availability and duration of the baseline data collected.

The three possible analytical approaches are described below and compared in Table 1. Gradient analysis focusses on the spatial component, Control Charts focus on the temporal component, while BACI designs are the simplest of the more sophisticated designs, combining both a spatial and temporal component.

1.1.1 Gradient Analysis

The most rudimentary of impact monitoring, generally focussing on the spatial component of post-spill impact is the gradient sampling design (Ellis and Schneider 1997). This approach was used to quantify hydrocarbon effects of the Montara oil spill on fish health (Gagnon and Rawson 2011). Sites are sampled at varying distances from the source of disturbance (e.g. the emission point of an oil spill). The gradient sampling design is used to detect the extent of impact, and to understand how the intensity of a disturbance determines the degree of impact (assuming that the disturbance is of

lower intensity the further away it is from its original point source). Analysis of data from the gradient sampling design is generally regression analysis, but can incorporate a range of analytical approaches including GAMs (Generalised additive models) which allow greater flexibility (Figure 1). The advantage of Gradient analysis is that it can be established post spill. The disadvantage is that the spill is not randomly located and its location may be confounded with underlying environmental variables. This is best dealt with by incorporating environmental covariates into the statistical model, as was performed in relation to the Deepwater Horizon blowout (Montagna et al. 2013).

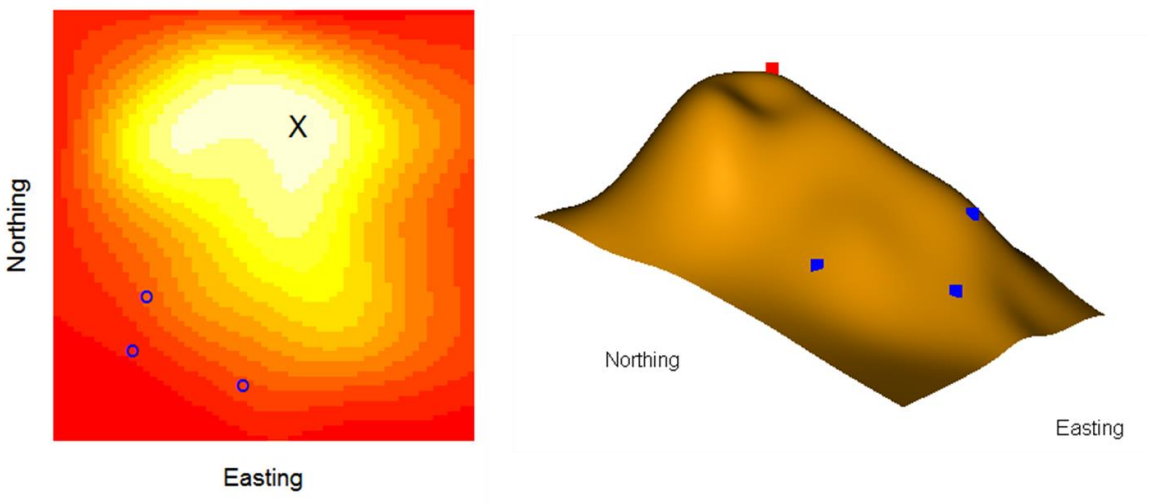

Figure 1: An example of gradient analysis, including a fitted Generalised Additive Model in three dimensions. The relationship is between a hydrocarbon concentration and distance from source ("X" or red dot).

1.1.2 Statistical Control Charts

Statistical control charts are a "means of displaying monitoring information in simple, practical and scientifically credible ways…" (Burgman et al. 2012) and are increasingly applied to environmental monitoring and to identify significant environmental change (Anderson and Thompson 2004, Gove et al. 2013, Stringell et al. 2013). Control charts are produced using data collected over a series of time steps. Control limits are determined from an initial 'reference' period and are a function of the variation around the long-term mean of the recorded data. In terms of oil spill monitoring, this would usually be a period prior to a disturbance event. Once a disturbance has occurred, if a measurement exceeds the control limits, then a significant impact of disturbance is indicated. Control charts are monitored until the variable of interest returns to within the control limits.

In terms of current on-going monitoring programs, these data serve as baseline data, used to populate control charts. Based on this data, control limits are estimated, and further post spill data are incorporated as it becomes available in order to quantify environmental impact. To increase strength of inference control charts should be created for each treatment (impacted and non-impacted). In particular, control charts provide implicit termination criteria for scientific monitoring by indicating when the variable of interest has returned to reasonable and tolerable values.

A particular advantage of statistical control charts is their ability to account for natural variation through time, and hence significant temporal changes in biological communities may be detected even when monitoring has been conducted at only one site. The critical requirement for statistical control charts is that at any given site, there is a sufficiently long reference period to capture the full extent of natural variation in biological communities at that site. There should also not be increasing

or decreasing trends in the variable of interest in the reference period. If no pre-spill baseline data is available, alternative approaches include deriving control limits from knowledge of the biological system or pre-determined thresholds (see below). The following sections summarise three variations of control charts, each appropriate for a particular type of data.

1.1.3 Univariate Control Charts

When one wishes to analyse one variable at a time, a univariate control chart may be used (Montgomery 2007, Gove et al. 2013). Examples of such variable are total percentage cover of coral in a transect, percentage cover of mangrove in a transect or remotely sensed image, or the number of breeding pairs of a species of seabird (Figure 2).

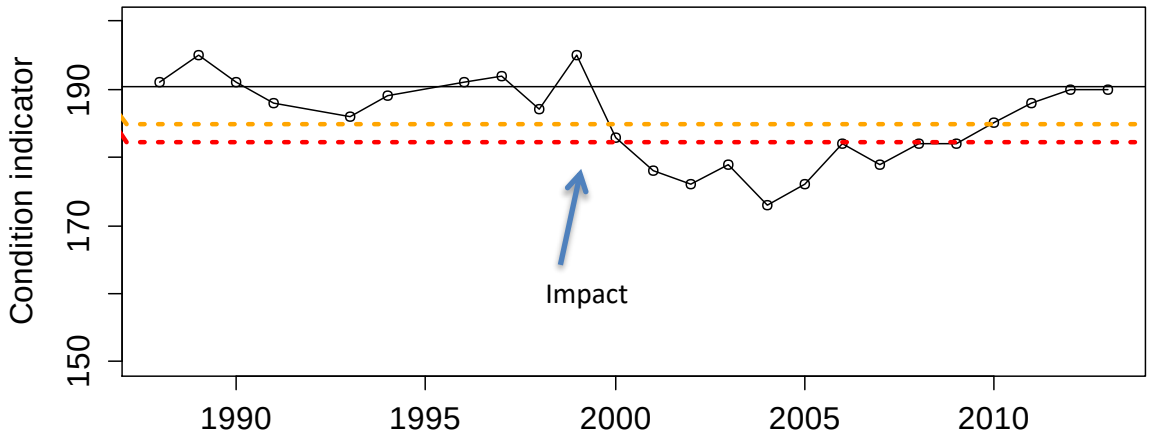

Figure 2: An example of univariate statistical control chart, changes to mangrove vegetation. The solid dark line represents the long-term mean of the condition indicator. The dotted yellow line represents the mean – 2 SD, and the dotted red line, mean – 3 SD. Following a disturbance in 1999, the initial control limit was breached, and in 2001, the final control limit was breached. Mangrove condition recovered to pre-impact levels in 2010.

1.1.4 Multivariate Control Charts

Multivariate control charts are used to examine changes in the whole species assemblage rather than a single species (Anderson and Thompson 2004; Figure 3).

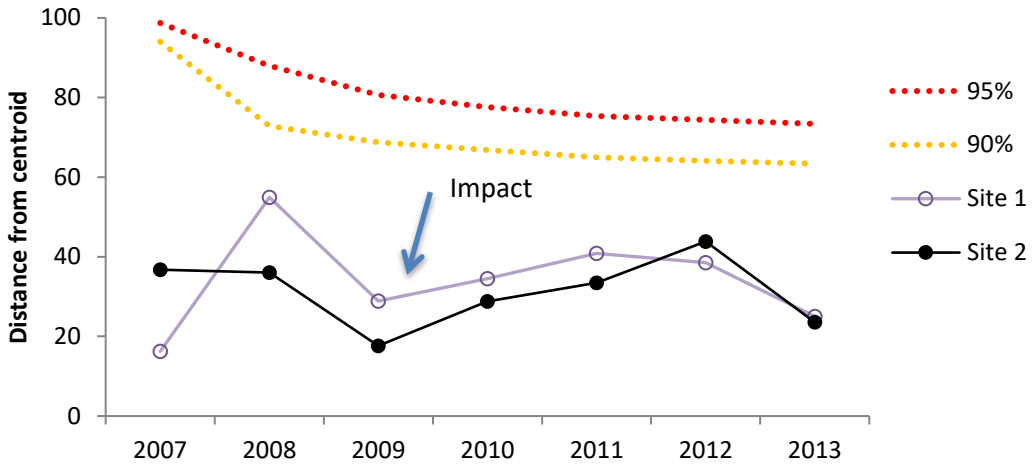

Figure 3: A multivariate control chart, demonstrating changes in the composition of a bird assemblage at two sites. No large changes in the breeding bird composition can be detected at any of the two sites studied, hence in an environmental report card, this value would appear as a green light. The results represent a summary of temporal change in the composition of breeding birds at each site. The value on the y-axis (i.e. distance from centroid) represents the change from the previous years. For example, the value for 2007 is the change from 2006. The value for 2008 is the change from the mean of 2006 and 2007.

There are challenges in interpreting multivariate control charts. Firstly, multivariate control charts do not show the direction of change and therefore it is not possible to link compositional change to particular variables (in this example, species). Secondly, defining significantly large changes is challenging. In Figure 3 the two dotted lines delineate a measure of likelihood of a change occurring. An observation above the 95% line would be unlikely (5%) to be purely by chance.

1.1.5 Reference Control Charts

Reference control charts are similar to statistical control charts in that the time-series data are used but differ in that the control limits are not set by variation in baseline data but are set by an understanding of the biological communities in question or regulatory requirements (Figure 4).

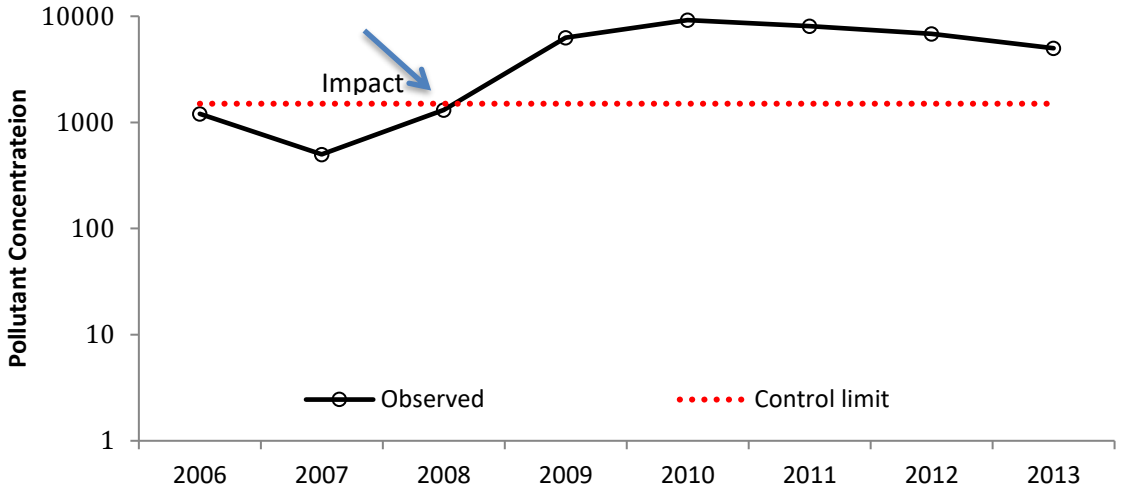

Figure 4: An example of reference control chart demonstrating changes in water quality in reference to an established pollutant threshold.

1.1.6 BACI Design

BACI designs are a popular experimental design used for detecting impacts of disturbance (Stewart-Oaten and Bence 2001). In contemporary statistics, BACI is not so much a discrete approach as one point on a broad continuum of statistical frameworks allowed by procedures such as Mixed Models. Sampling units are established both in areas that are expected to be disturbed and in adjacent areas (with similar biological communities) that are expected to remain undisturbed. The monitoring is carried out prior to the disturbance and continued after the disturbance, and therefore this type of design will often be most effective if it can take advantage of pre-impact conditions (Figure 5).

In terms of current on-going monitoring programs, such established sites would represent the "before" condition, and following the impact, some of these sites would be "impact" sites, while others would be "control" sites. Individual BACI designs may be tested for each receptor of interest.

Analysis of data from BACI designs is essentially a two-way analysis of variance with time (Before-After) as one factor and disturbance (Control-Impact) as another factor (Gotelli and Ellison 2004). The effects of disturbance can be detected when there is significant interaction between time and disturbance (resulting from significant difference between Control and Impact after the disturbance).

The major advantage of data from BACI design is that changes in biological communities due to factors other than impact can be factored out by careful experimental design. This design has been further developed to include MBACI (Multiple Before-after, Control-impact) designs (BACI with multiple and independent disturbed sites, Roberts et al. 2007), and within a mixed-effect model framework in which both unbalanced designs resulting from the MBACI framework and pseudo-replication (Hurlbert 1984, Underwood 1994) are properly accounted for (e.g. only one potentially impacted site is available, and so any replicate samples of the disturbed site does not accurately inform any site-to-site differences in impact). If the impact of an oil spill is geographically widespread, then it may be possible to collect data from multiple and independent disturbed sites.

For monitoring programs in marine environments, BACI designs may not be effective in detecting signs of disturbance because biological communities in marine environments tend to undergo large natural variations (Underwood 1991, 1994). Hence understanding the natural variation inherent in datasets and the consequences for interpretation is an important consideration. The critical requirement in BACI design is to locate control/analogue sites that are environmentally similar to the impact site(s). In scientific monitoring, sampling units may be established after the oil spill if the purpose was to detect recovery of impacted sites.

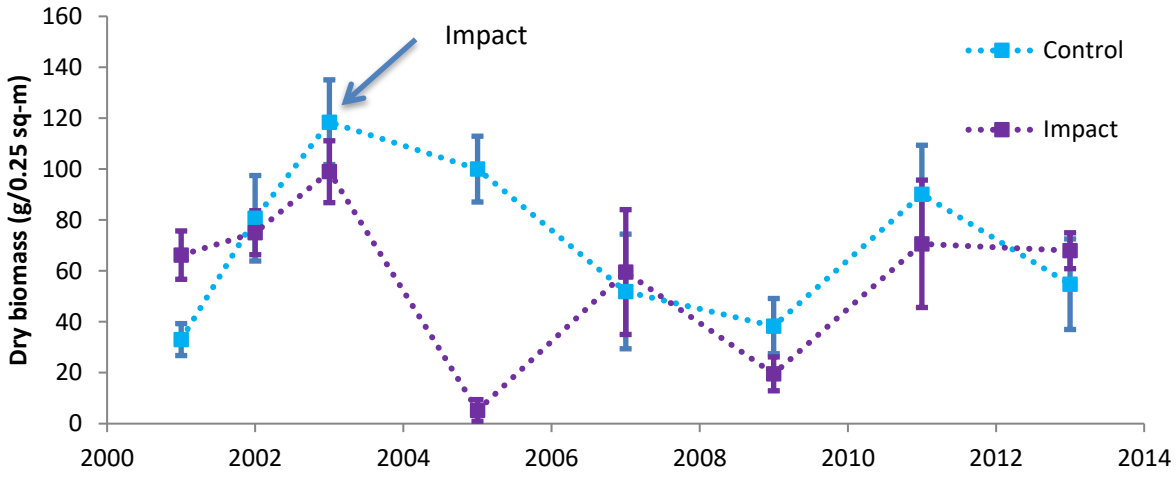

Figure 5: An example of monitoring results using BACI design based on the dry biomass of algae. In 2003, an impact has occurred, and the impact site has responded with a significant decline in biomass. By 2007 the impact site has recovered to levels similar to that of the control site. Error bars represent standard errors.

Table 1: Summary of data analysis techniques.

Analysis type		Description	Strengths	Limitations	Addressing limitations
Gradient analysis		Impact is quantified in terms of distance from spill	Can be established post-spill	Doesn't account for inherent spatial patterns present prior to spill	Include spatial covariates in model. Incorporate a temporal component.
Control chart	Univariate	Single variable is monitored and plotted over time, and breaching of control limits tested.	Control sites are not required. Takes account of natural variation in system.	Control limits do not necessarily have biological meaning. Doesn't control for broader spatial scale temporal variation.	Include control charts for control sites which incorporate broad scale temporal variation.
	Multivariate	Multiple variables are combined, monitored and plotted over time, and breaching of control limits tested.	Ability to combine suite of data (e.g., community composition) into one variable. Sites plots not required.	Individual responses are masked. Control limits do not necessarily have biological meaning. Significant control limits challenging to define. Direction of change is undefined.	Compliment with graphical approaches to identify direction of change and individual species responses.
	Reference	Control limits are based on knowledge of biological system (e.g., minimum viable population size, toxicity)	Control limits have recognised biological meaning or consequence.	Control limits may be considered arbitrary.	Use established standards for control limits.
Before-After, Control-Impact (BACI)		Quantifies state before and after potential impact, and also at impacted and control sites. Impact is tested by statistical interaction of terms.	Controls for natural variation, by incorporating control sites.	Limited power to detect significant impact. Requires appropriate matching of control (non-impacted) sites. Requires pre-impact data.	Increase power by increasing temporal component. Choose indicators with low natural variability.

1.2 Monitoring Designs and Statistical Power

Monitoring designs aimed detecting impact are required to consider the relative importance of Type I and Type II errors in statistical analyses and their relationship to high natural variability often seen in such system. Type I error is the risk of concluding an impact has occurred when in fact it hasn't (conventionally, this is most often set at 5%) while Type II is the risk of concluding there is no impact when in fact there has been an impact (ie., the impact has gone undetected). Traditional experimental designs are generally focused on the rejection of the null hypothesis and Type I errors, (hence emphasis on "P<0.05" as a test of significance) whereas in impact monitoring the concern should be primarily the risk of Type II errors (Burgman et al. 2012) – the risk that an operator causes an impact which goes undetected.

Environmental monitoring programs risk having no realistic chance of detecting significant impacts because they are prone to Type II errors due to high natural variability in these values (Osenberg et al. 1994, Underwood 1994, Field et al. 2006, Legg and Nagy 2006). Although less frequently explored, the Type II error rate is conventionally set at 20% (e.g., Chevron 2014), however this is generally considered too high where environmental values at risk are of high value (Burgman et al. 2012).

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Appendix C: Baseline Data Held by Western Gas

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Study	Reference	Overview
Sediment and infauna	RPS (2012). Sediment and Infauna - Field Survey Report. Hess Equus Project Environmental Impact Assessment. Report M11112/12:2. RPS, Perth, WA	• Objective - to describe the existing physicochemical • characteristics of the surface sediments and characterise infaunal community to inform assessment of potential impacts • Homogenous sediments and benthic habitat across project area • Sediments collected from the permit area were homogenous and free from contamination. • Infaunal diversity and relative abundance was considered low and generally typical of deep water sediments.
Water quality	RPS (2012). Baseline Water Quality Study - Field Survey Report - Hess Equus Gas Fields Development Project Environmental Impact Assessment. Report M11112/15. RPS, Perth, WA	• Summarises the results of the three seasonal baseline surveys (post exploratory drilling campaign) for the physicochemical environment of the Permit Area (WA-390-P). • The analyses of the vertical structure of physical, chemical and phytoplankton characteristics of the water column within the Hess permit area consistently show that the greatest changes are related to depth, with relatively little horizontal difference between sites from the same depth.
Seabirds and shorebirds	Desktop Review of Migratory Birds and Seabirds - Hess Equus Gas Fields Development Project Environmental Impact Assessment Document #: EQ1-ENV-RPT-01015-1	Desktop review of migratory birds and seabirds and assessment of potential impacts on birds and their habitat.
Marine fauna	RPS (2012). Desktop Review of Marine Fauna - Hess Equus Gas Fields Development Project Environmental Impact Assessment. Report M11112/05. RPS, Perth, WA	Desktop review of marine fauna to identify any sensitive marine fauna and their habitats and assess potential impacts of the project.
Benthic habitats	Benthic Habitats, Benthic Biota and Sediment Quality Technical Report – Hess Equus Project Environmental Impact Assessment Document #: EQ1-ENV-RPT-01012-0	• Provides detailed baseline information on the marine benthic habitats, benthic biota and sediments. • Collates information provided by: o ROV surveys o High res bathymetric data o Sediment quality surveys o Infaunal surveys o Sediment geotech studies • Includes baseline information re: NORM, hydrocarbon levels, nutrients and TOC, heavy metals.

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