5. IMPACT DESCRIPTION AND ASSESSMENT

This chapter describes and assesses the significance of potential impacts related to Shell's proposed exploration drilling programme within the area of interest in the Orange Basin Deep Water Licence Area and associated alternatives. All impacts are systematically assessed and presented according to predefined rating scales (see Appendix 3.1). Mitigation or optimisation measures are proposed which could ameliorate the negative impacts or enhance potential benefits, respectively. The status of all impacts should be considered to be negative unless otherwise indicated. The significance of impacts with and without mitigation is also assessed.

Three specialist studies were undertaken to address the key issues that required further investigation, namely; (1) cuttings and oil spill modelling (see Appendix 3.2), (2) the impact on commercial fishing catch and effort (see Appendix 3.3), and (3) the impact on marine fauna (see Appendix 3.4). In addition, this assessment used as a basis the issues identified in the Generic EMPr prepared for exploration drilling off the coast of South Africa (CCA and CMS 2001) and similar studies. The project team have assessed the relevance of these issues to this project.

Sections 5.1 to 5.5 assess impacts related to the proposed project and associated alternatives assuming a normal operations scenario, where it is assumed that operations proceed smoothly and without any major incidents (i.e. no major oil spills). Section 5.6 assesses the cumulative impact on the benthic environment and fishing industry. The potential impacts of accidental oil spill scenarios (upset conditions) are assessed in Section 5.7. The implications of not going ahead with the proposed project (i.e. the No-Go Alternative) are assessed in Section 5.8.

5.1 IMPACT OF NORMAL DRILLING UNIT, SUPPORT VESSELS, AIRCRAFT / HELICOPTER OPERATION AND WELL TESTING

5.1.1 EMISSIONS TO THE ATMOSPHERE

<u>Description of impact</u>

The main sources of air emissions (continuous or non-continuous) resulting from offshore drilling activities include:

- Exhaust gas emissions produced by the combustion of gas or liquid fuels in turbines, boilers, compressors, pumps and other engines for power and heat generation on offshore facilities including support / supply vessels and helicopters. This can be the most significant source of air emissions from offshore facilities;
- Fugitive emissions associated with leaking tubing, valves, connections, flanges, open-ended lines, pump seals, compressor seals, pressure relief valves or tanks, and hydrocarbon loading and unloading operations; and
- Well testing and associated venting and flaring of hydrocarbons. During well testing it may be necessary to vent or flare off some of the oil and gas brought to the surface. Flaring and venting is also an important safety measure used to ensure gas and other hydrocarbons are safety disposed of in the event of an emergency, power or equipment failure or other plant upset conditions.

Principal pollutants from these sources include nitrogen oxides (NO_X), sulphur oxides (SO_X), carbon monoxide (CO) and particulates. Additional pollutants can include: hydrogen sulphide (H_2S); Volatile Organic Compounds (VOC) methane and ethane; benzene, ethyl benzene, toluene and xylenes (BTEX); glycols; and polycyclic aromatic hydrocarbons (PAHs). Many of these compounds are known to contribute to atmospheric problems such as the greenhouse effect and ozone depletion.

Assessment

Fuel consumption of a standard semi-submersible drilling unit is estimated to be between 75 and 100 bbl/day. Typical emissions resulting from this consumption are indicated below:

- CO_2 = 32 tons/day;
- NO_2 = 0.6 tons/day; and
- CO = 0.015 tons/day (CCA & CMS 2001).

Note: These levels are based on standard fuel emission factors for each compound.

Additional air emissions would be generated by positioning the drilling unit and operation of all support vessels, fixed wing aircrafts (e.g. ATR42/72, B1900 or Embrear 120) and helicopters (e.g. Eurocopter EC225, S92 or AW 139/189). Emissions from support vessels would be similar to those from similar diesel-powered vessel of comparable tonnage (approximately 3 000 tonnes).

Flow testing would result in hydrocarbons being burned at the well site. A high-efficiency flare would be used to maximise combustion of the hydrocarbons. The duration of flow testing and the amount of hydrocarbons produced would depend on the quality of the reservoir but is kept to a minimum to avoid wasting potentially marketable oil and/or gas. Although the final well test programme would be prepared when the detailed geology and fluids are defined, it is estimated that the duration of flaring would be in the order of two to five days.

Based on the location of the area of interest (approximately 230 km offshore at its closest point) it is not expected that such emissions would have a direct effect on any other activity. The potential impact of emissions due to drilling activities related to the drilling unit (both alternatives) and support vessels would be essentially limited to the drilling area, of low intensity over the short-term (three months per well) and is considered to be of **VERY LOW** significance with or without the implementation of mitigation measures (see Table 5.1).

Mitigation

- All diesel motors and generators should receive adequate maintenance to minimise soot and unburnt diesel released to the atmosphere;
- Leak detection and repair programmes should be implemented for valves, flanges, fittings, seals, etc.;
- The following pollution prevention and control measures are proposed for gas flaring[4]:
  - A high-efficiency burner should be used for flaring (as proposed) in order to minimise emissions and hydrocarbon 'drop-out' during well testing;
  - Only the minimum volume of hydrocarbons required for the test should be flowed, without compromising safety, and well test durations should be reduced to the extent practical;
  - Flare combustion efficiency should be maximised by controlling and optimising flare fuel/air/stream flow rates;
  - The risk of pilot blow-out should be minimised by ensuring sufficient exit velocity and providing wind guards;
  - Where appropriate, a high integrity instrument pressure protection system should be used to reduce over pressure events;
  - Liquid carry over and entrainment in the flare stream should be minimised with a suitable liquid separation system;
  - Flame lift off and / or flame lick should be minimised; and
  - Odour and visible smoke emissions (no visible black smoke) should be monitored and controlled.

[4] Based on the International Finance Corporation's (IFC) Environmental, Health and Safety Guidelines for offshore oil and gas development, April 2007.

Table 5.1: Impact of atmospheric emissions from drilling unit, support operations and flow testing.

	Extent	Duration	Intensity	Probability	Significance	Confidence
Without mitigation	Local	Short-term	Low	Definite	**Very Low**	High
With mitigation	Local	Short-term	Low	Definite	**VERY LOW**	High

5.1.2 DISCHARGES/DISPOSAL TO THE SEA

Normal discharges to the marine environment occur from a variety of sources, including deck drainage, machinery space drainage, sewage, galley wastes and solid wastes from the drilling unit and support vessels. The sections below are applicable to both drilling unit options.

5.1.2.1 Deck Drainage

Description of impact

Drainage of deck areas from precipitation, sea spray or routine operations (e.g. deck and equipment cleaning and fire drills) may result in small volumes of oils, solvents or cleaners being introduced into the marine environment.

Assessment

The discharge into the sea of any oil or oily mixture that may originate from a drilling unit is prohibited in terms of Regulation 21 of MARPOL (Annex I) except when the oil content of the discharge without dilution does not exceed 15 ppm. To ensure MARPOL compliance all deck drainage from work spaces should be collected and piped into a sump tank on-board the drilling unit for treatment prior to discharge. Drainage from marine (weather) deck spaces would be discharged directly overboard. Oily waste substances would be shipped to land for treatment and disposal.

Based on the small volumes, distance offshore and high energy sea conditions, the potential impact of deck drainage from the drilling unit (both alternatives) and support vessels on the marine environment would be of low intensity, short-term duration and essentially limited to the immediate area around the drilling area. The potential impact of deck drainage on the marine environment is therefore considered to be of **VERY LOW** significance with or without mitigation (see Table 5.2).

Mitigation

The following measures are recommended for mitigation of deck drainage discharges from vessels:

- A Shipboard Oil Pollution Emergency Plan (SOPEP) must be prepared for the drilling unit and all other vessels and be in place at all times during operation;
- Deck drainage should be routed to a separate drainage system (oily water catchment system) for treatment to ensure compliance with MARPOL (15 ppm);
- All process areas should be bunded to ensure drainage water flows into the closed drainage system;
- Drip trays should be used to collect run-off from equipment that is not contained within a bunded area and the contents routed to the closed drainage system;
- Low-toxicity biodegradable detergents should be used in cleaning of all deck spillage;
- All hydraulic systems should be adequately maintained and hydraulic hoses should be frequently inspected; and

- Spill management training and awareness should be provided to crew members of the need for thorough cleaning-up of any spillages immediately after they occur in order to minimise the volume of contaminants washing off decks.

Table 5.2: Impact of deck drainage from drilling unit and support vessels.

	Extent	Duration	Intensity	Probability	Significance	Confidence
Without mitigation	Local	Short-term	Low	Highly Probable	**Very Low**	High
With mitigation	Local	Short-term	Low	Highly Probable	**VERY LOW**	High

5.1.2.2 Machinery space drainage

Description of impact

Small volumes of oil such as diesel fuel, lubricants, grease, etc. used within the machinery space of the vessels could enter the marine environment.

Assessment

All operations would comply fully with international agreed standards regulated under MARPOL 73/78. All machinery space drainage would pass through an oil/water filter to reduce the oil in water concentration to 15 ppm, in accordance with Regulation 21 of MARPOL (Annex I). Concentrations of oil reaching the marine environment through drainage of machinery spaces are therefore expected to be low.

Based on the small volumes, distance offshore and high energy sea conditions, the potential impact of machinery space drainage from the drilling unit (both alternatives) and support vessels would be of low intensity, short-term duration and essentially limited to the immediate area around the drilling area. The potential impact of machinery space drainage on the marine environment is therefore considered to be of **VERY LOW** significance with or without mitigation (see Table 5.3).

Mitigation

Mitigation is as for deck drainage (see Section 5.1.2.1).

Table 5.3: Impact of machinery space drainage from drilling unit and support vessels.

	Extent	Duration	Intensity	Probability	Significance	Confidence
Without mitigation	Local	Short-term	Low	Highly Probable	**Very Low**	High
With mitigation	Local	Short-term	Low	Highly Probable	**VERY LOW**	High

5.1.2.3 Sewage

Description of impact

Sewage poses an organic and bacterial loading on the natural degradation processes of the sea, resulting in an increased biological oxygen demand.

Assessment

The volumes of sewage wastes released from a drilling unit would be small and comparable to volumes produced by vessels of similar crew compliment (i.e. 100 to 150 personnel). All sewage would be treated to the required MARPOL 73/78 standard prior to release into the marine environment, where the high wind and wave energy conditions are expected to result in rapid dispersal. MARPOL Annex IV requires that sewage discharged from vessels be comminuted and disinfected and that the effluent must not produce visible floating solids in, nor cause discoloration of, the surrounding water. The treatment system must provide primary settling, chlorination and dechlorination before the treated effluent can be discharged into the sea. The discharge depth is variable, depending upon the draught of the drilling unit and support vessel at the time, but would not be less than 5 m below the surface.

Based on the small volumes, distance offshore and high energy sea conditions, the potential impact of sewage effluent from the drilling unit (both alternatives) and support vessels on the marine environment would be of low intensity, short-term duration and essentially limited to the immediate area around the drilling area. The potential impact of sewage on the marine environment is therefore considered to be of **VERY LOW** significance with or without mitigation (see Table 5.4).

<u>Mitigation</u>
Ensure compliance with MARPOL 73/78 standards.

Table 5.4: Impact of sewage effluent discharge from drilling unit and support vessels.

	Extent	Duration	Intensity	Probability	Significance	Confidence
Without mitigation	Local	Short-term	Low	Highly Probable	**Very Low**	High
With mitigation	Local	Short-term	Low	Highly Probable	**VERY LOW**	High

5.1.2.4 Galley waste

<u>Description of impact</u>
Galley wastes, comprising mostly of biodegradable food waste, would place a small organic and bacterial loading on the marine environment.

<u>Assessment</u>
The volume of galley waste from the drilling unit would be small and comparable to wastes from any vessel of a similar crew compliment (i.e. 100 to 150 personnel). The daily discharge from a drilling unit is typically about 0.2 m^3 (CCA & CMS 2001). Discharges of galley wastes, according to MARPOL 73/78 standards, would be comminuted to particle sizes smaller than 25 mm prior to disposal to the marine environment and no disposal within 3 nautical miles (± 5.5 km) of the coast.

Based on the small volumes, distance offshore and high energy sea conditions, the potential impact of galley waste disposal from the drilling unit (both alternatives) and support vessels on the marine environment would be of low intensity, short-term duration and essentially limited to the immediate area around the drilling area. The potential impact of galley waste on the marine environment is therefore considered to be of **VERY LOW** significance with or without mitigation (see Table 5.5).

<u>Mitigation</u>
Ensure compliance with MARPOL 73/78 standards.

Table 5.5: Impact of galley waste disposal from drilling unit and support vessels.

	Extent	Duration	Intensity	Probability	Significance	Confidence
Without mitigation	Local	Short-term	Low	Highly Probable	**Very Low**	High
With mitigation	Local	Short-term	Low	Highly Probable	**VERY LOW**	High

5.1.2.5 Solid waste

Description of impact
The accidental release of solid waste comprising non-biodegradable domestic waste, packaging and operational industrial waste into the sea could pose a hazard to marine fauna, may contain contaminant chemicals and could end up as visual pollution at sea, on the seashore or on the seabed.

Assessment
Solid waste generated during the exploration activities (excluding galley waste) would be transported to shore for disposal at a licensed landfill facility or an alternative approved facility. Consequently there would be no impact on the marine environment. However, there could be incidents (e.g. blown by wind) which could result in a small amount of waste entering the marine environment.

The potential impact of the disposal of solid waste from the drilling unit (both alternatives) and support vessels on the marine environment is therefore considered to be **INSIGNIFICANT** (see Table 5.6).

Mitigation
The following measures are recommended for the mitigation of waste:
- Initiate a waste minimisation system on board all vessels;
- On-board solid waste storage is to be secure; and
- The disposal of waste (solid and hazardous) onshore must be in accordance with the appropriate laws and ordinances.

Table 5.6: Impact of solid waste disposal from drilling unit and support vessels.

	Extent	Duration	Intensity	Probability	Significance	Confidence
Without mitigation	Local	Short-term	Zero	Improbable	**Insignificant**	Medium
With mitigation	Local	Short-term	Zero	Improbable	**INSIGNIFICANT**	Medium

5.1.3 NOISE FROM DRILLING VESSEL, SUPPORT VESSELS AND AIRCRAFT / HELICOPTER OPERATIONS

5.1.3.1 Noise from drilling and support vessel operations

Impact description
The noise from the drilling and support vessels could result in localised disturbance of marine fauna (note: noise from actual drilling operations is assessed in Section 5.2.3).

Impact assessment
Noise from a drilling and support vessels is likely to be no higher than those from other shipping vessels in the region. Underwater noise from the drill and support vessels is not considered to be of sufficient amplitude to cause direct harm to marine life.

The potential impact of noise generated by the drilling unit (both alternatives) and support vessels on marine fauna is considered to be localised, of low intensity in the short-term. The significance of this impact is therefore assessed to be **VERY LOW** with and without mitigation (Table 5.7).

Mitigation measures
No measures are deemed necessary to mitigate noise impacts from drilling and support vessel operations.

Table 5.7: Impact of noise from drilling and support vessel operations.

	Extent	Duration	Intensity	Probability	Significance	Confidence
Without mitigation	Local	Short-term	Low	Probable	**Very Low**	Medium
With mitigation	No mitigation is considered necessary.					

5.1.3.2 Noise from aircraft / helicopter operations

Impact description

Transportation of personnel to and from the drilling unit would most likely be provided by helicopter operations (e.g. Eurocopter EC225, S92 or AW 139/189) from the Kleinzee airport, while transportation to Kleinzee would be provided by fixed-wing flights (e.g. ATR42/72, B1900 or Embrear 120) from Cape Town. These operations could result in localised disturbance of fauna (seal and seabird colonies).

Impact assessment

Although reported behavioural reactions by seabirds, turtles and whales to aircrafts are highly variable and often anecdotal, it is safe to assume that any observed effects as a result of the aircraft and helicopter support would be in response to both acoustic and visual cues.

Low altitude flights (especially near the coast) can have a significant disturbance impact on cetaceans during their breeding and mating season. The level of disturbance would depend on the distance and altitude of the aircraft from the animals (particularly the angle of incidence to the water surface) and the prevailing sea conditions. In terms of the Marine Living Resources Act, 1998 (No. 18 of 1998) it is illegal for any vessel or aircraft to, without a permit or exemption, approach to within 300 m of whales within South African waters.

Similarly, low altitude flights over bird breeding colonies could result in temporary abandonment of nests and exposure of eggs and chicks leading to increased predation risk. The nearest seabird colonies are at Bird Island in Lamberts Bay and Sinclair Island in Namibia, 300 km to the south and 260 km to the north of Kleinzee, respectively. The Orange River RAMSAR site and IBA is located 130 km north of Kleinzee. Due to the large distances between these locations and Kleinzee they would to not be influenced by aircrafts travelling between Kleinzee and the drilling location or the fixed wing flight between Kleinzee and Cape Town.

Seals may also experience severe disturbance from low-flying aircraft usually reacting by showing a startle response and moving rapidly into the water. Although any observed response is usually short-lived, disturbance of breeding seals can lead to pup mortalities through abandonment or injury by fleeing, frightened adults. It is an offence in terms of the Seabirds and Seals Protection Act of 1973 to wilfully disturb seals on the coast or on offshore islands. Flight paths should thus avoid the seal colony at Kleinzee, which has the highest seal population and produces the highest number of pups on the South African coast.

Indiscriminate or direct flying over whales, seabird or seal colonies (or flying low level parallel to the coast) could have a significant disturbance impact on behaviour and breeding success. Although such impacts would be local in the area of the colony, they may have wider ramifications over the range of affected species and are deemed to range from low to high intensity. The significance of impact is considered to be **low** before mitigation. If the suggested mitigation measures are implemented, this impact is expected to be **VERY LOW** significance (see Table 5.8).

Mitigation measures

- All flight paths must be pre-planned to ensure that no flying occurs over coastal reserves (MacDougall's Bay), seal colonies (Buchu Twins, Kleinzee and Strandfontein Point), bird colonies (Bird

Island at Lambert's Bay) or Important Bird Areas (Orange River Mouth wetlands, Olifants River Estuary, Velorenvlei, Lower Berg River wetlands and the West Coast National Park and Saldanha Bay Islands);

- Extensive low altitude coastal flights (<2 500 ft and within 1 nm of the shore) should be avoided, particularly during the winter/spring (June to November inclusive) whale migration period and during the November to January seal breeding season. The flight path between the onshore logistics base in Kleinzee and drilling unit should be perpendicular to the coast. As no seasonal patterns of abundance are known for odontocetes occupying the proposed exploration area, a precautionary approach to avoiding impacts throughout the year is recommended;
- Aircrafts may not, without a permit or an exemption, approach to within 300 m of whales in terms of the Marine Living Resources Act, 1998. As this may be both impractical and impossible, it is recommended that an application for an exemption permit is made to DEA;
- The contractor should comply fully with aviation and authority guidelines and rules; and
- All pilots must be briefed on ecological risks associated with flying at a low level along the coast or above marine mammals.

Table 5.8: Impact of noise from helicopter operations.

	Extent	Duration	Intensity	Probability	Significance	Confidence
Without mitigation	Local	Short-term	Low to High	Probable	**Low**	Medium
With mitigation	Local	Short-term	Low	Probable	**VERY LOW**	Medium

5.2 IMPACT OF WELL DRILLING ON MARINE FAUNA

5.2.1 PHYSICAL DAMAGE AND SEDIMENT DISTURBANCE

Description of impact

Physical damage to the seabed and sediment disturbance could result from a number of activities, including:

- Drilling activities (e.g. localised removal of sediments and smothering); and
- Placement of wellheads and guide bases on seafloor, which would crush benthic epifauna.

Physical damage and disturbance has the potential to affect relatively immobile or sedentary benthic species directly and indirectly (e.g. loss of benthic prey items for bottom feeding species).

Assessment

Assuming an initial drill diameter of 36 inches (91 cm) during spudding, penetration of the seabed by the drill bit would disturb a surface area of approximately 0.65 m^2 per well and any benthic fauna present on the seabed and in the top 20 to 30 cm of sediment would be impacted. The installation of the wellhead (approximately 3 m^2) is also likely to result in localised disturbance of macrofauna in the immediate vicinity of the well site. Further loss or disturbance of the benthos due to smothering by disposal of drilling muds and cuttings is discussed further in Section 5.2.3.2. Since anchoring in the area of interest is not practical due to the water depths, there would be no additional disturbance from anchoring.

Sediment in the area of interest is dominated by muds and sandy muds (see Figure 4.5). Due to the high natural variability in benthic communities in the region, the structure of the communities in the area of interest would likely be highly spatially and temporally variable. The immediate effect on the benthos depends on their degree of mobility, with sedentary and relatively immobile species likely to be physically damaged or destroyed during the drilling disturbance. In the productive Benguela region, substantial areas on and off the edge of the continental shelf could potentially support deep water coral communities. These communities are sensitive to disturbance due to their long generation times.

Despite the current lack of knowledge of the community structure and endemicity of macro-infauna off the edge of the continental shelf, the South Atlantic bathyal and abyssal unconsolidated habitat types that characterise depths beyond 500 m are rated as 'Least Threatened' (see Figures 4.9 and 4.14). This primarily reflects the great extent of these habitats in the South African EEZ.

Considering the available area of similar habitat on and off the edge of the continental shelf in the Atlantic Offshore Bioregion, this minimal disturbance of and reduction in benthic biodiversity can be considered negligible, with no cascade effects on higher order consumers expected. Impacts on the offshore benthos as a result of physical damage and sediment disturbance are considered to be very localised. The intensity and duration of the impact depends on the substrate type with impacts on unconsolidated sediments being considered to be of medium intensity in the short-term (recovery is expected to take place within two to five years), while impacts on rock outcrops / reefs being considered to be of high intensity in the medium to long-term. Therefore, this impact on unconsolidated sediments is assessed to be of **VERY LOW** significance with and without mitigation, while the impact on rock outcrops / reefs is assessed to be of **medium** significance without mitigation and **VERY LOW** with mitigation (see Table 5.9).

Mitigation

- The existing 3D seismic data should be used to conduct a pre-drilling geohazard analysis of the seabed and near-surface substratum in order to map and avoid potentially vulnerable habitats; and
- A Remotely Operated Vehicle (ROV) should be used to survey the seafloor prior to drilling in order to confirm the presence or absence of any significant topographic features (e.g. rocky outcrops), vulnerable habitats (e.g. hard grounds) and / or species (e.g. cold-water corals, sponges) in the area. If detected, the well position should be adjusted to avoid drilling in the immediate vicinity of these vulnerable habitats.

Table 5.9: Assessment of impact of physical damage and sediment disturbance on offshore benthic communities.

	Extent	Duration	Intensity	Probability	Significance	Confidence
Unconsolidated sediments						
Without mitigation	Local	Short-term	Medium	Definite	**Very Low**	High
With mitigation	Local	Short-term	Medium	Definite	**VERY LOW**	High
Hard grounds / reefs						
Without mitigation	Local	Medium- to Long-term	High	Improbable	**Medium**	High
With mitigation	Local	Short-term	Medium	Improbable	**VERY LOW**	High

5.2.2 IMPACTS RELATED TO THE DISCHARGE OF CUTTINGS, DRILLING FLUID AND CEMENT

5.2.2.1 Introduction

As described in Chapter 3, during drilling cuttings would be discharged during both the riserless and risered drilling stages. These two stages are summarised again below:

- During the riserless drilling stage cuttings and drilling fluid (WBM) from the top-hole sections of the well would discharged directly onto the seafloor adjacent to the wellbore where they would primarily have smothering effects on benthic macrofauna. It is estimated that approximately 300 - 400 m^3 and 550 m^3 of cuttings and WBM, respectively, would be discharged directly on the seafloor. The cuttings discharged at the seabed during the spudding of a well would form a highly localised spoil mound around the wellbore, thinning outwards. The cone created by the cuttings is predicted to be in the order of 80 cm thick close to the wellbore, thinning outwards to a thickness of 3 cm at a radius of 120 m. The total predicted area affected by the discharges would thus be in the order of 0.045 km^2.

- Once the marine riser is connected, the drilling fluid (SBM including cuttings) is circulated up to the drilling unit where the drilling fluid is cleaned and the cuttings discharged into the sea. Before discharge, the drill cuttings would be treated to reduce their oil content to 6.9% or less of dry cuttings weight. The rate of cuttings discharge decreases with increasing well depth as the hole diameter becomes smaller and penetration rates decrease. The total volume of surface released cuttings during the risered drilling stage is estimated to be in the order of 150-200 m^3 for each well. These cuttings would contain approximately 235.5 mT of residual SBM. The cuttings discharged from the drilling unit form two plumes as they are discharged. The heavier cuttings and flocculated clay/barite particles (>0.2 mm), which typically constitute 83% of the discharge, settle to the seabed relatively near the wellbore while the fine-grained unflocculated solids and dissolved components of the mud (17% of the discharge) are dispersed in the water column at increasing distances from the drill unit. The dispersion pattern and degree of accumulation depends on water depth, current strength and the frequency of storm surges. The results of the cuttings dispersion modelling study (see Appendix 3.2) show that the significant depths at the well site, the moderate to strong current speeds and relatively low mass of cuttings discharged, result in the cuttings being spread over a large area (between 25.9 and 29.8 km^2), with relatively low deposition thicknesses of less than 1 mm predicted for distances greater than about 150 m from the well. It is also important to bear in mind that cuttings discharge would be intermittent as drilling operations occur for only one third to one half of the total time the drilling unit is on location.

The discharge of cuttings and drilling fluids could:

- smother of relatively immobile or sedentary benthic species (see Section 5.2.2.2);
- result in biochemical effects, including direct toxicity and bioaccumulation (see Sections 5.2.2.3 and 5.2.2.4);
- increase turbidity and reduce light for photosynthesis and foraging (see Section 5.2.2.5); and
- reduce oxygen levels in the near-surface sediment layers (see Section 5.2.2.6).

Each of these impacts is assessed below.

5.2.2.2 Smothering by cuttings and drilling fluid and plume turbidity

<u>Description of impact</u>

The primary impact of discharged cuttings and drilling fluid (or mud) is smothering of relatively immobile or sedentary benthic species both directly (e.g. mortality and clogging of feeding mechanisms) and indirectly (e.g. loss of benthic prey items for bottom feeding species, disturbance of migration routes and impact on those species that spawn on the seabed or have a benthic juvenile development stage).

<u>Assessment</u>

The effects of smothering on the receiving benthic macrofauna are determined by (1) the depth of burial; (2) the tolerance of species (life habitats, escape potential, tolerance to hypoxia, etc.); (3) the nature of the depositing sediments; and (4) duration of burial.

In areas where sedimentation is naturally high (e.g. wave-disturbed shallow waters) the ability of taxa to migrate through layers of deposited sediment is likely to be well developed. However, sedentary and relatively immobile species that occur in waters beyond the influence of aeolian and riverine inputs, such as the area of interest, would be more susceptible to smothering. Benthic and demersal species that spawn, lay eggs or have juvenile life stages dependent on the seafloor habitat (e.g. hake) may be negatively affected by smothering effects. Due to the offshore location of the area of interest, plankton abundance is expected to be low, with the major fish spawning and migration routes occurring further inshore on the shelf (see Figure 4.12 and 4.13).

Although there is considerable variability in species response to specific sediment characteristics, higher mortalities have been recorded when the deposited sediments have a different grain-size composition from that of the receiving environment, which would be the case in the discharge of drill cuttings. Migration ability and survival rates of organisms are generally lower in silty sediments than in coarser sediments. Provided the sedimentation rate of incidental deposition is not higher than the velocity at which the organisms can move or grow upwards, such deposition need not necessarily have negative effects.

Studies have found that changes in abundance and diversity of macrofaunal communities in response to deposited cuttings are typically detected within a few 100 m of the discharge, with recovery of the benthos observed to take from several months to several years after drilling operations had ceased. Substantial recovery is expected within a year. Many benthic infaunal species are able to burrow or move through the sediment matrix, and some infaunal species are able to actively migrate vertically through overlying deposited sediment thereby significantly affecting the recolonisation and subsequent recovery of impacted areas. Due to the high natural variability of benthic communities in the region, the structure of the recovering communities would likely be highly spatially and temporally variable. In addition, short-term physical disturbance resulting from exploration drilling would be no more stressful than the regular naturally occurring anoxic events typical of the West Coast continental shelf areas.

The smothering effects resulting from the discharge of drilling solids at the wellbore is assessed to have an impact of high intensity on the benthic macrofauna of unconsolidated sediments in the cuttings footprint, whereas discharges from the drilling unit would have a medium intensity impact. In both cases, the impact is highly localised and recovery is expected within a few years (2 to 5 years). The impact is thus considered to be of **LOW** significance for discharges at the wellbore and **VERY LOW** significance for discharges from the drilling unit, both with and without mitigation. However, should the cuttings footprint overlap with vulnerable communities on hard ground, the smothering effects could potentially have an impact of high intensity, and recovery would only be expected over the medium- to long-term due to their long generation times. This impact is considered to be of **medium to high** significance before mitigation and **LOW** after mitigation (see Table 5.10).

<u>Mitigation</u>

- If vulnerable seabed communities are identified in the vicinity of the proposed well location using the existing 3D seismic data and / or ROV (see mitigation in Section 5.2.1), the well position should be adjusted accordingly or innovative technologies and operational procedures for drilling solids discharges should be considered to minimise the impacts (e.g. the use of weighted mud (i.e. a mud with a high density) when drilling tophole sections to limit the extent of dispersion); and
- The dispersion of the discharged cuttings and mud should be aided by placing the cuttings chute at least 5 m below the sea surface.

Table 5.10: Impact on benthic communities as a result of smothering and plume turbidity.

	Extent	Duration	Intensity	Probability	Significance	Confidence
Unconsolidated sediments						
Without mitigation	Local	Short-term	Medium to High	Highly probable	**Very Low to Low**	High
With mitigation	Local	Short-term	Medium to High	Highly probable	**VERY LOW TO LOW**	High
Hard grounds / reefs						
Without mitigation	Local	Medium- to Long-term	High	Highly probable	**Medium to High**	Medium
With mitigation	Local	Short-term	Medium	Highly probable	**LOW**	Medium

5.2.2.3 Direct biochemical effects of discharged drilling fluid and contaminated cuttings

Description of impact

The primary effects related to the discharge of WBMs and SBMs include direct toxicity and bioaccumulation. The effects may be of significance in terms of:

- Chronic accumulation of persistent contaminants in the marine environment;
- Acute or chronic effects on biota, including effects on productivity, within the human food-chain (i.e. indirect effects on human health and commercial interests); and
- Acute or chronic effects on other biota (i.e. indirect effects on biodiversity).

Assessment

As indicated previously, two types of drilling fluid would be used during drilling. During the initial riserless drilling stage WBF would be used. However, during the risered drilling stage, a low toxicity SBM would be used, when WBMs cannot provide the necessary characteristics. It is estimated that approximately 550 m^3 of WBMs and 235 mT of SBMs would be discharged to the sea.

The disposal of mud into the marine environment and its subsequent effect has been extensively investigated through field and laboratory studies. Several metals typically occur in significantly higher concentrations in drilling muds than in uncontaminated marine sediments. However, most of these are not bioavailable to benthic fauna and thus do not bioaccumulate in the marine food chain. Toxicity testing of WBMs and SBMs has indicated that they constitute a low risk of chemical toxicity to marine communities. The two most abundant ingredients in WBMs, barite and bentonite, are insoluble and non-biodegradable. Other additives such as gluteraldehyde, inorganic salts and lignosulfonate thinners are only mildly toxic to marine life, but are present in such low concentrations that evidence of long-lasting ecological impacts are lacking. The additives include low toxicity mineral oil, corrosion inhibitors, detergents, defoamers, and emulsion breakers, but are usually not present in concentrations high enough to contribute significantly to whole mud toxicity. Similarly, the potential for significant bioaccumulation of SBMs in the marine environment is unlikely due to their extremely low water solubility and consequent low bioavailability. Due to the high dilution and wide dispersal of the dissolved and particulate components of SBMs, the biological effects associated with their use typically do not extend beyond 250 – 500 m from the drilling unit (Husky 2000, 2001; Buchanan *et al.* 2003; OGP 2003), with complete recovery of impacted communities being predicted within 3 - 5 years.

Assuming that the WBMs to be used in drilling the initial section of the well do not contain spotting fluids or lubricating hydrocarbons, the impacts of discharges of these drilling fluids to both the water column and the sediments are considered of low intensity. As the area affected by discharged drilling fluids would be localised (0.045 km^2), any potential adverse effects of WBMs on sessile benthos would be of **VERY LOW** significance before and after mitigation. In the case of SBMs, the impacts of discharged muds are considered of medium intensity. However, as the area affected by discharged drilling fluids would be localised (<30 km^2) and of very thin deposition thickness, any potential adverse effects on sessile benthos or on the feeding, spawning and recruitment of mobile predators, are also considered to be of **VERY LOW** significance before and after mitigation (see Table 5.11).

Mitigation

The following measures should be implemented to mitigate any negative effects of drilling fluid discharges:

- Maximise the use of WBM at all times, using risered SBMs only when necessary;
- Ensure only low-toxicity and partially biodegradable additives are used;
- Ensure regular maintenance of the on-board solids control package;
- All recovered SBM should be stored on-board and taken to shore for treatment and reuse; and
- The dispersion of the discharged cuttings should be aided by placing the cuttings chute at least 5 m below the sea surface.

Table 5.11: The assessment of biochemical effects on benthic communities related to the discharge of drilling fluid and contaminated cuttings.

	Extent	Duration	Intensity	Probability	Significance	Confidence
WBM						
Without mitigation	Local	Short-term	Low	Highly Probable	**Very Low**	Medium
With mitigation	Local	Short-term	Low	Highly Probable	**VERY LOW**	Medium
SBM						
Without mitigation	Local	Short-term	Medium	Highly Probable	**Very Low**	Medium
With mitigation	Local	Short-term	Medium	Highly Probable	**VERY LOW**	Medium

5.2.2.4 Direct biochemical effects related to cementing operations

Description of impact

The primary effects related to the discharge of cement, as with the discharge of drilling fluid, include direct toxicity and bioaccumulation.

Assessment

Typically, cement and cement additives are not discharged from drilling units. However, during the initial cementing operation, excess cement emerges out of the top of the well and onto the seafloor in order to ensure the conductor pipe is cemented all the way to the seafloor. During this operation a maximum of 150% of the required cement volume would be pumped into the space between the casing and the borehole wall (annulus). In the worst case scenario approximately 210 m^3 of cement could be discharged onto the seafloor. It should, however, be noted that if cement returns are observed on the seafloor pumping would be terminated.

Various chemical additives are used in the cementing programme to control its properties, include setting retarders and accelerators, surfactants, stabilisers and defoamers. The formulations would be adapted to meet the requirements of the particular well. Their concentrations, however, typically make up <10% of the overall cement used. Furthermore, the additives have a low toxicity to marine life and the organic additives are partially biodegradable.

The impact related to the discharge of the excess cement around the wellbore and leaching of the additives into the surrounding water column is considered to be extremely localised, of low intensity in the short-term. Therefore, the biochemical impact is assessed to be of **VERY LOW** significance with and without mitigation (see Table 5.12).

Mitigation

Although the use of cement is unavoidable, the following measures should be implemented to mitigate any negative effects:

- Avoid excess cement usage by using a ROV to monitor discharges to the seafloor around the drill casing; and
- Ensure only low-toxicity and partially biodegradable cement additives are used.

Table 5.12: The assessment of biochemical effects on benthic communities related to the discharge of cement.

	Extent	Duration	Intensity	Probability	Significance	Confidence
Without mitigation	Local	Short-term	Low	Highly Probable	**Very Low**	Medium
With mitigation	Local	Short-term	Low	Highly Probable	**VERY LOW**	Medium

5.2.2.5 Indirect effects related to increased turbidity

Description of impact

The discharge of cuttings would result in changes in water turbidity in the vicinity of the discharge point, which could reduce light penetration through the water column with potential adverse effects on the photosynthetic capability of phytoplankton and the foraging efficiency of visual predators.

Assessment

Turbid water is a natural occurrence along the southern African west coast, resulting from aeolian and riverine inputs, re-suspension of seabed sediments in the wave-influenced nearshore areas and seasonal phytoplankton production in the upwelling zones. However, further offshore in the proposed area of interest, surface waters tend to be clearer and less productive as they are beyond the influence of coastal upwelling (see Figure 4.7). Consequently, the major spawning areas are all located on the continental shelf well inshore of the proposed area of interest (see Figures 4.12 and 4.13). Any potential effects of turbid water plumes generated during cutting disposal on phytoplankton and ichthyoplankton production, fish migration routes and spawning areas would thus be negligible.

Increased turbidity of near-bottom waters through disposal of cuttings at the wellbore and sea surface may place transient stress on sessile and mobile benthic organisms, by negatively affecting filter-feeding efficiency of suspension feeders or through disorientation due to reduced visibility. However, in most cases sub-lethal or lethal responses occur only at concentrations well in excess of those anticipated at the wellbore. Furthermore, as marine communities in the Benguela are frequently exposed to naturally elevated suspended-sediment levels, they can be expected to have behavioural and physiological mechanisms for coping with this feature of their habitat.

The impact of increased turbidity in the water column and elevated suspended sediment concentrations would thus be comparatively localised, of low intensity over the very short term (days), and is considered to be of **VERY LOW** significance with or without mitigation (see Table 5.13).

Mitigation

No additional mitigation measures are deemed necessary.

Table 5.13: The assessment of the indirect effects related to increased turbidity.

	Extent	Duration	Intensity	Probability	Significance	Confidence
Without mitigation	Local	Short-term	Low	Probable	**Very Low**	Medium
With mitigation	No mitigation is considered necessary.					

5.2.2.6 Indirect effects related to oxygen depletion

<u>Description of impact</u>
The release of particulate organic matter into the water column can result in local organic enrichment and consequent oxygen depletion through decomposition, thereby changing the chemical properties of the near-surface sediment layers by generating potentially toxic concentrations of sulfide and ammonia. Oxygen depletion in the sediments around a well site may also develop in response to organic enrichment following fall-out of fouling organisms off submerged drilling unit structures.

<u>Assessment</u>
Organically enriched sediments (often hypoxic or anoxic) harbour markedly different benthic communities to oxygenated sediments. WBM cuttings typically contain low concentrations of biodegradable organic matter and do not support large populations of bacteria. However, SBMs typically degrade rapidly and can cause localised hypoxia in underlying sediments.

Marine organisms respond to hypoxia in various different ways which can result in reduced growth and feeding, and may eventually affect individual fitness. More mobile species would be able to actively avoid hypoxia, although this may render them more vulnerable to predation. However, hypoxia may eliminate relatively immobile or sedentary benthic species, thereby changing the species composition of the community.

The bulk of the seawater in the study area comprises South Atlantic Central Water, which has depressed oxygen concentrations (approximately 80% saturation value), with lower oxygen concentrations (<40% saturation) occurring frequently due to nutrient remineralisation in bottom waters. Benthic communities in the study area will therefore most likely be adapted to low oxygen conditions and will be characterised either by species able to survive chronic hypoxia, or colonising and fast-growing species able to rapidly recruit into areas that have suffered oxygen depletion.

Development of anoxic conditions beneath deposited cuttings is unlikely due to the low deposition thicknesses (<1 mm) predicted in the cuttings fallout footprint for distances beyond approximately 150 m from the well location. Should anoxic conditions develop, these are likely to be limited to within the 0.045 km^2 footprint of the WBMs depositional area, where they would have an impact of medium intensity on the benthic macrofauna, with recovery expected within a few months. The impact is thus considered to be of **VERY LOW** significance with and without mitigation (see Table 5.14).

<u>Mitigation</u>
No mitigation measures are possible or considered necessary.

Table 5.14: The assessment of biochemical effects on benthic communities related to the development of anoxic sediments.

	Extent	Duration	Intensity	Probability	Significance	Confidence
Without mitigation	Local	Short-term	Medium	Probable	**Very Low**	Medium
With mitigation	No mitigation is possible or considered necessary.					

5.2.3 DRILLING NOISE

Impact description

The noise from drilling operations could result in localised disturbance of marine fauna.

Impact assessment

The sound level generated by drilling operations using either rotary or downhole motor drilling falls within the 120-190 dB re 1 µPa range at the drilling unit, with main frequencies of less than 0.2 kHz. The noise generated by drilling operations thus falls within the hearing range of most fish and marine mammals, and would be audible for considerable ranges (in the order of tens of kms) before attenuating to below threshold levels.

Underwater noise from drilling operations is not considered to be of sufficient amplitude to cause direct harm to marine life. However, the drilling operations may induce localised behavioural changes in some marine mammals. Research has found that the responses of cetaceans to noise sources are often dependent on the perceived motion of the sound source as well as the nature of the sound itself. For example, many whales are more likely to tolerate a stationary source than they are one that is approaching them (Watkins 1986; Leung-Ng & Leung 2003) or are more likely to respond to a stimulus with a sudden onset than to one that is continuously present (Malme et al. 1985).

The potential impact of underwater noise generated during drilling operations using either rotary or downhole motor drilling on marine fauna is considered to be localised, of low intensity in the short-term. The significance of this impact is therefore assessed to be **VERY LOW** with and without mitigation (Table 5.15).

Mitigation measures

No measures are deemed necessary to mitigate noise impacts from support vessel operations.

Table 5.15: Impact of noise from drilling operations.

	Extent	Duration	Intensity	Probability	Significance	Confidence
Without mitigation	Local	Short-term	Low	Probable	**Very Low**	Medium
With mitigation	No mitigation is considered necessary.					

5.2.4 FAUNAL ATTRACTION TO DRILLING UNITS

Description of impact

Marine fauna may be attracted to a drilling unit for a number of reasons, including structural stimuli, protection, illumination (operating lights and flaring) and food availability. The attraction of fauna may impact species through both the ingestion of oil or contaminants from the sea surface or within prey tissues and nocturnal kills from birds flying into flares or lighting structures.

Assessment

Seabirds, fish, cephalopods (squids), seals and cetaceans may be attracted to the strong operating lights required during drilling activities and to flaring during any flow testing. Potential attraction may increase during fog when greater illumination is caused by refraction of light by moisture droplets.

Attraction to food supply may result from both the disposal of organic wastes (leading to an extreme local increased productivity or a direct supply of food), the drilling unit acting as a local reef (enhancing food supply) and through indirect attraction of prey species. Many seabird species forage at night on bioluminescent plankton prey and any light would result in obvious attraction.

Most seabirds are found relatively close inshore (10-30 km), well outside the area of interest. However, African Penguins and Cape Gannets are known to forage up to 60 km and 140 km offshore, respectively. Most of the pelagic seabird species in the region reach highest densities offshore of the shelf break (200 to 500 m depth), also well inshore of the proposed area of interest. However, the lighting may still cause some disturbance or disorientate pelagic seabirds feeding in the area.

Seals are highly mobile animals with a general foraging area covering the continental shelf up to 120 nm (approximately 220 km) offshore. Since the closest seal colonies at Kleinzee and Strandfontein are more than 225 km from the proposed area of interest, numbers can be expected to be low.

The extent of impact is likely to be limited to the visual stimulus of the drilling unit (both alternatives), while the duration would be limited to three months per well (i.e. short-term). Although the intensity of impact is likely to range from low (altered distribution and behaviour) to high (mortality) for individuals, the intensity of the impact on the population is expected to be low. The significance of impact is deemed **VERY LOW** with or without mitigation (see Table 5.16).

<u>Mitigation</u>
The following mitigation is recommended to mitigate the impacts of faunal (particularly seabird) attraction:

- Non-essential lighting should be minimised on all platforms to reduce nocturnal attraction. However, such measure should not undermine work safety aspects or concerns; and
- A monitoring programme of faunal attraction should be implemented where any seabird injuries and mortalities are logged.

Table 5.16: Impact of faunal attraction to drilling unit.

	Extent	Duration	Intensity	Probability	Significance	Confidence
Without mitigation	Local	Short-term	Low	Probable	**Very Low**	Medium to High
With mitigation	Local	Short-term	Low	Probable	**VERY LOW**	Medium to High

5.2.5 PHYSICAL PRESENCE OF SUBSEA INFRASTRUCTURE

<u>Description of impact</u>
The presence of the subsea infrastructure (e.g. wellhead and guide base) would effectively increase the amount of hard substrate that is available for the colonisation of benthic organisms. This may increase biodiversity and biomass in the vicinity of physical structures on the seabed.

<u>Assessment</u>
Wells would either be suspended or abandoned at the end of well drilling. If the well is suspended the wellhead (3 - 4 m high) would be left on the seafloor. If the well is abandoned, the wellhead would either remain on or be removed from the seafloor. Shell’s preferred alternative would be to leave the wellhead on the seafloor. This subsea infrastructure may support an increased richness, diversity and abundance of marine species. Studies have shown that oil and gas infrastructure appears to provide a sheltering habitat for fish usually associated with complex reef habitats, and it has been proposed that infrastructure may positively affected larval production, which could subsequently result in increased recruitment success.

The presence of subsea infrastructure (namely two wellheads) could therefore alter the community structure in an area. While this may have positive implications to certain fish species (e.g. kingklip and jacopever), which show a preference for structural seabed features, it may enhance colonisation by non-indigenous species thereby posing a threat to natural biodiversity.

The increase of surface area afforded by the proposed wellheads is small and highly localised (3 m^2 in extent; 3-4 m high) and is likely to have an impact of low intensity on the benthic macrofauna. The duration of the impact ultimately depends on whether the wellheads are removed or left on the seafloor during abandonment. If the wellhead is removed from the seafloor the duration would be short-term. However, if the wellhead is left on the seafloor the impact would be permanent. Overall the significance of this impact is considered to range from **VERY LOW (neutral)** if the wellheads are removed from the seafloor to **LOW (neutral)** if the wellheads are abandoned on the seafloor (see Table 5.17).

Mitigation
No mitigation is considered necessary.

Table 5.17: Assessment of impact on biodiversity and biomass due to the physical presence of infrastructure.

	Extent	Duration	Intensity	Probability	Significance	Confidence
Removal of wellheads from the seafloor						
Without mitigation	Local	Short-term	Low	Highly Probable	**Very Low to Low (neutral)**	Medium
With mitigation	No mitigation is considered necessary.					
Abandon wellheads on the seafloor						
Without mitigation	Local	Permanent	Low	Highly Probable	**Low (neutral)**	Medium
With mitigation	No mitigation is considered necessary.					

5.2.6 INTRODUCTION OF NON-INDIGENOUS INVASIVE MARINE SPECIES THROUGH VESSELS AND EQUIPMENT TRANSFER AND BALLAST WATER DISCHARGE

Description of impact
Larvae, cysts, eggs and adult marine organisms are frequently firmly attached to artificial structures such as vessel hulls and infrastructure that have been in the sea for any length of time. Vessels and the transportation of infrastructure from one place to another in the ocean provide the potential for translocation of introduced or alien species. In addition, the discharge of ballast water also provides the potential for translocation of introduced or alien species.

The relocated organism may be able to thrive and outcompete local species naturally occurring in the region, resulting in a loss of overall regional biodiversity and, in extreme cases, an invasion of the foreign species.

Assessment
Underwater footage of existing petroleum infrastructure on the Agulhas Bank has shown evidence of invasion by a foreign anemone species (*Metridium senile*), which occurs in abundance on pipelines and other hard, artificial structures. This species of anemone is not endemic to South Africa and was most likely introduced from the North West Atlantic region (K. Sink *pers. comm*.). Even the transport of species from the South Coast to the West Coast can result in the introduction of an invasive species, although this is usually

less likely than invasive species being introduced from foreign countries. Currently three marine species are known to be invasive in South African waters, namely the Mediterranean mussel (*Mytilus galloprovincialis*), the European shore crab (*Carcinus meanas*) and the Pacific barnacle (*Balanus glandula*). However, the difficulty in detection, identification and the cryptic nature of some species potentially makes this number an underestimate (C.L. Griffiths *pers. comm*.).

The drilling unit (and possibly some of the support vessels) contracted for the proposed drilling campaign would have spent time outside of South Africa's EEZ prior to drilling. This exposure to foreign water bodies increases the risk of introducing invasive or non-indigenous species. In addition, the slow speed at which a semi-submersible drilling unit is towed through water bodies further facilitates the accumulation of fouling species. The risk of this impact is, however, reduced by the highly dynamic, wave-exposed coastline of South Africa, which contributes to minimising the establishment of alien invasive species resulting in comparatively low numbers of such species in the region.

The potential impact related to the introduction of alien invasive marine species is considered to be of medium intensity in the long-term and is expected to have an extent ranging from regional to national. The significance of impact is consequently deemed **high to very high** without mitigation. With the implementation of the proposed mitigation the impact is considered to be improbable and of **MEDIUM** significance (see Table 5.18).

It should be noted that this impact is not unique to the proposed project, but rather a threat common to the South African offshore environment from the numerous vessels that pass through South African coastal waters daily.

<u>Mitigation</u>

- Unless thoroughly cleaned, no infrastructure (e.g. wellheads, BOPs and guide bases) should be deployed that has been used in other regions;
- A ballast water management plan must be prepared for the drilling unit;
- De- and re-ballasting of vessels must be undertaken only under strict adherence to International Maritime Organisation (IMO) guidelines (Guideline A.868(20)) governing discharge of ballast waters at sea. De- and re-ballasting at sea currently provides the best available measure to reduce the risk of transfer of harmful aquatic organisms, but is subject to ship-safety limits. The IMO states that vessels using ballast water exchange should, whenever possible, conduct such exchange at least 200 nm from the nearest land and in water of at least 200 m depth[5]. Where this is not feasible, the exchange should be as far from the nearest land as possible, and in all cases a minimum of 50 nm from the nearest land and preferably in water at least 200 m in depth; and
- Other precautionary guidelines recommended by the IMO include:
  - > During the loading of ballast, every effort should be made to avoid the uptake of potentially harmful aquatic organisms, pathogens and sediment that may contain such organisms, through adequate filtration procedures;
  - > Where practicable, routine cleaning of the ballast tank to remove sediments should be carried out in mid-ocean or under controlled arrangements in port or dry dock, in accordance with the provisions of the ship's ballast water management plan; and
  - > Avoidance of unnecessary discharge of ballast water.

[5] Note: the proposed area of interest for well drilling in located approximately 125 nm from the coast in water depths ranging between 1 500 m and 2 100 m.

Table 5.18: Assessment of impact related to the potential introduction of alien/invasive marine species through equipment transfer and ballast water discharge.

	Extent	Duration	Intensity	Probability	Significance	Confidence
Without mitigation	Regional - National	Long-term	Medium	Probable	**High to Very High**	Medium
With mitigation	Regional - National	Short- to Medium-term	Low	Improbable	**MEDIUM**	Medium

5.3 IMPACT ON OTHER USERS OF THE SEA

5.3.1 POTENTIAL IMPACT ON FISHING INDUSTRY

Description of impact

Exploration drilling could impact the fishing industry as a result of the 500 m safety zones around the drilling unit (both alternatives). The safety zone could result in the temporary loss-of-access to fishing grounds and associated loss of catch from these areas. In addition, depending on the success of the drilling programme, two wellheads could potentially be suspended or abandoned on the seafloor. This could potentially disrupt fishing activities and increase fishing effort due to the reduction in the length of trawls and time lost hauling and setting gear in order to avoid the wellheads.

Assessment

The extent of commercial fishing in and around the licence area and area of interest is described in detail in Section 4.1.4.1. The only commercial sector that could be affected by the proposed exploration drilling is the large pelagic long-line fishery. This fishery operates extensively from the continental shelf break into deeper waters, year-round. Pelagic long-line vessels are primarily concentrated seawards of the 500 m depth contour where the continental slope is steepest and can be expected within the area of interest. Records (recent and historical) show that between approximately 1% and 2% of the national catch and effort has been recorded in the area of interest. The impact on the large pelagic long-line sector is considered to be localised and of medium intensity in the short-term. The significance of this impact is, therefore, assessed to be **VERY LOW** with and without mitigation (see Table 5.19). The proposed abandonment of the wellhead on the seafloor would have no additional impact on this fishery.

The proposed exploration drilling would have **NO IMPACT** on the demersal trawl, demersal long-line (hake- and shark-directed), small pelagic purse-seine, demersal long-line (hake and shark), tuna pole, traditional line-fish and West Coast rock lobster sectors, as there has been no catch or effort (recent or historic) recorded within the proposed area of interest.

In the case of the demersal trawl sector, which operates along the 1 000 m depth contour just inshore of the area of interest, there is a concern that the abandonment of the wellhead on the seafloor could have a potential future impact on the fishery. In historically trawled areas, predominantly on the shelf in waters shallower than 500 m water depth, the trawling industry has objected to and requested the removal of abandoned wellheads and other structures associated with oil and gas development. Although the expansion of trawling into waters deeper than 1 000 m water depth is uncertain, it is unlikely that trawling effort would move into the proposed area of interest, which has water depths ranging between 1 500 m and 2 100 m (noting that the technology exists to trawl to these depths but that such activity would require approval from the national fisheries management authority). Thus it is anticipated that the abandonment of the wellhead on the seafloor would have no long-term impact on the demersal trawl sector.

Mitigation

The mitigation measures listed below are unlikely to reduce the significance level of the potential impact, however, they would minimise any likely disruptions to drilling and fishing operations.

- Prior to the commencement of drilling activities the following key stakeholders should be consulted and informed of the proposed drilling programme (including navigational co-ordinates of well location, timing and duration of proposed activities) and the likely implications thereof (specifically the 500 m exclusion zone and the movements of support vessels):
  - Fishing industry / associations: South African Tuna Long-line Association, South African Deep-sea Trawling Industry Association, South African Tuna Association and Fresh Tuna Exporters Association; and
  - Other key stakeholders: DAFF, DEA, PASA, Transnet National Ports Authority (ports of Cape Town and Saldanha Bay), South African Maritime Safety Authority (SAMSA) and South African Navy Hydrographic office.

  These stakeholders should again be notified at the completion of drilling when the drilling unit and support vessels are off location.
- Shell must request, in writing, the South African Navy Hydrographic office to release Radio Navigation Warnings and Notices to Mariners throughout the drilling period. The Notice to Mariners should give notice of (1) the co-ordinates of the well location, (2) an indication of the proposed drilling timeframes, (3) an indication of the 500 m safety zone around the drilling unit, and (4) provide details on the movements of support vessels servicing the drilling operation. These Notices to Mariners should be distributed timeously to fishing companies and directly onto vessels where possible;
- Any fishing vessel targets at a radar range of 24 nm from the drilling unit should be called via radio and informed of the safety requirements around the drilling unit;
- The drilling unit vessel should be accompanied by a support vessel equipped with appropriate radar and communications be kept on 24-hour standby near the drilling unit in order to ensure that other vessels adhere to the safety zone; and
- Any wells suspended or abandoned on the seafloor must be surveyed and accurately charted with the South African Navy Hydrographic office.

Table 5.19: Assessment of the potential impact of drilling on commercial fishing activities.

	Extent	Duration	Intensity	Probability	Significance	Confidence
Large pelagic long-line						
Without mitigation	Local	Short-term	Medium	Highly probable	**Very Low**	High
With mitigation	Local	Short-term	Zero	Highly probable	**VERY LOW**	High
Demersal trawl, small pelagic purse-seine, demersal long-line (hake- and shark-directed), tuna pole, traditional line-fish, West Coast rock lobster						
NO IMPACT						

5.3.2 POTENTIAL IMPACT ON FISHERIES RESEARCH

Description of impact

Fisheries research on demersal and small pelagic fish resources is undertaken by DAFF off the South African coastline on a bi-annual basis in order to set the annual TAC. The presence of the drilling unit (both alternatives) and associated 500 m safety zone could interfere with this research. In addition, depending on the success of the drilling programme, two wellheads could potentially be suspended or abandoned on the seafloor. This could potentially disrupt demersal research surveys.

Assessment

Demersal trawl positions are randomly selected to cover specific depth strata that range from the coast to the 1 000 m bathymetric contour (see Figure 4.37), thus inshore of the proposed area of interest. Pelagic surveys are undertaken up to approximately the 200 m bathymetric contour and thus inshore of the proposed area of interest. The proposed exploration drilling operation would thus have **NO IMPACT** on demersal and pelagic research surveys.

Mitigation

Although there is no anticipated impacts on fisheries research it is recommended that the managers of the research survey programmes are notified of the exact well locations and timing of drilling.

5.3.3 POTENTIAL IMPACT ON MARINE PROSPECTING, MINING, EXPLORATION AND PRODUCTION ACTIVITIES

Description of impact

The issuing of rights for different minerals (e.g. diamonds, phosphate, heavy minerals, platinum group metals, gold, sapphires, manganese nodules and agricultural minerals), as well as oil and gas, in the same area could result in a conflict between rights holders. While the drilling unit (both alternatives) is operational, a temporary 500 m radius statutory activity safety zone around the drilling unit would be in force. The total area of the exclusion zone is approximately 0.8 km^2. Localised temporary cessation of prospecting and mining in the safety zone could occur.

Assessment

Prospecting and mining

More than half of the proposed area of interest overlaps with a recently approved large phosphate prospecting area (see Figure 4.43). As the prospecting could take place over a very large area, it is unlikely the area of overlap would affect prospecting operations. The licence area does not overlap with any diamond mining concessions (see Figure 4.41) or other known prospecting or exploration areas for manganese, heavy minerals, platinum group metals, gold, sapphire, etc.

The potential impact on prospecting and mining in the proposed area of interest is considered to be localised and of very low intensity in the short-term. The significance of this potential impact is thus assessed to be **INSIGNIFICANT** with and without mitigation (see Table 5.20).

Exploration and production

Exploration for oil and gas is currently being undertaken in a number of licence blocks off the West Coast of South Africa (see Figure 4.40). Should any of the adjacent operators undertake a seismic survey at a similar time to the proposed exploration drilling there could be a localised impact, of low intensity in the short-term. The significance of this impact is therefore assessed to be **very low** without mitigation and **INSIGNIFICANT** with mitigation (see Table 5.20). There are currently no production activities off the West Coast of South Africa.

Mitigation

- Shell should engage timeously with adjacent prospecting / exploration right holders to discuss the scheduling of proposed drilling activities in order to reduce the risk of delay to or interference with the proposed drilling programme; and
- Any dispute arising should be referred to the Department of Mineral Resources or PASA for resolution.

Table 5.20: Assessment of impacts on marine prospecting, mining, exploration and production activities.

	Extent	Duration	Intensity	Probability	Significance	Confidence
Prospecting and mining						
Without mitigation	Local	Short-term	Very Low	Improbable	**Insignificant**	High
With mitigation	Local	Short-term	Zero	Improbable	**INSIGNIFICANT**	High
Exploration and production						
Without mitigation	Local	Short-term	Low	Improbable	**Very Low**	High
With mitigation	Local	Short-term	Very Low	Improbable	**INSIGNIFICANT**	High

5.3.4 POTENTIAL IMPACT ON MARINE TRANSPORT ROUTES

Description of impact

The presence of the drilling unit with the associated 500 m safety zone could interfere with shipping in the area.

Assessment

The majority of shipping traffic is located on the outer edge of the continental shelf with traffic inshore of the continental shelf along the West Coast largely comprising fishing and mining vessels, especially between Kleinzee and Oranjemund. Figure 4.38 and 4.39 show that the majority of the shipping traffic *en route* to and from Cape Town would pass though the licence area and possibility though the area of interest.

Although the safety zone around the drilling unit (both alternatives) would be relatively small (0.8 km^2) all vessels would be prohibited from entering this area. The drilling unit would, however, be stationary during drilling and is therefore easily avoidable. The impact on shipping traffic is considered to be localised, of medium to high intensity in the short-term. The significance of this impact is therefore assessed to be **very low to low** without mitigation. With the implementation of the proposed mitigation the impact is considered to be improbable and of **VERY LOW** significance (see Table 5.21).

Mitigation

Recommendations to mitigate the potential impacts on marine transport routes are similar to those recommended for fishing (refer to Section 5.3.1). In addition, the following is recommended:

- The drilling unit and support vessels must be certified for seaworthiness through an appropriate internationally recognised marine certification programme (e.g. American Bureau of Shipping, Det Norske Veritas, Lloyds Register, etc.). The certification, as well as existing safety standards, requires that safety precautions would be taken to minimise the possibility of an offshore accident.
- Collision prevention equipment should include radar, multi-frequency radio, foghorns, etc. Additional precautions include: the support vessels, the enforcement of the 500 m safety zone around the drilling unit, cautionary notices to mariners and access to current weather service information;
- The drilling unit and support vessels must be fully illuminated during twilight and night; and
- Report any emergencies to SAMSA.

Table 5.21: Assessment of interference with marine transport routes.

	Extent	Duration	Intensity	Probability	Significance	Confidence
Without mitigation	Local	Short-term	Medium to High	Probable	**Very Low to Low**	Medium
With mitigation	Local	Short-term	Low	Improbable	**VERY LOW**	Medium

5.4 IMPACT ON CULTURAL HERITAGE MATERIAL

Description of impact

Drilling activities and the installation of subsea infrastructure could disturb cultural heritage material on the seabed, particularly historical shipwrecks.

Assessment

The majority of known shipwrecks off the coast of South Africa occur in waters shallower than 100 m within 50 km of the coast. No wrecks are known in the proposed area of interest. Thus the likelihood of disturbing a shipwreck is expected to be very small considering the vast size of the South African offshore area.

It should also be noted that the final well location would be based on a number of factors, including further analysis of existing 3D seismic data, the geological target, seafloor surface conditions and obstacles (see Section 3.3.1). The preference would be to have a level surface area to facilitate spudding and installation of the wellhead. Since the proposed drill location would be analysed for seabed obstacles, any visible wrecks would more than likely be avoided in any event.

However, in the unlikely event of disturbing unknown or buried cultural heritage material during drilling, the impact significance is considered to be **medium** without mitigation and **INSIGNIFICANT** with mitigation (see Table 5.22).

Mitigation

- A ROV should be used to survey the seafloor prior to drilling in order to confirm the presence or absence of any cultural heritage material (e.g. shipwrecks) in the area. If detected, the well position should be adjusted accordingly; and
- If any cultural heritage material is found during activities the South African Heritage Resources Agency (SAHRA) should be notified immediately. If any material older than sixty years is to be disturbed a permit would be required from SAHRA.

Table 5.22: The assessment of the potential impact of drilling activities on heritage material.

	Extent	Duration	Intensity	Probability	Significance	Confidence
Without mitigation	Local	Permanent	Medium	Improbable	**Medium**	Medium
With mitigation	Local	Permanent	Zero to Very Low	Improbable	**INSIGNIFICANT**	Medium

5.5 SOCIO-ECONOMIC IMPACTS OF DRILLING ACTIVITIES

5.5.1 POTENTIAL IMPACT RELATED TO JOB CREATION

Description of impact

The proposed development would create a minor number of local employment and business opportunities.

Assessment

Exploration drilling is highly technical and requires specialised drilling units and crews, most of which are based outside South Africa. There would, however, be opportunities for local companies to provide support services in Cape Town / Saldanha Bay and Kleinzee, e.g. vessel supplies, helicopter operations, catering, cleaning, security, etc. Therefore, job creation opportunities would be limited. In addition, drilling activities would be of very short duration (i.e. three months per well).

The overall positive impact of job creation related to exploration drilling is considered to be regional, of very low to low intensity over the short-term for both the onshore logistic base alternatives, namely Cape Town or Saldanha Bay. Thus the potential impact of job creation during this phase of exploration is considered to be ***VERY LOW (positive)*** with and without mitigation (see Table 5.23).

Mitigation

The use of local companies for support services should be promoted as far as possible. In addition, local skills should be developed where possible.

Table 5.23: Assessment of impact related to job creation.

	Extent	Duration	Intensity	Probability	Significance	Confidence
Without mitigation	Regional	Short-term	Very Low to Low	Probable	***Very Low (positive)***	Medium
With mitigation	Regional	Short-term	Very Low to Low	Probable	***VERY LOW (POSITIVE)***	Medium

5.5.2 POTENTIAL IMPACT RELATED TO THE GENERATION OF DIRECT REVENUES

Description of impact

Direct revenues would be generated as a result of the proposed drilling operations. Revenue generating activities are related to the actual operations and include refuelling, vessel / gear repair, port dues, helicopter services, hire of local fishing vessels as support vessel, and local employment and business opportunities.

Assessment

It is anticipated that proposed drilling would have very little effect on the economy due to the very short duration (three months per well) and the relatively small amounts of additional revenue generated. The overall positive impact on the economy is considered to be regional, of low intensity over the short-term. Thus the potential impact of the generation of direct revenues during this phase of exploration is considered to be of ***VERY LOW (positive)*** significance for both the onshore logistic base alternatives, namely Cape Town or Saldanha (see Table 5.24). However, should such exploration identify viable hydrocarbon reserves, this could result in an oil and/or gas production project with associated demand for local materials and possibly labour as well as the generation of tax revenues.

Mitigation

No mitigation is considered necessary.

Table 5.24: Assessment of impact related to the generation of direct revenues.

	Extent	Duration	Intensity	Probability	Significance	Confidence
Without mitigation	Regional	Short-term	Low	Probable	***Very Low (positive)***	Medium
With mitigation	Regional	Short-term	Low	Probable	***VERY LOW (POSITIVE)***	Medium

5.5.3 POTENTIAL TRAFFIC IMPACT AT THE ONSHORE LOGISTICS BASE

Description of impact

The transportation of materials and equipment to the proposed onshore logistics would increase traffic volumes in either the Cape Town or Saldanha harbour precinct, which may result in some traffic congestion.

Assessment

It is expected that the supply of materials and equipment to the onshore base would generate a small volume of cars and trucks (in the order of 10 to 20 vehicles per day). As the current traffic volumes at the Cape Town harbour are quite significant (hundreds per day) the additional volume generated by the logistics base is not expected to have any material effect of the current levels-of-service[6]. Although current traffic volumes at the Saldanha Bay harbour are much lower than in Cape Town, the harbour has sufficient capacity to accommodate the anticipated traffic volumes. This potential impact is considered to be local in extent, short-term and of low intensity for both the onshore logistic base alternatives. The significance of this potential impact is, therefore, assessed to be **VERY LOW** before and after mitigation (see Table 5.25).

Since the transportation of personnel to and from the drilling unit would most likely be provided by fixed-wing flights from Cape Town to Kleinzee and then by helicopter to the drilling unit, there is no anticipated impact in Kleinzee.

Mitigation

No mitigation measures are considered necessary.

Table 5.25: Assessment of impact related to increased traffic volumes at the onshore logistics base.

	Extent	Duration	Intensity	Probability	Significance	Confidence
Without mitigation	Local	Short-term	Low	Probable	**Very Low**	Medium
With mitigation	Local	Short-term	Low	Probable	**VERY LOW**	Medium

5.6 CUMULATIVE IMPACT

Description of impact

In this section, the potential impact associated with the cumulative effect of the proposed project and other developments in the area and region are described. The IFC defines cumulative impacts as *'impacts that result from the incremental impact, on areas or resources used or directly impact by the project, from other existing, planned or reasonably defined developments at the time the risks and impacts identification process*

[6] Level-of-Service is a qualitative measure describing the operational conditions within a stream of traffic and includes factors such as speed, travel time, ability to manoeuvre, traffic interruptions, safety, waiting time periods (delay), and driver comfort and convenience.

is conducted'. Significant cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.

Thus existing and proposed infrastructure in the West Coast offshore has and will continue to have an impact on benthic faunal communities and reduced fishing grounds. Impacts on benthic faunal communities relate to physical disturbance of the seabed, discharges to the benthic environment and presence of permanent infrastructure on the seabed. The suspension or abandonment of wellheads on the seafloor could result in the loss of catch from these areas due to the reduction in the length of trawls and time lost hauling and setting gear in order to avoid the wellheads.

<u>Assessment</u>

Cumulative effects are difficult to predict as they are the result of complex interactions between multiple projects or activities. This difficulty is compounded by the fact that details of the future development are largely unknown. Moreover, whether or not a potential future development actually occurs is dependent on a number of factors that are unknown at this stage. Consequently, cumulative impacts are qualitatively assessed herein, i.e. high-level descriptions of the potential impact are provided.

Until oil and gas discoveries are made, it is difficult to predict whether and when any future oil and gas activity might occur, or the type, location, duration or level of those potential activities. In addition, methods to explore for, develop, produce, and transport petroleum resources would vary depending on the area, operator and discovery.

Mitigation and management of cumulative impacts often require cooperation with other stakeholders or at a government level, and are frequently beyond the ability of a single project development to control solely. In line with international good practice, mitigation should be commensurate with the level of contribution to the cumulative impact by the developer.

Marine fauna

The cumulative impacts associated with the drilling of possibly two exploration wells in the area of interest located in the Atlantic Offshore Bioregion, relate to physical disturbance of the seabed, discharges to the benthic environment and presence of permanent infrastructure on the seabed. The proposed exploration wells would impact an area of approximately 0.09 km^2 per well in the Atlantic Offshore Bioregion, which is considered an insignificant percentage of the bioregion as a whole. Cumulative impacts from other hydrocarbon exploration ventures in the area are likely to be limited. Although no wells have been drilled in this bioregion to date, further exploratory drilling is proposed in Block 1, to the north and inshore of the Orange Deep Water Licence Area and within the Namaqua Bioregion. In the Namaqua Bioregion approximately 40 wells have been drilled since 1976, of which 35 wellheads remain on the seafloor. The majority of these occur around the Ibhubesi Gas Field in Block 2A. The total historical area impacted by the drilling of 40 exploration wells due to, *inter alia*, the discharge of drill cuttings is estimated at around 10 km^2, or approximately 0.038% of the Namaqua Bioregion. This area is, however, probably exaggerated as each historic well has more than likely recovered by now, as recovery is expected within a few years (2 to 5 years) of well drilling.

Other activities that may have contributed to cumulative impacts on the benthic environment in the Orange Deep Water Licence area include limited historical deep water trawling and the installation of the subsea telecommunications cables, which traverse the licence area in a NW-SE direction beyond the 2 000 m contour. The subsea cables, however, lie offshore of the area of interest for exploratory drilling.

The proposed exploration drilling operations would, in the short-term, impact an additional area of approximately 0.09 km^2 per well (i.e. a radius of 150 m from the drill site were the thickness exceeds 1 mm) in the Atlantic Offshore Bioregion, which is considered an insignificant percentage of the bioregion as a whole. The cumulative impact as a result of all existing and proposed wellheads (and associated infrastructure) on the West Coast is considered to be of **LOW** significance.

Fishing

The only sector likely to be affected by the suspension or abandonment of wellheads on the seafloor is the demersal sector. As mentioned above, there are 35 wellheads which have been abandoned on the seafloor, 12 of which coincide with the demersal trawl grounds, which extend in a continuous band along the shelf edge between the 300 m and 1 000 m bathymetric contours (see Figure 4.18). The resulting loss of fishable area due to the safety zones required around these 12 wells is 9.42 km2 (500 m around each wellhead) over a total trawl footprint area of approximately 38 500 km2 on the West Coast (i.e. 0.02%). Following a recent increase in oil and gas-related exploration activities within the South African offshore environment, the fishing industry has raised concerns about the potential cumulative effects of oil and gas development on the industry. There are a number of other possible well drilling projects off the West Coast that need to be taken into consideration, including:

- Cairn: possible 11 wells within Block 1;
- Thombo Petroleum Ltd: possible five wells in Block 2B; and
- Sunbird Energy (Pty) Ltd: possible 99 wells in Block 2A. There is also a proposal for a 400 km offshore production pipeline from the licence area to the Western Cape (this component has not yet been approved).

Most of the wells associated with the above-mentioned projects, except five of the Cairn wells in the western deep water portion of Block 1, are considered to fall outside the demersal trawl grounds. Since the demersal trawl grounds are located inshore of Shell's area of interest, the suspension or abandonment of possibly two wells on the seafloor would not add to the existing cumulative impact, which is considered to be of **LOW** significance.

5.7 ACCIDENTAL RELEASE OF OIL

5.7.1 INTRODUCTION

The nature of offshore drilling operations is such that there is an inherent risk of oil entering the marine environment as a consequence of an unplanned oil spill event. Depending on location and severity of an incident, oil could reach the coast.

Reservoir hydrocarbons, of which the exact composition is unknown, are a possible source of oil. Other possible oil sources include; various oil derived materials stored and used in bulk onboard the drilling unit and support vessels. The most relevant of these materials are diesel or marine gas oil (MGO), lubricating oils and hydraulic oils.

The purpose of an EIA is to assess the likely effects of both planned and credible potential unplanned events associated with the proposed project. This section has been included to consider the potential impacts of an unplanned accidental oil release (upset condition).

5.7.1.1 Oil spill modelling

There are a number of oil spill sources and types that could arise during drilling operations (see Table 5.26). From the list of potential spill sources and types identified, a representative range of credible (albeit unlikely) oil spill scenarios were selected to inform the oil spill modelling study (see Appendix 3.2). The objective of oil spill modelling is to identify the consequences of different spill scenarios and in particular identify the probability of oil impacting the coastline or nearshore receptors.

Table 5.26: List of spill sources and spill type.

No.	List of Potential Spill Sources	Spill Type
1	Loss of well control and blow-out	Large release, long duration, offshore – oil
2	Drilling unit grounding, collision or structural failure resulting in the total loss of diesel inventory and other oil inventory.	Medium release, short duration, offshore – diesel/oil and/or synthetic based mud
3	Dumping of riser content due to loss of station keeping or collision.	Medium release, short duration, offshore –synthetic mud
4	Leak from base oil, hydraulic oil, diesel or lube oil storage, or inadvertent opening of master dump valve and discharge of one pit of mud to sea.	Limited release, short duration, offshore – diesel, oil or synthetic based mud
5	Grounding, collision, structural failure of support vessels resulting in the total loss of diesel inventory and other oil inventory.	Medium release, short duration, near-shore – diesel/oil and/or synthetic mud
6	Loss of containment during transport to / from drill site resulting in the release of synthetic based muds or other oil products	Limited release, short duration, onshore, potentially to sea – synthetic based mud or oil

It is important not only to understand the main risks of oil spills associated with exploration drilling, but also the consequences if any spills were to occur. A key element of identifying the consequence of a spill is to understand what is likely to happen to the oil in the marine environment. Oil spill trajectory modelling plays an important role in quantifying the probable fate of an oil spill and hence in quantifying environmental risk from oil spills. Oil spill modelling has been used to predict the consequences of a range of spill scenarios.

It is important to note that, in line with established practice, all the modelling scenarios have been run with the assumption that no oil spill response measures (e.g. use of dispersants, skimmers, booming, etc.) would be implemented and that no mitigating actions would be taken at the point of spillage (e.g. pumping oil out of ruptured tanks). Therefore, the results of the modelling present the ‘worst case’ that could result from any particular oil spill. In reality, were an oil spill to occur, Shell would initiate appropriate response measures to limit the extent and impact of a spill.

5.7.1.2 Modelled oil spill scenarios and parameters

The four oil spill scenarios modelled in the EIA are set out in Table 5.27. The scenarios were run as stochastic simulations. Stochastic (or probabilistic) simulations provide insight into the probable behaviour of potential spills in response to temporally and spatially varying meteorological and oceanographic conditions. Stochastic analysis provides information on the likely extent of the oil spill footprint and the associated probability of oiling, as well as the shortest time required for oil to reach any point within the oiled area.

Two small operational and two large oil spill scenarios have been modelled in order to predict the trajectory and fate of the oil. Small operational oil spills may occur at the drill vessel, for example during fuel transfer or due to the rupture of hydraulic lines. Large oil spills may occur due to a blowout at the wellhead on the seabed. The inputs to the model included the bathymetry, currents and winds and the oil spill scenarios described in Table 5.27 below.

The model outputs are presented in Section 5.7.1.6.

Table 5.27: Modelled oil spill scenarios.

MODELLING CRITERIA	OIL SPILL SCENARIOS			
	1 (1 t of hydraulic fluid)	2 (10 t of diesel)	3 (5-day blow-out)	4 (20-day blow-out)
Description	Operational spill of hydraulic fluid, e.g. due to rupture of a hydraulic line on the drill vessel	Operational spill of diesel, e.g. due to hose rupture during fuel transfer from support vessel to drill vessel	Large blow-out at seabed capped after 5 days	Large blow-out at seabed capped after 20 days
Oil type	Hydraulic fluid	Diesel fuel oil	Light to medium crude	Light to medium crude
Vertical position of spill	On water surface at drill vessel	On water surface at drill vessel	At wellhead on seabed	At wellhead on seabed
Location of spill	15.000 E, 30.750 S	15.000 E, 30.750 S	15.000 E, 30.750 S	15.000 E, 30.750 S
Duration of spill	Instantaneous	Instantaneous	5 days	20 days
Rate of oil release	Instantaneous	Instantaneous	80 000 bbl/day = 10 811 t/day	80 000 bbl/day = 10 811 t/day
Total oil discharged	7.4 bbl = 1 t	74 bbl = 10 t	0.4 million bbl = 54 055 t	1.6 million bbl = 216 223 t
Duration of spill (days)	Instantaneous	Instantaneous	5	20
Duration of simulation (days)	3	3	65	80
Time offset between simulations (days)	3	3	10	20
Number of simulations	485	485	140	70

5.7.1.3 *Model description*

The oil spill modelling was performed using the MIKE 21/3 Oil Spill Model developed by DHI in Denmark. The application of the model is described in the User Manual (DHI, 2012c), while full details of the physical processes being simulated and the numerical solution techniques are described in the Scientific Documentation (DHI, 2012d).

This model is used for modelling the fate of oil discharged or accidentally spilled in lakes, estuaries and coastal areas or to the open sea. The model describes the total amount of spilled oil as an assemblage of smaller oil amounts represented by individual oil track particles[7].

The following weathering processes can be included in the model: spreading, evaporation, dissolution, vertical oil dispersion, settling, biodegradation, dissolution and photo-oxidation. These weathering processes are illustrated in Figure 5 1, while the relative importance of these processes over time is schematised in Figure 5 2. The dominant weathering processes for the two small spills are evaporation and dispersion, whereas for crude oil the weathering processes over the short-term (hours to weeks) includes evaporation, dispersion, dissolution, photo-oxidation, emulsification and spreading, whereas biodegration and sedimentation dominate the weathering processes over the medium- to long-term (weeks to years).

[7] These Lagrangian particles are advected by a pre-defined three-dimensional current field with an additional wind drift component in the case of oil at the water surface. Vertical oil movement is driven by differences in oil density and water density in both the upward and downward direction and is based on Stokes Law. Horizontal and vertical dispersion due to unresolved turbulence is modelled using the random walk method.

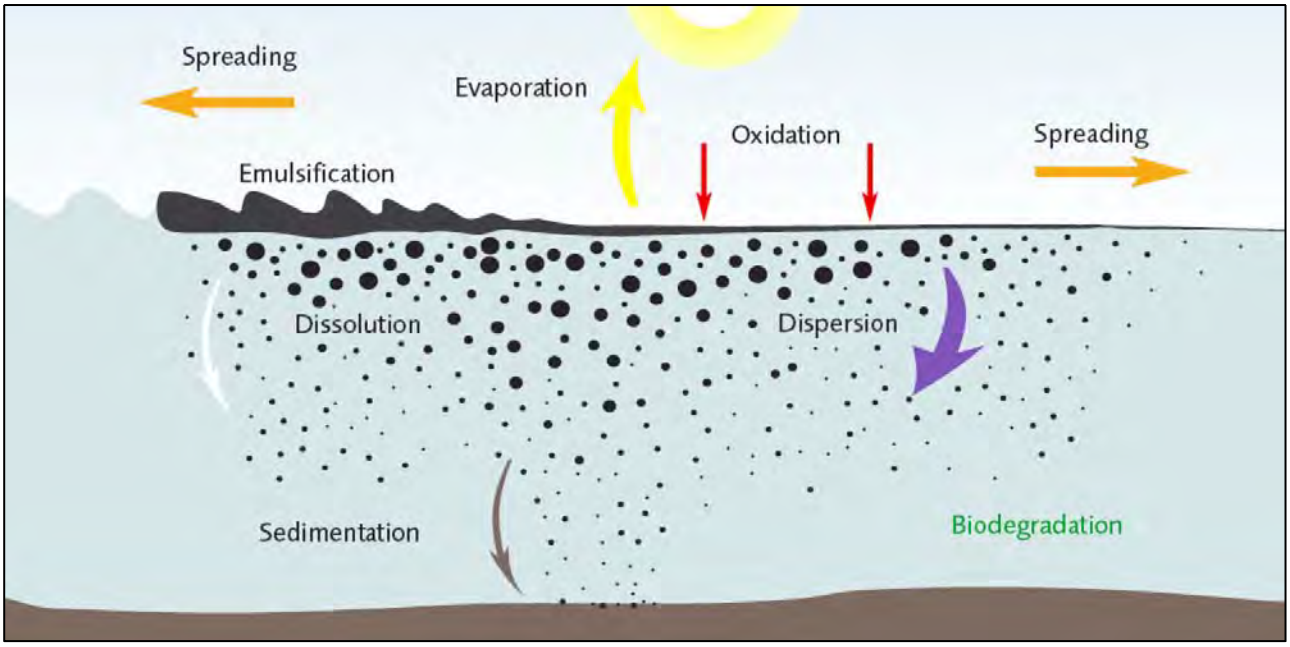


Figure 5.1: Oil weathering processes (ITOPF, 2002).

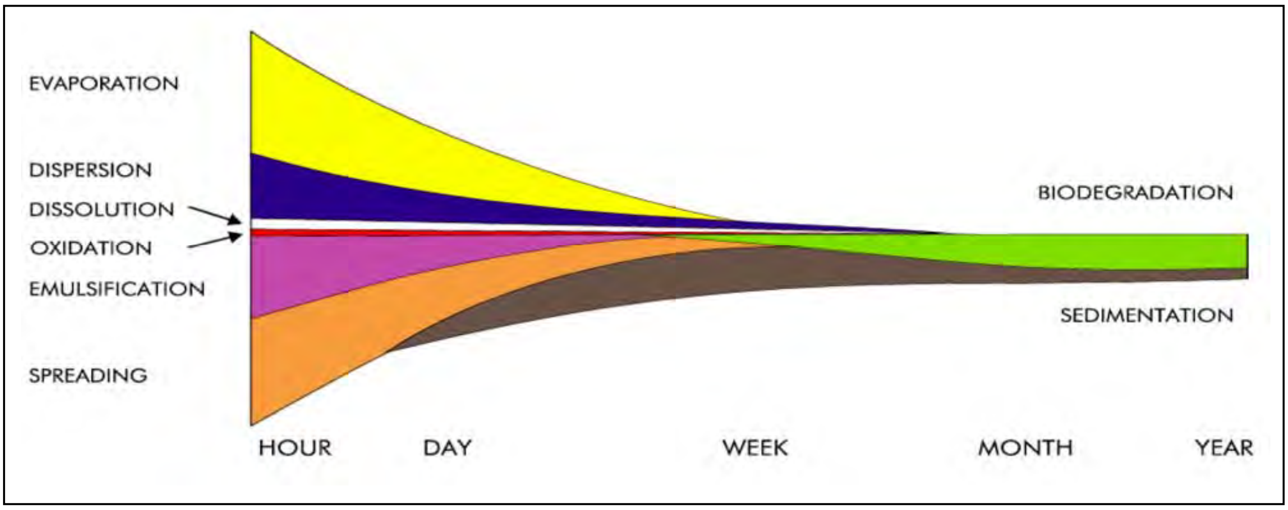


Figure 5.2: A schematic representation of the fate of a crude oil spill showing changes in the relative importance of weathering processes with time - the width of each band indicates the importance of the process (ITOPF, 2002).

5.7.1.4 *Oil characterisation*

In the model the oil is divided into two main fractions:

- A light volatile fraction of aromatics and other oil components with a molecular weight less than approximately 160 g/mol and a boiling point well below 300°C; and
- A heavy fraction with a molecular weight > 160 g/mol and a boiling point above 250°C - 300°C.

The volatile fraction is subject to all the weathering processes presented in Figures 5.1 and 5.2, whilst the heavy fraction is subject to all the weathering processes except evaporation. The model has detailed formulations for all the weathering processes, although in this study a parameterised approach was applied, as described below.

In the case of the small spill of hydraulic fluid, the dominant weathering process is oil dispersion. This was modelled as a first order decay process, as detailed in Table 5.28. In the case of the small spill of diesel, the dominant weathering process is evaporation and oil dispersion. Evaporation was modelled according to the 'Model of Reed' (DHI, 2012), where the evaporation rate is a function of vapour pressure, slick area, wind speed and particle diameter. The primary model input parameter for evaporation was the proportion of volatile oil fractions and the vapour pressure. The oil dispersion was modelled as a first order decay process, as detailed in Table 5.28.

Table 5.28: Oil characterisation.

Parameter	Hydraulic fluid	Diesel fuel oil	Crude oil
API (1)	28.1	37.6	35.0
Oil density (kg/m^3)	887	837	850
Proportion volatile oil fractions (2) (%)	0	100	60
Proportion heavy oil fractions (3) (%)	100	0	40
Density volatile oil fractions (kg/m^3)	-	837	796
Density heavy oil fractions (kg/m^3)	887	-	931
Evaporation vapour pressure (atm) (4)	-	$2x10^{-5}$	$2x10^{-5}$
Rate of oil dispersion (half-life in days) (5)	2.0 (6)	0.6 (7)	-
Rate of oil dispersion/dissolution/biodegradation/photo-oxidation/settling – fast weathering scenario (half-life in days)	-	-	4 (8)
Rate of oil dispersion/dissolution/biodegradation/photo-oxidation/settling – medium weathering scenario (half-life in days)	-	-	10 (9)
Rate of oil dispersion/dissolution/biodegradation/photo-oxidation/settling – slow weathering scenario (half-life in days)	-	-	30 (10)
Droplet diameter for faction number 1/2/3/4/5/6 (um) (11)	-	-	50/80/150/250/500/1000
Rise speed for fraction number 1/2/3/4/5/6 (m/s) (12)	-	-	0.25/0.61/2.12/6.10/23.02/80.56
Time to surface for fraction number 1/2/3/4/5/6 (days) (13)	-	-	80/33/9.5/3.3/0.9/0.3

Table 5.28 notes:

(1) The American Petroleum Institute gravity scale, $API = \frac{141.5}{specific\ gravity} - 131.5$.

(2) Light volatile oil fraction with molecular weight less than approximately 160 g/mol and a boiling point well below 300°C.

(3) Heavy oil fraction (> 160 g/mol) with a boiling point above 250°C - 300°C.

(4) For a 10 m/s wind this results in approximately 90% of the volatile oil fraction evaporating within 2 days.

(5) The rate is expressed as the half-life, which is the time needed for 50% of the oil to disappear from the sea surface. After six half-lives have passed, about 1% of the oil will remain.

(6) Based on the dispersion rate of hydraulic oil with an API of 28.1 and a viscosity of 46.0 cSt at 40°C predicted by the ADIOS weathering model (NOAA, 2009).

(7) Based on dispersion rate of diesel fuel oil with an API of 37.6 predicted by the ADIOS weathering model (NOAA, 2009).

(8) Based on the half-life of a Group 3 oil (ITOPF, 2002).

(9) Based on previous oil spill modelling results in this region showing 18% of Bonny Light Crude remaining on the water surface 11 days after the end of the release (ASA, 2005).

(10) Based on the longest half-life reported in literature for microbial decay of the Deepwater Horizon oil spill (Reddy, 2012), i.e. non-evaporative weathering is assumed to be dominated by biodegradation. Note that in all cases the non-evaporative weathering is applied to both the subsurface as well as the surface oil.

(11) Based on droplet diameters modelled for an Ekofisk oil blowout (Spaulding et al., 2000) and the Deepwater Horizon blowout (North, 2011). The four larger fractions will reach the surface rapidly (within 0.3 to 3.3 days) whilst the two smaller fractions will take longer than 30 days. This is consistent with the assumption used by (North, 2011) that for the Deepwater Horizon oil spill up to two thirds of the oil was either captured or found on the surface within a relatively narrow radius of the source.

(12) Based on Stokes law.

(13) Based on release depth of 1740 m, i.e. water depth of 1800 m less the 60 m near-field rise of the plume.

5.7.1.5 *Simulations*

A number of stochastic model simulations were performed for each spill in order to model the probability of oiling over the range of expected environmental conditions. Details of the model simulations for each spill are provided in Table 5.27. In the case of the large blow-out spills (spill numbers 3 to 4) the simulation was continued for 60 days after the end of the spill to allow time for the oil to reach the surface and subsequently spread and weather. It should be noted that there is little benefit in setting the time offset between simulations longer than the duration of the spill, as this will simply repeat part of the release under the same hydrodynamic conditions. For this reason only 70 different simulations were performed for spill scenario 4, which has a release duration of 20 days.

The simulations cover four years of current and wind data. The effect of the season on the model results was assessed by considering only the model results where the majority of the discharge occurred in the season of interest. Summer is defined as the months of October through to March, while winter is defined as the months of April through to September.

As the small operational spills would typically occur near the sea surface and involve the light volatile fraction of aromatics and other oil components with a low molecular weight, such spills would disperse rapidly from the point source and remain at the sea surface for no more than a few days.

In the case of the large blow-out of oil at the seabed, all the weathering processes shown in Figures 5.1 and 5.2 will occur to some extent over the duration of the spill. To offset any uncertainties related to the characteristics of the released oil, three different weathering rates were modelled: fast, medium and slow weathering. The medium weathering scenario is considered to be the most likely scenario.

As the blow-out plume leaves the well on the seabed the momentum of the discharge, as well as the buoyancy of the oil/gas mixture, is anticipated to result in a rapid rise of the plume in the water column. However, the gas hydrate formation and the entrainment of ambient water are likely to result in the plume being trapped in the order of 60 m above the seabed (Spaulding et al., 2000). Thereafter, the oil particles would rise towards the surface as a function of oil droplet diameter and the differences in oil and water density. The larger fractions would reach the surface within 0.3 to 3.3 days, whereas the smaller fractions would take in excess of 30 days to reach the surface.

5.7.1.6 *Model outputs*

The model outputs from the oil spill modelling study include:

- Snapshots of surface oiling for a single spill event over time (e.g. after 14 days);
- Area swept by oil for all times during a single spill event ;
- The oil mass balance over time for a single spill event;
- The probability of oiling of the sea surface and the shoreline considering all spill simulations; and
- Minimum time to oiling considering all spill simulations.

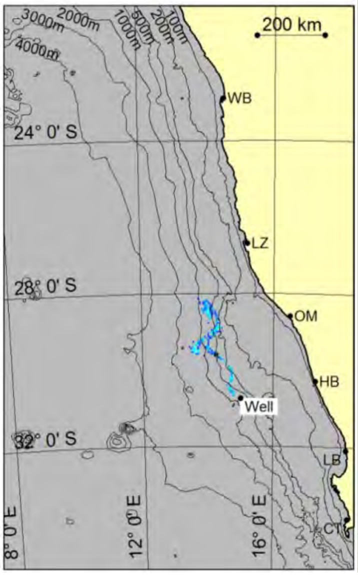
In order to understand the results of the oil spill modelling study, it is important to be able to differentiate between the different model outputs, specifically those considering a single spill event and those considering all spill simulations. An explanation of the key model outputs is provided in Box 5.1 below.

Box 5.1: Explanation of the key model outputs.

Plots of an actual spill event in the Orange River Deep Water Licence Area is shown in Figure a and b. These plots show the actual trajectory of a single spill modelled under specific conditions. The probablity plot (Figure c) shows the entire area swept by oil under all spill events / simulations. The probablity plot thus depicts a much larger area of possible oiling compared to what would actually occur under a single spill event.

Single spill event example

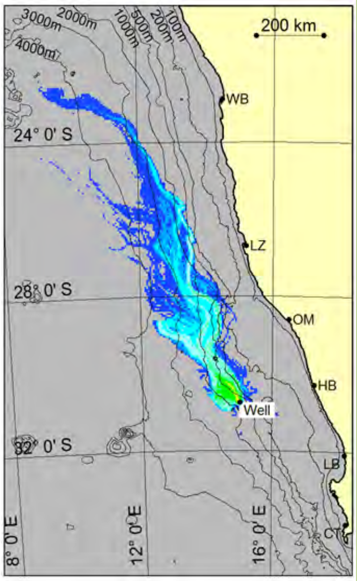
Figure (a):



This example shows a snapshot of a single spill event indicating the extent of surface oil after 14 days.

Note: Colours show oil thickness on the water surface.

Figure (b):

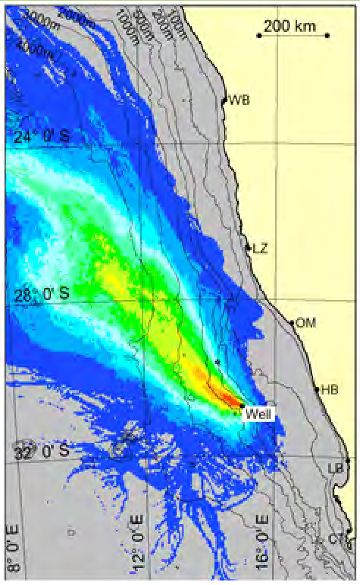


This example shows the area swept by oil for all times during a single spill event. The oil may only be present at a particular location for a short period in order for this location to be considered as having being oiled.

Note: Colours show maximum oil thickness on the water surface.

Probability of all simulations

Figure (c):



This example shows a probability plot showing the probability (%) of oiling under all 140 spill simulations for the 5-day blowout scenario (medium weathering in summer).

Note: Colours show probability percentage ranging from red (> 90%) to dark blue (0-10%).

The results of the oil spill modelling study for each of the four spill scenarios are summarised below.

Scenario 1: 1 ton of hydraulic fluid:

A spill of 1 ton of hydraulic fluid is predicted to travel as a narrow plume up to 150 km north-westwards from the source (see Figure 5.3). The oil would remain on the sea surface for a maximum of 2 days before a combination of oil dispersion and spreading reduces the oil thickness to below 0.3 µm[8]. There is no probability of a 1 ton hydraulic fluid spill reaching the shoreline, which is located approximately 230 km east of the area of interest for well drilling. Figure 5.4 shows the probability of surface oiling within a 150 km radius of the well during the summer and winter spill scenarios.

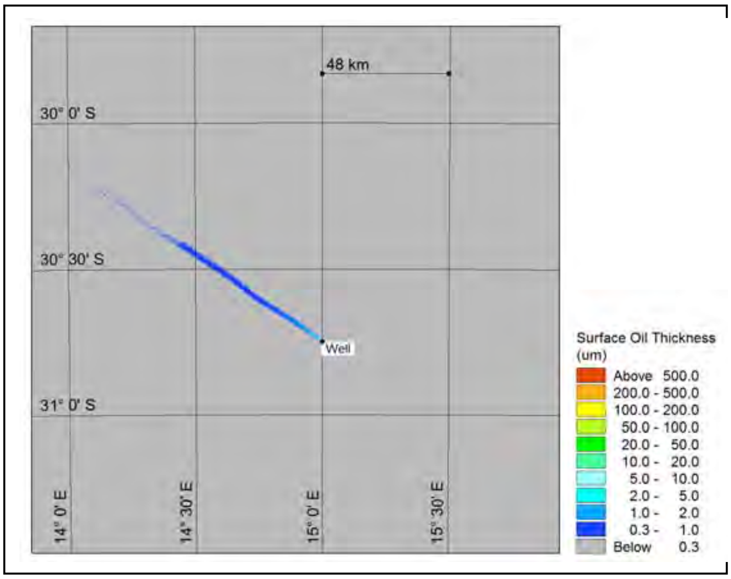


Figure 5.3: 1 ton of hydraulic fluid spill scenario: Predicted oil trajectory for one spill simulation. Plot shows the maximum oil thickness on the water surface at any time during the spill, i.e. the area swept by oil.

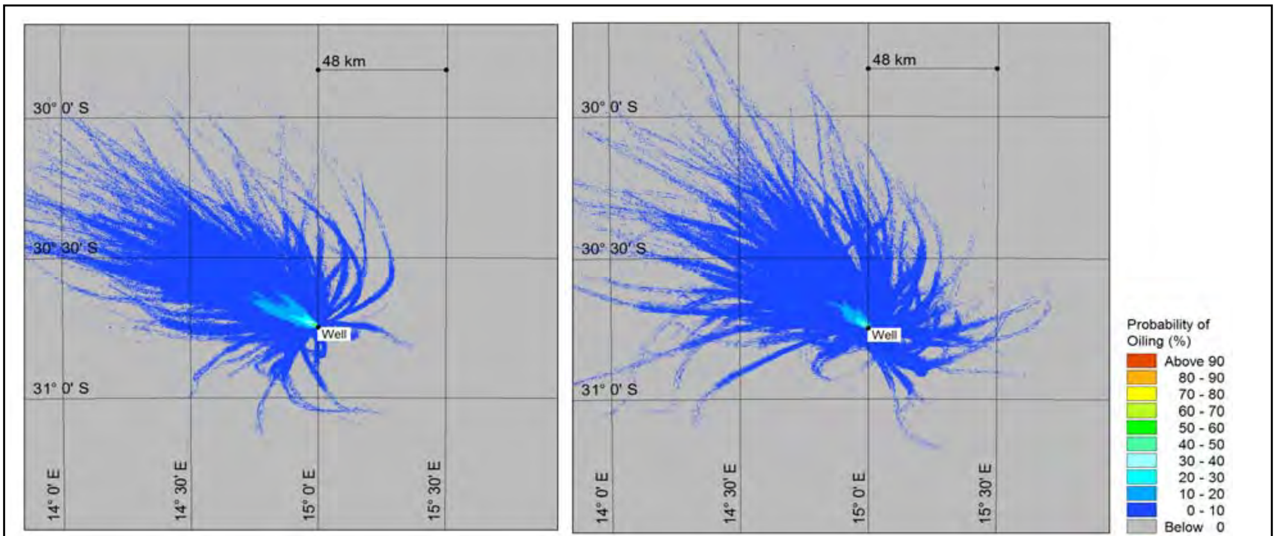


Figure 5.4: 1 ton of hydraulic fluid spill scenario: Probability of surface oiling in (a) summer and (b) winter for all 485 spill simulations.

[8] This oil thickness can be described as a 'bright colours sheen' on the water surface (NOAA 2009).

Scenario 2: 10 ton diesel spill:

A 10 ton diesel spill is predicted to move approximately 110 km from the source, also as a narrow plume predominantly in a north-westerly direction (see Figure 5.5). The diesel would remain on the sea surface for no more than 1.5 days before a combination of oil dispersion and spreading reduces the oil thickness below 0.3 µm. There is no probability of a 10 ton diesel spill reaching the shoreline, which is located approximately 230 km east of the area of interest for well drilling. Figure 5.6 shows the probability of surface oiling within a 110 km radius of the well during the summer and winter spill scenarios. Although the diesel spill scenario is ten times larger than the 1 ton hydraulic oil spill scenario, the area oiled is smaller due to evaporation and the more rapid dispersion of diesel.

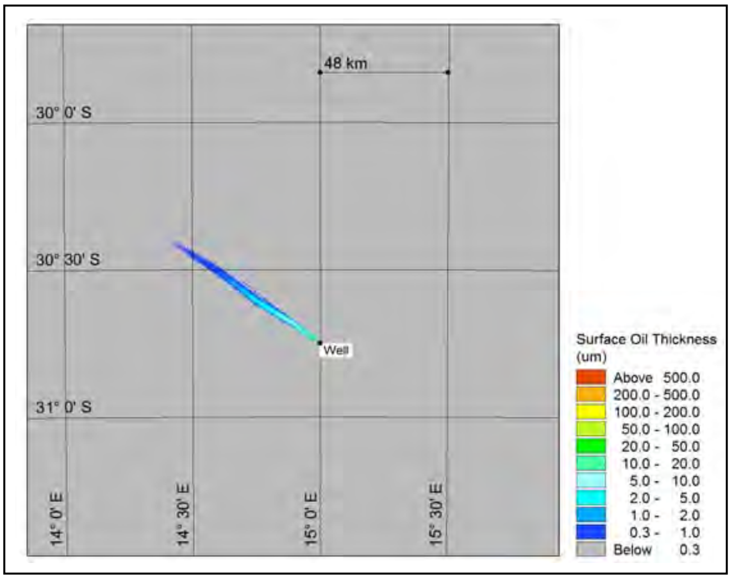


Figure 5.5: 10 ton of diesel spill scenario: Predicted oil trajectory for one spill simulation. Plot shows the maximum oil thickness on the water surface at any time during the spill, i.e. the area swept by oil.

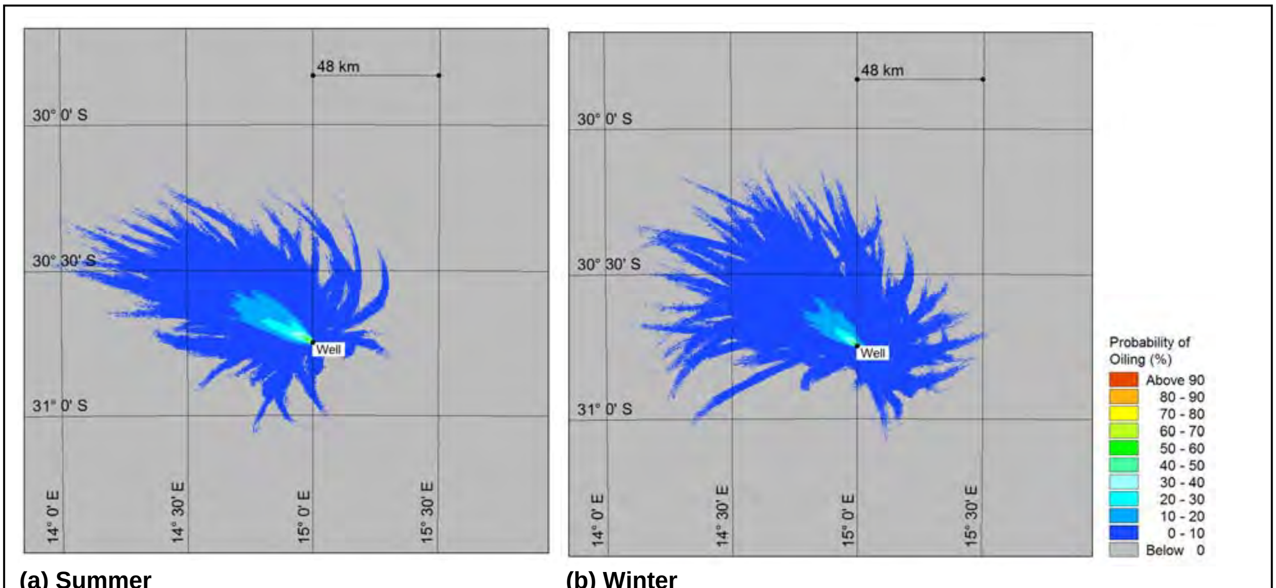


Figure 5.6: 10 tons of diesel spill scenario: Probability of surface oiling in (a) summer and (b) winter for all 485 spill simulations.

Scenario 3: Five-day blow-out scenario:

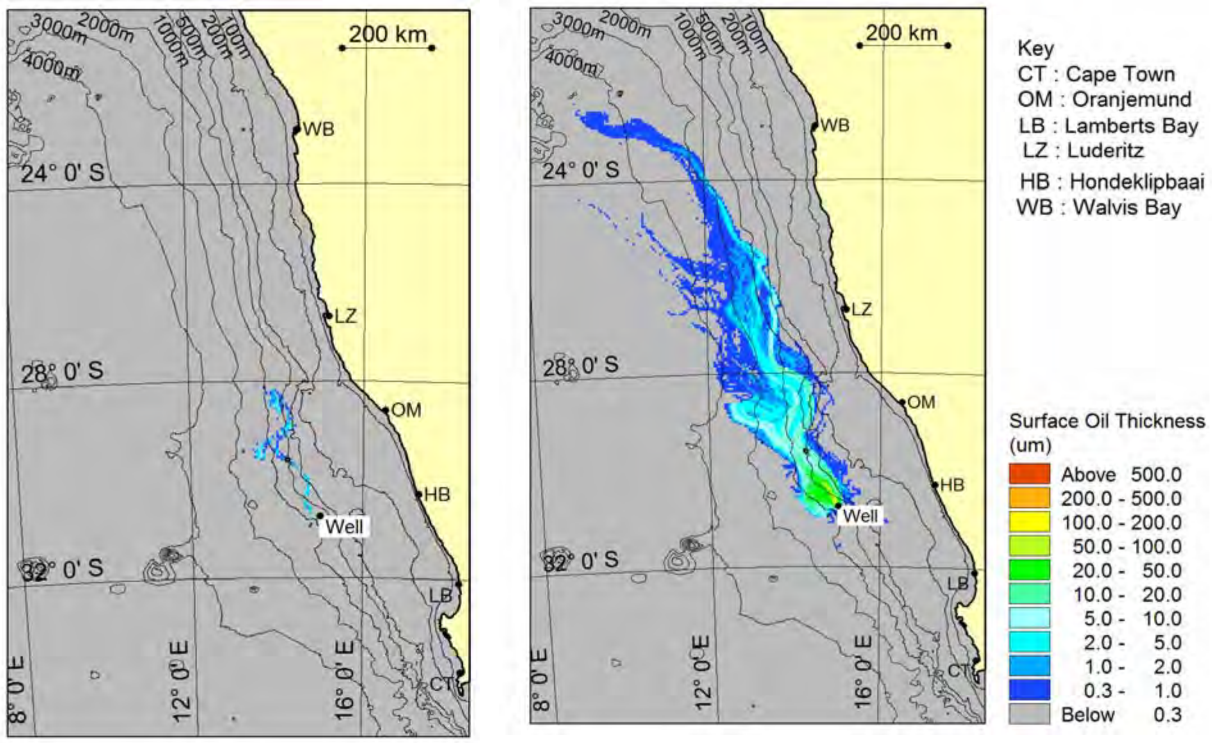
A large blow-out oil spill under the 5-day scenario is predicted to result in extensive areas of oiling of both sub-surface and particularly surface waters. Once the oil reaches the surface it would generally move in a north-westerly direction as a relatively confined plume due to the prevailing near-surface currents and winds (see Figure 5.7). The probability of the oil spill reaching the coastline depends on season and the weathering scenario (fast, medium or slow). During summer the strong south-easterly winds would tend to transport the oil away from the shoreline, whilst the weaker winds in winter increase the probability of shoreline oiling.

Under the following scenarios oil is not predicted to reach the shore:

- During summer oil is not predicted to reach the shoreline under all weathering scenarios (see Figure 5.8; Table 5.29); and
- During winter oil is not predicted to reach the shoreline under the fast and medium weathering (see Figure 5.9a; Table 5.30).

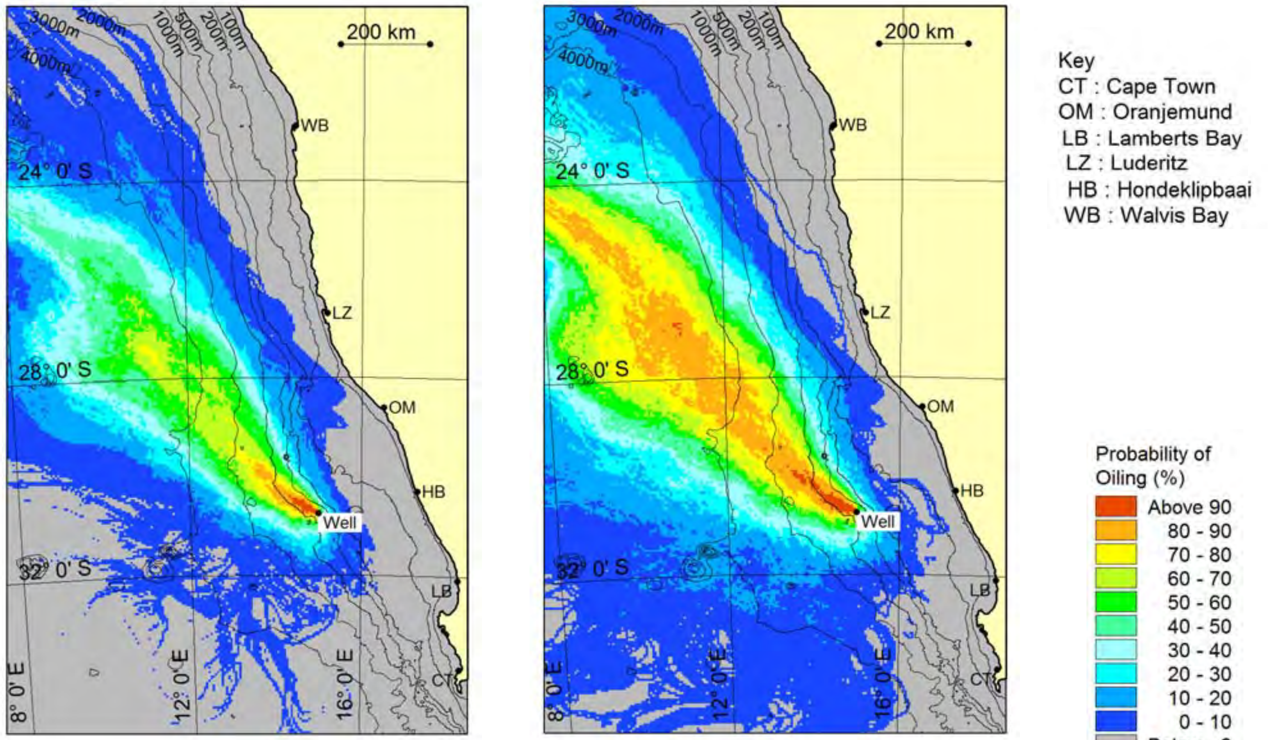
Under the following scenarios oil is predicted to reach the shore, assuming no mitigation measures are put in place:

- During winter there is a <10% probability of shoreline oiling at various point between Oranjemund and Cape Town under the slow weathering scenario (see Figure 5.9b; Table 5.30). The oil would be present on the water surface for more than 40 days after the start of the spill. This assumes no mitigation in terms of an oil spill management plan.



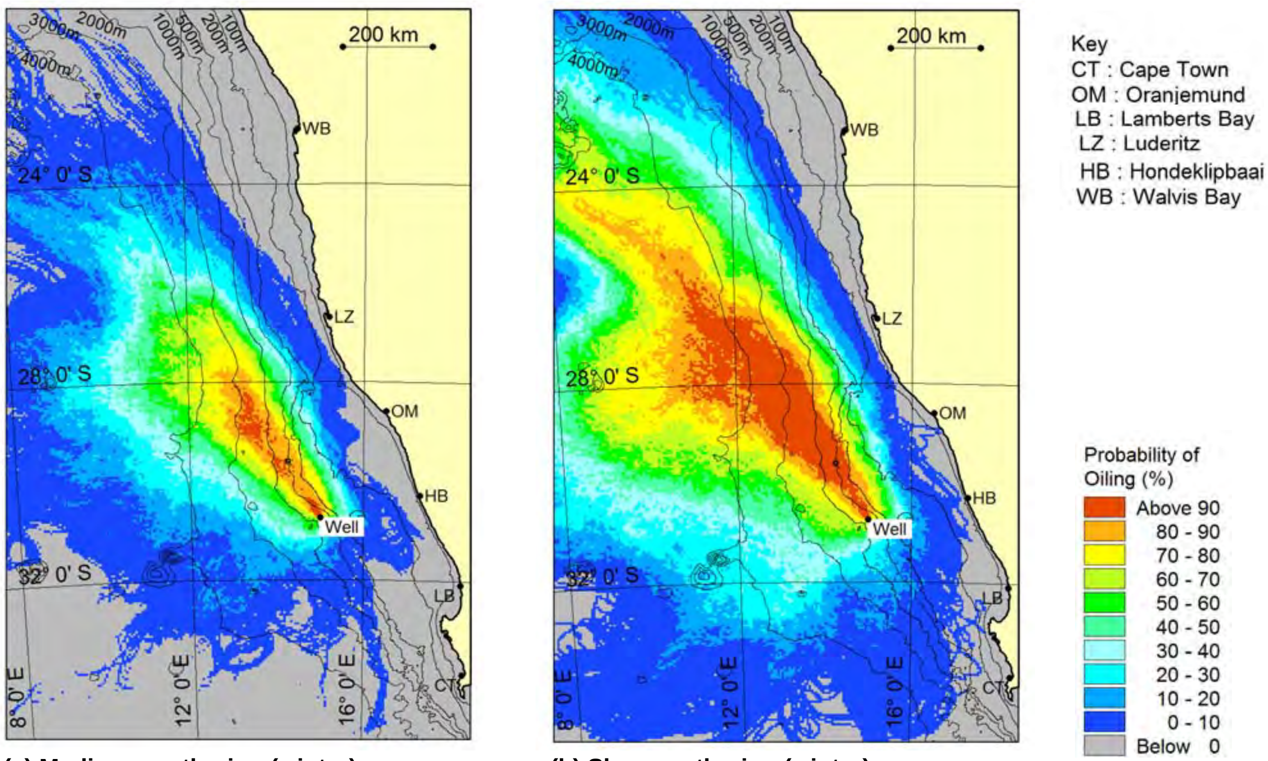
(a) Snapshot (after 14 days) **(b) Predicted oil trajectory of one spill simulation**

Figure 5.7: Five-day blow-out, medium weathering, scenario where the oil approaches the shore: (a) Snapshot of a single spill event indicating the extent of surface oil after 14 days; (b) Predicted oil trajectory of one spill simulation where the oil approached the shore. Plots show the maximum oil thickness on the water surface at any time during the spill, i.e. the area swept by oil.



(a) Medium weathering (summer) **(b) Slow weathering (summer)**

Figure 5.8: Five-day blow-out scenario: Probability of surface oiling for a spill event in <u>summer</u> for (a) medium and (b) slow weathering scenarios for all 140 spill simulations.



(a) Medium weathering (winter) **(b) Slow weathering (winter)**

Figure 5.9: Five-day blow-out scenario: Probability of surface oiling for a spill event in <u>winter</u> for (a) medium and (b) slow weathering scenarios for all 140 spill simulations.

Scenario 4: Twenty-day blow-out scenario:

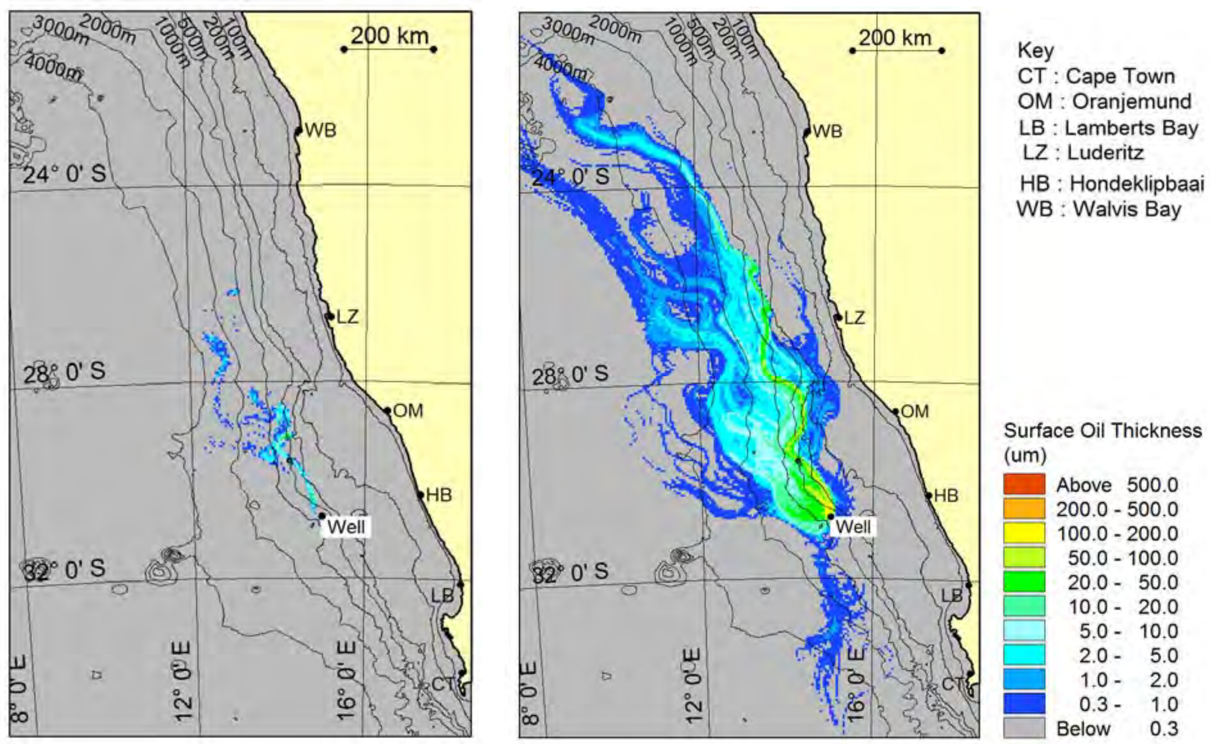
The results of the 20-day blow-out scenario are qualitatively similar to those for the 5-day blow-out, where during the summer the strong south-easterly winds would tend to transport the oil away from the shoreline, whilst the weaker winds in winter increase the probability of shoreline oiling. The difference is that the longer release increases the duration that oil is present on the water surface and thus increases the probability of oiling, particularly in the area north-west of the well (see Figure 5.10).

Under the following scenarios oil is not predicted to reach the shore:

- During summer oil is not predicted to reach the shoreline under the fast and medium weathering scenarios (see Figure 5.11a; Table 5.29).

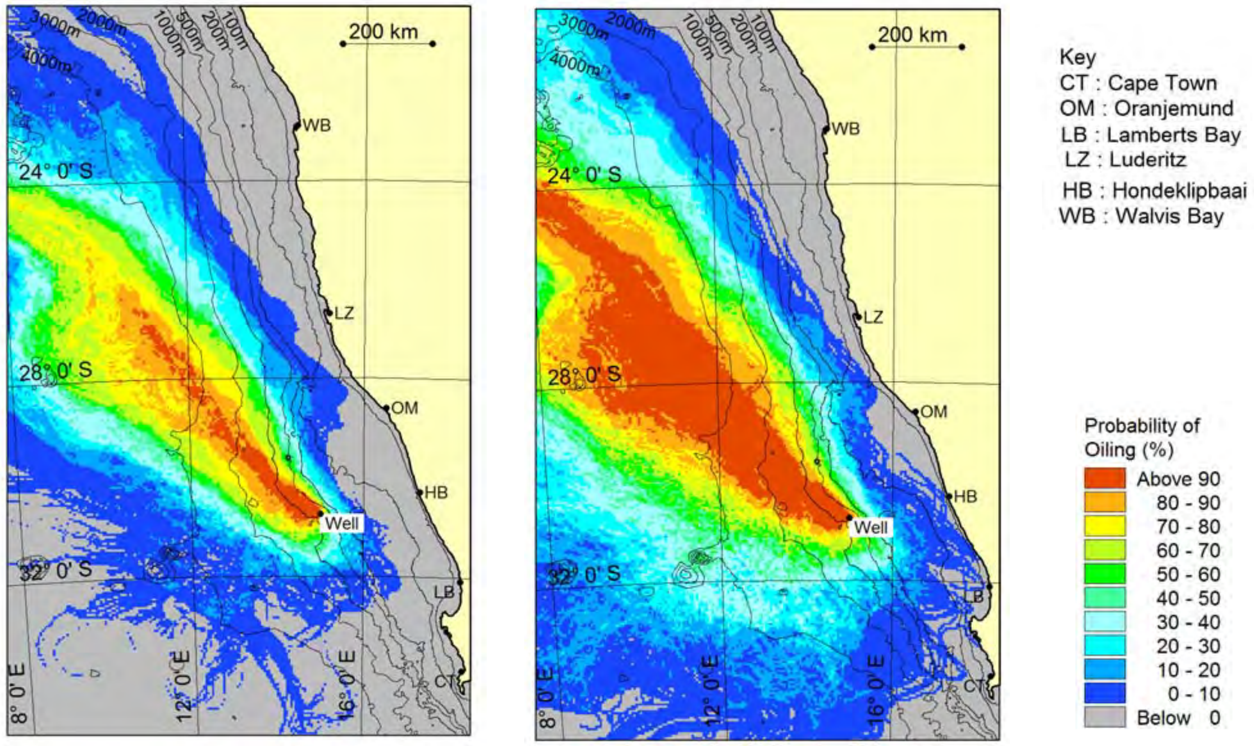
Under the following scenarios oil is predicted to reach the shore, assuming no mitigation measures are put in place:

- During winter there is a <10% probability of shoreline oiling between Lüderitz to Oranjemund under the medium weathering scenario (see Figure 5.12a; Table 5.30);
- During winter and summer there is a <10% probability of shoreline oiling under the slow weathering scenario (see Figure 5.12a and b; Table 5.29 and 5.30).



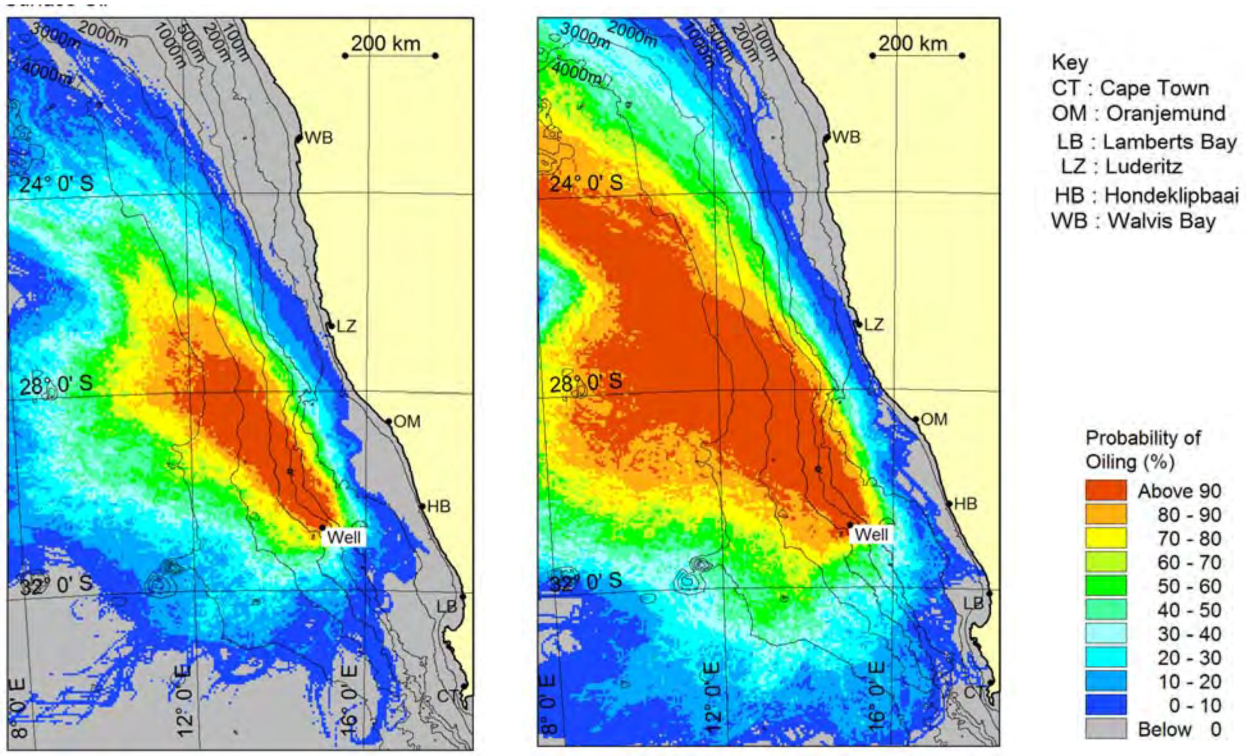
(a) Snapshot (after 14 days) **(b) Predicted oil trajectory of one spill simulation**

Figure 5.10: Twenty-day blow-out, medium weathering, scenario where the oil approaches the shore: (a) Snapshot of a single spill event indicating the extent of surface oil after 14 days; (b) Predicted oil trajectory of one spill simulation where the oil approached the shore. Plots show the maximum oil thickness on the water surface at any time during the spill, i.e. the area swept by oil.



(a) Medium weathering (summer) **(b) Slow weathering (summer)**

Figure 5.11: Twenty-day blow-out scenario: Probability of surface oiling for a spill event in <u>summer</u> for (a) medium and (b) slow weathering scenarios for all 70 spill simulations.



(a) Medium weathering (summer) **(b) Slow weathering (summer)**

Figure 5.12: Twenty-day blow-out scenario: Probability of surface oiling for a spill event in <u>winter</u> for (a) medium and (b) slow weathering scenarios for all 70 spill simulations.

Table 5.29: Probability of shoreline oiling for a spill event in summer.

Section of shoreline	5-day blowout			20-day blowout		
	Fast weathering	Medium weathering	Slow weathering	Fast weathering	Medium weathering	Slow weathering
North of Walvis Bay	0	0	0	0	0	0
Walvis Bay to Lüderitz	0	0	0	0	0	0
Lüderitz to Oranjemund	0	0	0	0	0	0
Oranjemund to Hondeklipbaai	0	0	0	0	0	<10%
Hondeklipbaai to Lamberts Bay	0	0	0	0	0	<10%
Lamberts Bay to Cape Town	0	0	0	0	0	<10%

Table 5.30: Probability of shoreline oiling for a spill event in winter.

Section of shoreline	5-day blowout			20-day blowout		
	Fast weathering	Medium weathering	Slow weathering	Fast weathering	Medium weathering	Slow weathering
North of Walvis Bay	0	0	0	0	0	0
Walvis Bay to Lüderitz	0	0	0	0	0	<10%
Lüderitz to Oranjemund	0	0	<10%	0	<10%	<10%
Oranjemund to Hondeklipbaai	0	0	<10%	0	0	<10%
Hondeklipbaai to Lamberts Bay	0	0	0	0	0	<10%
Lamberts Bay to Cape Town	0	0	<10%	0	0	<10%

5.7.2 POTENTIAL IMPACTS OF AN ACCIDENTAL OIL SPILL

5.7.2.1 Small instantaneous spills

Description of impact

A small operational spill could have an impact on marine fauna (and associated habitats) and the fishing industry in the offshore, nearshore and shoreline environs.

Assessment

There is a far greater probability of a minor accidental spill of hydrocarbons, chemicals or drilling mud due to normal operations than for a blow-out scenario. The small events would be relatively short-lived on the water surface (< 2 days) and there would be no probability of the oil reaching the shoreline. Smaller spills from vessel in or *en route* to port pose a far greater risk to the nearshore environment. Unless a spill is contained and managed within a port, a nearshore spill is likely to reach the shore through wave action and tidal currents. The impact of an operational spill at the well site or near the coast on marine fauna is considered to be regional, of zero (e.g. benthic) to high (e.g. birds) intensity depending on the faunal group in the short-term. Collectively this impact is considered to be of **medium** significance before mitigation and of **LOW** significance with mitigation. The potential impact on the fishing industry is considered to be of to be localised, of low intensity in the short-term. Thus this impact is considered to be of **VERY LOW** significance before and after mitigation (see Table 5.31).

Mitigation

Shell follows a systematic approach to HSSE management in order to achieve high standards of operation and continuous performance improvement. As part of the procurement process, Shell would evaluate Contractor competence in HSSE management capability.

The following mitigation should also be implemented:

- A SOPEP must be prepared for the drilling unit and all other vessels and be in place at all times during operation;
- Oil pollution emergency procedures for small spills must be integrated with the drilling units emergency procedures for all incidents covered in the Emergency Procedures Manual;
- A Tiered response plan must be prepared;
- Arrangements must be put in place for rapid deployment of Tier 1 response at the spill site (e.g. from support vessel);
- Personnel must be trained in emergency procedures;
- Training and exercise programmes must be established to ensure that the response activity can be effectively executed; and
- Onboard spill equipment and spill containment materials must be in place, maintained and positioned in clearly identified locations.

Table 5.31: Assessment of the impact related to a small accidental oil spill.

	Extent	Duration	Intensity	Probability	Significance	Confidence
Marine fauna						
Without mitigation	Regional	Short-term	High	Improbable	**Medium**	High
With mitigation	Regional	Short-term	Medium	Improbable	**LOW**	High
Fishing (all sectors)						
Without mitigation	Local	Short-term	Low	Improbable	**Very Low**	Medium
With mitigation	Local	Short-term	Low	Improbable	**VERY LOW**	Medium

5.7.2.2 Large blow-outs

Description of impact

In the event of a blow-out, oil could be released, which could have an impact on marine fauna (and associated habitats) and the fishing industry in the offshore, nearshore and shoreline environs.

Assessment

The greatest environmental threat from offshore drilling operations is the risk of a major spill of crude oil occurring either from a blow-out or loss of well control. Oil spilled in the marine environment would have an immediate detrimental effect on water quality. Most of the toxic effects are associated with the monoaromatic compounds and low molecular weight polycyclic hydrocarbons, as these are the most water-soluble components of the oil. Oil is most toxic in the first few days after the spill, losing some of its toxicity as it begins to weather and emulsify.

Based on the results of the oil spill modelling study (see Section 5.7.1), oil is predicted to reach the shore under the following scenarios:

- 5-day blow-out scenario: During winter there is a <10% probability of shoreline oiling at various point between Oranjemund and Cape Town under the slow weathering scenario.
- 20-day blow-out scenario:
  - During winter there is a <10% probability of shoreline oiling between Lüderitz to Oranjemund under the medium weathering scenario; and
  - During winter and summer there is a <10% probability of shoreline oiling along the central and southern Benguela coastline off South Africa and Namibia under the slow weathering scenario.

It is evident from these results that drilling during winter would increase the probability of shoreline oiling in the event of a spill. Thus if drilling is confined to summer, as proposed, the probability is significantly reduced.

Plankton (comprising phytoplankton and zooplankton)
Heavy loss of pelagic eggs and fish larvae can occur if they were present in the area of oil spill. The time of year during which a large spill takes place would greatly affect the degree of impact that would result. Should it coincide with a major spawning peak, it could result in severe mortalities and hence a reduction in recruitment. However, it should be pointed out that spawning and recruitment success is subject to variability in environmental conditions that have a far greater impact than would be posed by a single large spill.

Benthic fauna
Oil in sediments as a result of accidental spillages can result in physical smothering of the benthos and chronic pollution of the sediments. Tolerances and sensitivities between species vary greatly and generalisations cannot be made confidently. Some burrowing infauna (e.g. polychaetes and copepods) show high tolerances to oils, as the weathered product serves as a source of organic material that is suitable as a food source. Polychaetes in particular can take advantage of bioturbation and degradation of oiled sediments. This results in highly modified benthic communities with (potentially lethal) ‘knock-on’ effects for higher order consumers. Sessile and motile molluscs (e.g. mussels and crustaceans) are frequent victims of direct oiling or coating. Filter-feeders in particular are susceptible to ingestion of oil in solution, in dispersion or adsorbed on fine particles. Chronic oiling is known to cause a multitude of sub-lethal responses in taxa at different life stages, variously affecting their survival and potential to re-colonise oiled areas.

Fish
Impacts of oil on juvenile and adult fish can be lethal, as gills may become coated with oil. Sub-lethal and long-term effects can include disruption of physiological and behavioural mechanisms, reduced tolerance to stress, and incorporation of carcinogens into the food chain. However, being mobile, fish are likely to be able to avoid a large spill. A large-scale pollution event in the nursery areas extending from Saldanha Bay northwards to the Namibian border would have a potentially critical impact on juvenile commercial and other fin fish species using the inshore and bay areas as nursery grounds. These species (juveniles) are unlikely to be able to move out of the area and depending on the scale of the event, finfish mortality is expected with a resulting impact on the fishery (see fisheries impact below). The peak nursery period for juvenile finfish occurs from December through to March. Thereafter, most juvenile small pelagic species migrate southwards out of the bays.

Birds
Birds, both at sea and along the coast, are vulnerable to oil spills. Individual pelagic seabirds, which become oiled, almost certainly will die as a result of even moderate oiling which damages plumage and eyes. Even if oiled seabirds are collected for cleaning and rehabilitation the success rate is low. Ingestion of oil in an attempt to clear oil from plumage can also result in anaemia, pneumonia, intestinal irritation, kidney damage, altered blood chemistry, decreased growth, impaired osmoregulation, and decreased production and viability of eggs.

Turtles

The impact of oil spills on turtles is thought to primarily affect hatchling survival. Turtles encountered in the project area would mainly be migrating adults and vagrants.

Seals

Little work has been done on the effect of an oil spill on fur seals, but they are expected to be particularly vulnerable as oil would clog their fur and they would die of hypothermia (or starvation, if they had taken refuge on land).

Cetaceans (dolphins and whales)

The impact of oil pollution on local and migrating cetacean populations would obviously depend on the timing and extent of the spill. In particular, oil pollution in areas of cetacean critical habitat (areas important to the survival of the population), such as the extreme near-shore calving grounds of the Southern Right whale or summer feeding grounds in the Cape Columbine – Yzerfontein area, would be the most likely to impact populations. In extreme circumstances a large spill could impact a whale or dolphin population where the spill impacts critical habitat of that population. It is assumed that the majority of cetaceans would be able to avoid oil pollution, though effects on the population could occur where the region of avoidance is critical to population survival. The area of most concern is the calving and nursery ground of Southern Right whales in sheltered bays of the south coast between June and November (inclusive) each year when number of individuals is higher. Although adult whales have been noted to swim, and even feed through heavy concentrations of oil, Southern Right whale calves have a far higher surfacing rate than adults and could possibly be affected by inhalation of volatile hydrocarbons.

Commercial and recreational fishing

There are several probable impacts of large oil spills on fisheries. These include:

- Displacement of species from normal feeding areas;
- Physical contamination of animals (including eggs and lave) resulting in mortality and / or physiological effects such as clogging of gills;
- Exclusion of fisheries from polluted areas; and
- Gear damage due to oil contamination.

In the event of an oil spill, fishing may have to be temporarily suspended through having to avoid fishing in oiled waters and may suffer gear damage due to oil contamination. Oil contamination would potentially have the greatest impact on commercial fisheries for rock lobster and sessile filter feeding (e.g. mussels) and grazers (e.g. abalone). Mortality is expected to be high on filter feeders and, to a lesser extent, grazers. These species have low mobility and no means to escape contamination and ultimately mortality. Thus, mussel and oyster farms (mariculture facilities) on the West Coast and in Saldanha Bay could be impacted if the extent of the contamination included these areas. For a large oil spill, fishing / mariculture activities and revenues could be affected over a wide area until such time as the oil has either been dispersed or broken down naturally.

Coastal environments

Sandy beaches on exposed coasts with high wave and solar energy would be the least impacted and recover most rapidly. Similarly exposed rocky shores after initial mortalities would recover relatively rapidly. The most sensitive coastal areas are coastal lagoons and estuaries. Should oil enter these systems in any quantity the impact would be severe. Secondary impacts on lagoon- and estuary-dependent biota would be equally severe.

Summary

While the probability of a major spill happening is extremely small, the impact nonetheless needs to be considered as it could have devastating effects on the marine environment. Assuming the worst-case scenario of a 20-day blow-out of slow-weathering crude oil, the potential impact on the marine environment would be of high intensity and would likely persist over the medium- to long-term. Results of the oil spill modelling study indicated that the spill would spread in a north-westerly direction, extending over 650 km into Namibian waters thus being of international extent. The probability of surface oil reaching the coast is, however, low (<10%), with the area potentially affected being between Hondeklipbaai and Saldanha.

In the unlikely event of an oil spill due to a well blow-out, the impact on marine fauna is collectively considered to be of **very high** significance before mitigation and of **HIGH** significance with mitigation (see Table 5.32). The potential impact on the fishing industry is thus considered to range from **LOW** (for the pelagic long-line and tuna pole sectors) to **MEDIUM** (for the demersal trawl, demersal long-line (hake and shark), traditional line-fish and West Coast rock lobster sectors) to **HIGH** (for the small pelagic purse-seine sector) with and without mitigation (see Table 5.32).

Table 5.32: Assessment of impact related to a large oil spill from a blow-out or loss of well control.

	Extent	Duration	Intensity	Probability	Significance	Confidence
Marine fauna						
Without mitigation	International	Medium- to Long-term	High	Improbable	**Very High**	High
With mitigation	Regional	Medium-term	High	Improbable	**HIGH**	High
Fishing (demersal trawl, demersal long-line, purse-seine and West Coast rock lobster)						
Without mitigation	Regional	Short- to medium-term	High	Improbable	**Medium to High**	Medium
With mitigation	Regional	Short- to medium-term	High	Improbable	**MEDIUM TO HIGH**	Medium
Fishing (pelagic long-line, tuna pole and traditional line-fish)						
Without mitigation	Regional	Short-term	Medium	Improbable	**Low**	Medium
With mitigation	Regional	Short-term	Medium	Improbable	**LOW**	Medium

Mitigation

This section provides specific detail of how Shell would address mitigation planning to avoid likely large oil spills associated with well blow-out events. The specific systems include:

- Bow-Tie Risk Model; and
- Oil Spill Contingency Planning Process.

Bow-Tie Risk Model

The potential impacts (consequences) of an incident (as a result of their activities) are managed using the Bow-Tie Risk Model (see Figure 5.13). The model involves knowing and understanding the risks/hazards (by identifying the hazards and potential effects) and managing the risks/hazards (by preventing, mitigating and recovering from the incident/event). The objectives of the Bow-Tie Risk Model are to assure that hazards are managed to an acceptable level (called "As Low As Reasonably Practicable" - ALARP). This method creates a clear differentiation between proactive (creating barriers to minimise likelihood of incidents) and reactive (responses to mitigate consequences after an incident occurring) risk management. Barriers interrupt the unwanted scenarios (upset condition) so that the threats do not result in a loss of control or do not escalate into an actual impact (the consequences).

The Bow-Tie Risk Model for Oil Spill Prevention, Response and Planning for the proposed exploration drilling in the Orange Basin Deep Water Licence Area is shown in Figure 5.14.

Further detail on the controls and responses for the proposed exploration drilling programme is provided in Table 5.33.

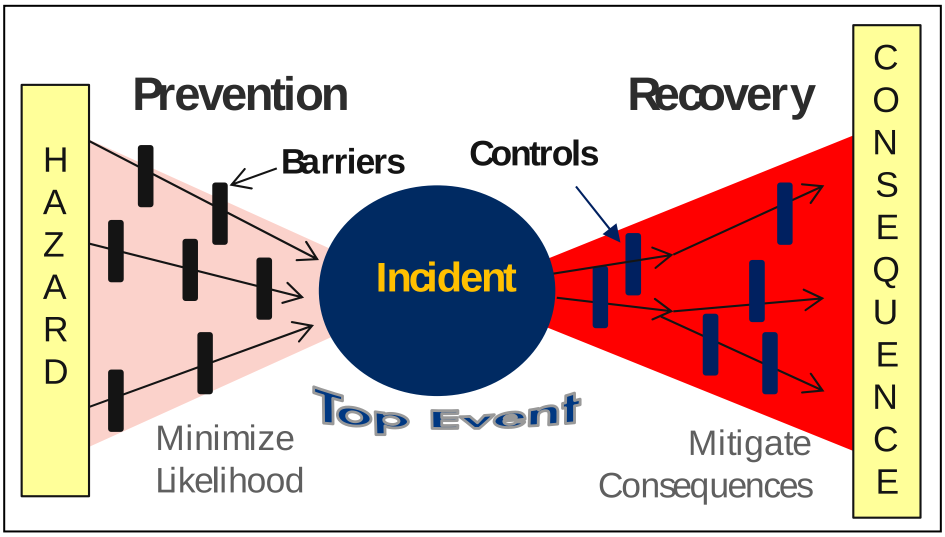


Figure 5.13: Bow-Tie Risk Model.

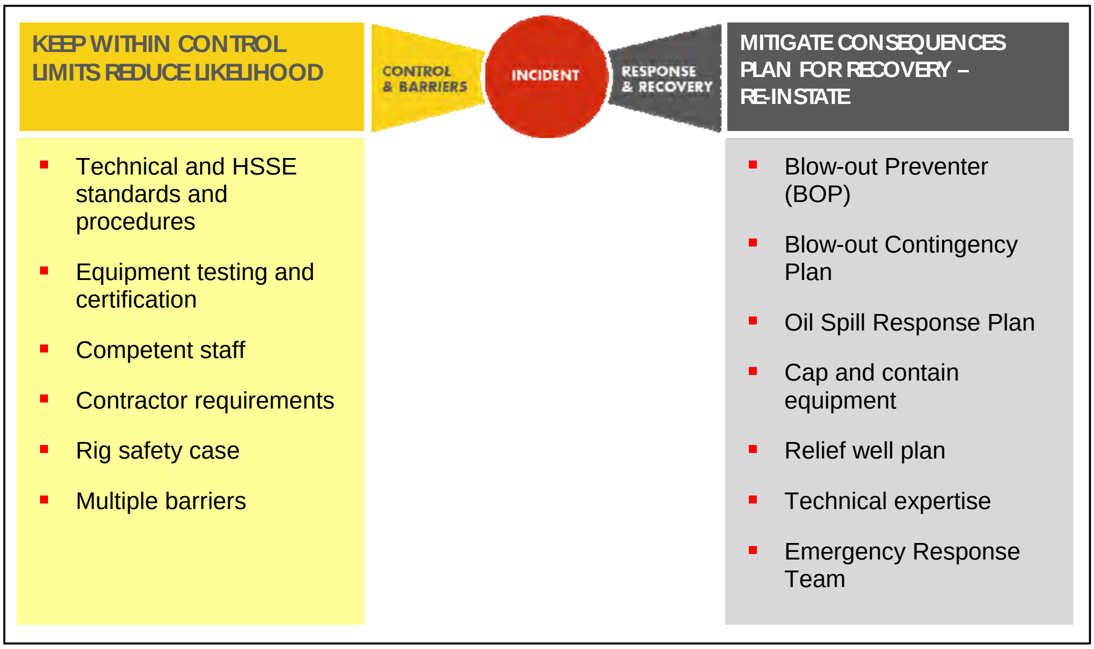


Figure 5.14: Proposed Bow-Tie Risk Model for Oil Spill Prevention, Response and Planning for the proposed exploration drilling in the Orange Basin Deep Water Licence Area, illustrating the high level controls and responses.

Table 5.33: Description of the Barriers and Controls (for avoidance/prevention) and Response and Recovery (Mitigation) to deal with oil spills.

Barriers and Controls (Avoidance/Prevention Actions)	
Design and Technical Integrity	The Shell Wells Standard defines HSSE and technical requirements for wells. It also details assurance and competency requirements for well engineering and completion and well intervention personnel. • Well designs would be undertaken in accordance with Shell design manuals and standards to comply with, or exceed, industry standards. • Well materials would be procured in accordance with Material Procurement Specifications. • Identified risks would be captured in a wells risk register to ensure concept and design risks are mitigated. • All safety critical elements, performance standards and design parameters would be identified by a Shell Well Design Engineer who would provide a well specification and operating and integrity parameters for the construction and operation of the well.
Multiple Well Casings	Casings would be designed to withstand a variety of forces, such as collapse, burst or tensile failure, as well as chemically aggressive brines. They would be run to prevent caving-in of upper formations, provide strong foundations for high density fluids, isolate zones of fluid loss or different pressure gradients and prevent fluid loss into or contamination of production zones.
Multiple Barriers	**Wellbore Pressure:** Subsurface pressures above and within the hydrocarbon-bearing strata would be controlled by the use of weighted drilling mud. The hydrostatic pressure of the drilling mud in the well would be adjusted by adding weighting agents such as barites to ensure that it is greater than the formation pressure to prevent the undesired influx of fluids into the wellbore (known as a 'kick'). Pressure monitoring would be undertaken during drilling to ensure that kicks are avoided or managed to prevent escalation into a blowout.
	Blow-out Preventer (BOP) Stack: BOP stacks are a set of two or more BOPs used to control the pressure of a well through mechanical devices designed to rapidly seal the well (or "shut in") in an emergency. Typically a BOP stack would comprise both annular valves (a rubber sealing ring squeezed to seal on pipe) and ram preventers (cutting jaws to shear through the drill pipe and seal off the well) together with hydraulic accumulators and controls.
Competent Staff	Shell has competent people who would design the well and conduct independent sign-off for its design. When a deep-water exploration well is drilled Shell can use sensors that transmit real-time information, such as pressure and temperature, back to operations centres around the world. Engineers would interpret this information to assess conditions and potential risks. If anything out of the ordinary is observed, such higher than expected pressures underground, the engineers may advise the rig to adjust the drilling plan and take extra precautions to reinforce the well before continuing.
Testing and Certification	Safety critical equipment would be subject to testing and certification to ensure that it meets design specifications. The well design, drilling, preparation and completion plans would go through several stages of review involving experts from Shell and the drilling Contractor prior to the commencement of drilling operations.
Response and Recovery (Mitigation Actions)	
Oil Spill Response Plan	Shell projects are subject to a comprehensive oil spill response planning to cover accidental spills. There are three principal components underpinning an Oil Spill Response Plan (OSRP): • Crisis management (Emergency Command and Control Management); • Spill response, containment and clean-up; and • Well control. Oil spill response planning is based on the principal of a tiered response.
Emergency Command and Control Management	Emergency Command and Control Management arrangements range from the On-scene Commander, normally at the source of the incident, to the main Emergency Control Centre (ECC) Incident Commander who takes over control. As each level is activated the level of response would equally escalate.
Well Control	Whilst the OSRP defines the approach and strategy required to manage the containment, removal and clean up following a major spill, the well control process is focussed on stopping the source of the leak. A Well Control Contingency Plan (WCCP) would be put in place for each well covering seabed debris clearance; subsea dispersant injection; capping stack deployment and application; and relief well drilling.
Cap and Containment Equipment	If the BOP does not successfully shut off the flow from the well, the drilling rig would disconnect and move away from the well site while crews mobilise a capping system. The capping system would be lowered into place from its support barge and connected to the top of the blowout preventer to stop the flow of oil or gas. Shell is a partner in an industry collaboration, where the company Oil Spill Response Limited (OSRL) operates advanced well intervention and capping equipment from Saldanha Bay for deployment in the event of a subsea well control incident. This would significantly reduce the spill period and thus the likelihood of oil reaching the shore in the event of a blow-out.

Oil Spill Contingency Planning Process

According to IPIECA (2005), it is widely accepted that contingency planning leads to more effective and efficient response to an incident. Plans should outline appropriate response strategies with the aim of reducing ecological, economic and social damage and subsequent compensation claims. Plans should also identify appropriate resources and expertise.

Since the size, location and timing of an oil spill are unpredictable, it is important that any response arrangements are flexible enough to cope with this uncertainty. In the contingency planning process a risk assessment must be carried out (IPIECA, 2005). Oil spill risks and the responses they require are usually classified according to the size of a spill, its characteristics (types of oil react differently when spilled on water) and its proximity to a response resource. In order to plan for the range of potential spill sizes, from small operational spills to worst-case scenarios, industry and governments frequently follow the concept of a ‘tiered response’. The concept allows for the correct level of equipment and resources to be available, within a minimum response time appropriate to the risk and for the efficient escalation of response level by calling upon supplementary resources out (IPIECA, 2005). The tiered response concept is further detailed in Box 5.2.

Shell would develop an Oil Spill Response Plan (OSRP) in advance of the drilling operation in order to provide guidance on the necessary actions to prevent and / or minimise any accidental discharge of oil and to mitigate negative effects. The OSRP would be developed in accordance with tiered preparedness and response, regulatory requirements, Shell standards and international best practice. The planning process would incorporate at a minimum stakeholder engagement, a risk analysis, identification of scenarios, development of response strategies, identification of resources and response capability, and development of supporting plans. This would be compiled into an OSRP, which would be implemented through training and exercises. The constituent parts and contents of an OSRP are outlined in Box 5.3 and 5.4, respectively. The OSRP would be submitted to the competent authorities (namely DEA and SAMSA) for approval.

Following a blow-out, Shell’s preferred mitigation strategy would be to cap the well. The main advantage of well-capping is that it can be undertaken relatively quickly (i.e. within weeks). However, in some cases capping may not be straightforward, for example:

- If the wellhead cannot easily be reached (e.g. debris);
- If damage to the wellhead prevents the foreseen capping methods; and
- If released hydrocarbons prevent boats from approaching the site.

In these cases, the back-up plan may be to drill a relief well. A relief well is sometimes needed after the well has been capped to regain full control over the well. A relief well requires many complicated operations, not the least of which is the drilling of relief well(s) in the vicinity of the blow-out, which may take months to complete.

Regardless of the spill source, the OSRP should consider the options available to minimise, control or stop the continual flow of oil / gas into the environment. In the context of loss of well control this may involve an evaluation of the relative merits of various intervention such as well capping, relief wells or other suitable options.

A Well Control Contingency Plan (WCCP) would also be developed to provide a working methodology for Shell to safely and effectively manage, respond to, and recover from an uncontrolled well incident (blowout). The WCCP would be developed to supplement the OSRP. The WCCP would include potential control measures that could be taken to prevent further release or escalation of release of hydrocarbons. This may include measures that would be taken to stop the maximum anticipated discharge of hydrocarbons from the reservoir and an estimate of the maximum duration of the release. The WCCP would outline the measures for the capping of a well and the drilling of a relief well to re-establish primary well control of the original well. The WCCP would need to demonstrate that there is adequate planning or provision in place for unforeseen events. The WCCP would also provide a description of how the response activities would be coordinated. The WCCP would provide an indicative timetable for sourcing a drilling rig (including provision for suspension of any current operations), relocating the drilling rig to the relief well site, and drilling the relief well and decommission the original well.

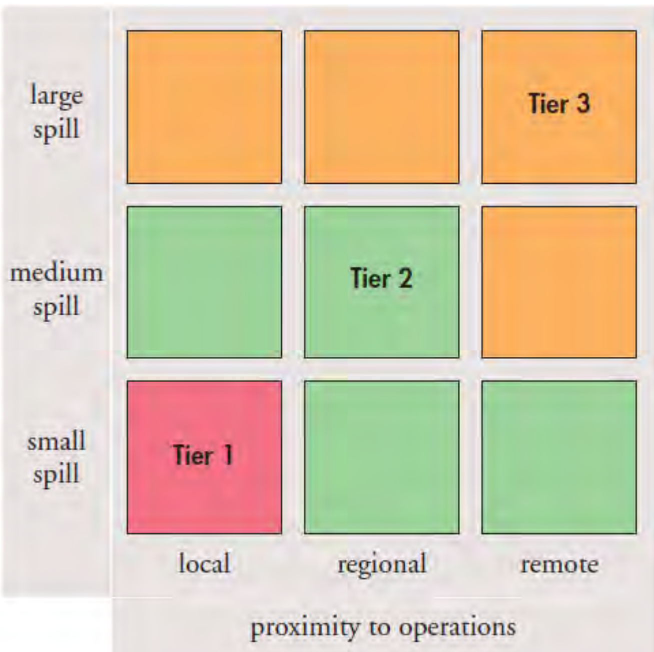
Box 5.2: Tiered Preparedness and Response.

Shell uses the Tiered Preparedness and Response concept which ensures the appropriate resources are considered for all potential scenarios identified in the plan.

Tiered Preparedness and Response gives a structured approach to both establishing oil spill preparedness and undertaking a response. It allows potential oil spill incidents to be categorised in terms of their potential severity and the capabilities that need to be in place to respond (IPIECA, 2007). Conventionally the concept has been considered as a function of size and location of a potential oil spill, with three tiers typically defined (see table and figure below).

Tier categories

Tier 1	Minor spills, including incipient spills that are quickly controlled, contained and cleaned up using local (onsite or immediately available) company/contractor owned equipment and personnel resources. For offshore facilities, local resources could include those at the facility, on nearby support vessels or at a designated shore support base or staging area. A Tier 1 spill would typically be resolved within a few hours or days.
Tier 2	Tier 2 events are more diverse in their scale and by their nature involve potentially a broad range of impacts and stakeholders. Moderate spills, controlled or uncontrolled, requiring activation of significant regional oil spill response resources and all or most of the Spill Management Team. Tier 2 response resources are varied in their provision and application. Management responsibilities are usually shared in a collaborative approach and a critical feature is the integration of all resources and stakeholders in the response efforts. A Tier 2 spill response may continue for several days or weeks.
Tier 3	Major spills, controlled or uncontrolled, requiring activation of large quantities and multiple types of response resources including those from out of the region, and possibly international sources. Tier 3 events are rare but have the potential to cause widespread damage and affect many people. Tier 3 response resources are concentrated in a relatively few locations, held in readiness to be brought to the country when needed. Such significant events usually call for the mobilisation of very substantial resources and a critical feature is their rapid movement across international borders and the integration of all resources into a well-organized and coordinated response. The entire Spill Management Team would be required and would likely be supplemented by outside organisations. A Tier 3 spill response may continue for many weeks or months.



The framework for Tiered Preparedness and Response (IPIECA, 2007)

Box 5.3: Constituent parts of an Oil Spill Response Plan (OSRP).

Incident Scenarios	Through the risk assessment process, scenarios must be selected for planning purposes in the OSRP based on the greatest risk in the unlikely event of an incident. Likely scenarios include: • Oil spills arising from exploration drilling activities; • Oil spills arising from activities in ports and harbours; • Oil spills arising from activities involving support vessels (e.g. bunkering); • Small, instantaneous releases (e.g. operational batch spill of fuel); • Synthetic-based mud spill; • Vessel spill (offshore and nearshore); and • Subsea blow-out.
Logistics & Mobilisation	Effective oil spill response is dependent on many factors, one being logistics, mobilisation of resources and ongoing support. The OSRP must outline or link to additional plans: • Existing contracted response resources (equipment, aircraft, vessels, source control, etc.); • Mobilisation times and guidance; • Internal and external response personnel / subject matter experts; • Communications capabilities; • Facilities; and • Support capabilities (food, supplies, PPE, etc.).
Incident Command System	The Incident Command System, which Shell utilises for managing incidents, is a scalable, systematic method for coordinating and controlling the wide variety of response activities, resources and organisations from a central command post. Key aspects of the Incident Command System include: • Common Terminology; • Span of control; • Coordination of equipment, personnel and resources; and • Communications.
Response Tools	The OSRP must outline the key oil spill response strategies that are considered during an incident. It must provide decision-making guidance or references to assist in determining the appropriate response technique and tactics such as: • Dispersants; • In-situ burning; • Mechanical recovery; • Physical removal; and • Natural process. The Incident Management Team would work in coordination with authorities and stakeholders to manage all response activities over the course of the incident. The objectives, strategies and response tactics must be documented within the Incident Action Plan.
Responding to an Incident	The response process begins with incident detection, notifications, activation of response resources (personnel and equipment and establishing the incident command. Through the planning process, the Incident Management Team is able to respond and continuously adjust based on the conditions during the incident.
Well Control	In the unlikely event of an uncontrolled subsea flow from the well, multiple response options may include: • A capping stack system is available via existing arrangement with OSRL (industry consortium); • Capping stack and accessories for this well will be mobilised; • Subsea dispersant injection capability; and • Drilling a relief well. The Well Control Contingency Plan (WCCP) and associated technical plans must outline the procedures and logistics for the available response options.
Marine and Coastal Habitats	The OSRP must include an assessment of the sensitivity of the marine and coastal receiving environment. It would outline: • An assessment of habitats in the Orange Basin area; • Logistics and resource requirements (personnel, equipment, facilities, etc.); • Strategies and operational guidance for development of appropriate tactics (e.g. hazing, recovery) should an incident occur; and • Rehabilitation guidance (stabilisation, decontamination, washing, conditioning, release).

Box 5.3 (cont.)

Information Management	Information management during an incident is critical to facilitate a safe response and ensure authorities and stakeholders are informed of response progress. An information tool may be used that provides a single source of data and information for situational awareness, coordination, communication and data archival to support emergency management and response personnel and other stakeholders involved in or affected by an incident.
Waste Management	The OSRP must provide guidance on managing waste during an incident (e.g. procedures, resources). Many response techniques generate large volumes of oily waste in a short period of time. The OSRP guidance must expand on the operational Waste Management Plan (non-incident related). Key components include waste collection and storage, transportation, treatment and disposal. Examples of waste generated during an oil spill include: • Oily liquids; and • Solids (e.g. used sorbents, contaminated PPE, shoreline materials).
Stakeholder Engagement	The OSRP must outline guidance for two key areas of spill response - Public Information (media) and Liaison. These are focussed on communicating information about the event to meet the needs of the public and stakeholders. Liaison involves communicating with assisting and cooperating agencies and stakeholder groups that are expected to provide input during the response process. Public Information involves the timely provision of information about the response efforts to stakeholders, the media and general public.
Operational Implementation	Implementation of the OSRP is dependent on the comprehensive preparedness and response programme. The scenarios, personnel, equipment, ongoing training and exercises are necessary to ensure capability to respond to any incident. There is continuous evaluation improvement through these activities to ensure that the OSRP meets the needs of all stakeholders.
Training and Exercises	**Training:** Responders are trained based on the OSRP and in their designated roles for spill response operations and incident management. Training may include: • Incident Command System; • Spill Response; and • Media and Stakeholder engagement. **Exercises:** Exercises enable participants to work together in conducting simulated responses to hypothetical incidents in order to demonstrate proficiency and validity of response plans. Types of exercises include: • Discussion-based (table top) exercises; • Notification and communication tests; • Equipment deployment; and • Full scale exercises. **Participants:** Typical training and exercise participants include: • Incident management team; • Field responders; • Regulators; and • Stakeholders. **Continual Process:** Training and exercises occur throughout the preparedness process.

Box 5.4: Contents of an Oil Spill Response Plan (OSRP).

An OSRP would include the following sections:

- Chapter 1: Introduction and Plan Overview;
- Chapter 2: Legal and Regulatory Overview;
- Chapter 3: Oil Spill Risk Assessment;
- Chapter 4: Oil Spill Response Strategy;
- Chapter 5: Response Actions;
- Chapter 6: Oil Spill Response Management;
- Chapter 7: Oil Spill Response Resources;
- Chapter 8: Environmental and Socio-Economic Setting;
- Chapter 9: Health, Safety and Security;
- Chapter 10: Communications;
- Chapter 11: Finance, Claims and Compensation;
- Chapter 12: Demobilisation and Termination of Response;
- Chapter 13: Preparedness;
- Appendix A: Health and Safety Guidelines;
- Appendix B: Facility Description;
- Appendix C: Communications;
- Appendix D: Documentation;
- Appendix E: Public Information and External Relations;
- Appendix F: Risk Assessment and Scenario Planning;
- Appendix G: Training, Drills and Exercises; and
- Appendix H: Prevention and Detection.

5.8 NO-GO ALTERNATIVE

Description of impact

The implications of not going ahead with the proposed exploration in the Orange Basin Deep Water Licence Area are as follows:

- South Africa would lose the opportunity to further establish the extent of indigenous oil / gas reserves on the West Coast; and
- If economic oil and gas reserves do exist and are not developed, South Africa would lose the opportunity to maximise the use of its own indigenous oil and gas reserves, and create an oil and gas industry on the West Coast.

Assessment

The potential impact related to the lost opportunity to further explore oil and gas reserves on the West Coast and maximise the use of South Africa's own reserves should they exist is considered to be of **MEDIUM** significance (see Table 5.34).

Table 5.34: Assessment of impact related to No-Go alternative.

	Extent	Duration	Intensity	Probability	Significance	Confidence
Without mitigation	National	Permanent	Low	Improbable	**MEDIUM**	Low