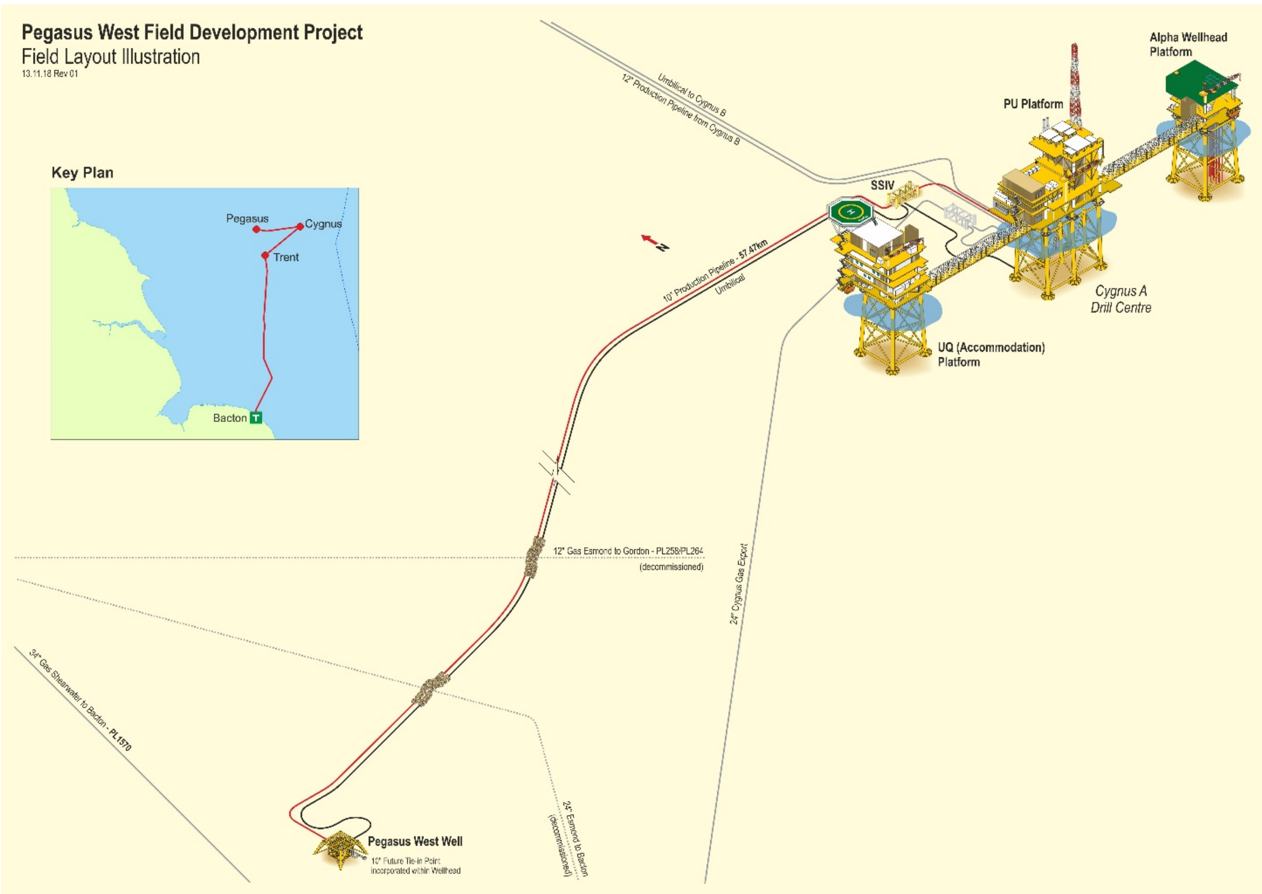
Pegasus West Development Environmental Statement



SPIRIT ENERGY

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INFORMATION SHEET

Project Name:	Pegasus West Development
Development Location:	Blocks 43/13b, 43/14, 43/15, 44/11 and 44/12
Licence No.:	P1724, P1727 and P2128
Project Reference No.:	D/4269/2021
Type of Project:	Tie-back Development
Undertaker:	Spirit Energy Resources Limited add Spirit Energy North Sea Limited

	Equity Holder/ % Holding of Each Licence	**P2128**	**P1724**	**P1727**
Licencees/Owners:	Spirit Energy Resources Limited	61.25%	-	-
	Spirit Energy North Sea Limited	-	61.25%	61.25%
	Neptune E&P UK Limited	38.75%	38.75%	38.75%

Short Description:

The Pegasus field will be developed via tie-back of the Pegasus West well 43/13b-7 to the existing Neptune Energy-operated Cygnus gas development. The proposed development comprises:

- The completion for production of the Pegasus West 43/13b-7 well;
- The installation of a 10” nominal bore (NB) carbon steel production pipeline approximately 56.8 km in length (including tie-in spools), and a 119 mm outer diameter (OD) electro-hydraulic-chemical umbilical approximately 57.0 km in length, between Pegasus West and the existing Cygnus development;
- The installation of subsea production infrastructure including a Xmas tree and wellhead protection structure (WPS) at Pegasus West and a subsea isolation valve (SSIV) at Cygnus;
- Modifications to the Cygnus topside facilities; and
- Processing of Pegasus West hydrocarbons at Cygnus with onward export to Bacton gas terminal.

Key Dates:	Cygnus topside modifications, hook-up and commissioning	Q4 2022 – Q2 2024
	Well re-entry and completion	Q4 2022
	Installation and testing of subsea infrastructure	Q2-Q3 2023
	First Gas	Q1-Q3 2024

Significant Environmental Impacts Identified:

The significance of the impacts of all planned activities, following the application of control and mitigation measures, is considered **low,** with the exception of those associated with the permanent physical presence of installed seabed infrastructure and seabed disturbance, the impacts of which are considered **medium** and ‘as low as reasonably practicable’.

The significance of the risk associated with an unplanned (accidental) large hydrocarbon release, again following control and mitigation, is considered **medium** and ‘as low as reasonably practicable’.

Generally, the impacts identified are considered localised and short term with low potential for long term or transboundary and cumulative impacts. The proposed Pegasus West Development does not contradict any marine planning objectives or marine planning oil and gas policies.

Statement Prepared By: Genesis Oil and Gas Consultants Ltd. and Spirit Energy

Company:	**Job Title**	**Relevant Qualifications/Experience**
Spirit Energy	Senior Environmental Advisor	25 years’ experience in industry
Genesis Oil and Gas Consultants Ltd	Senior Consultant Environmental Engineer	22 years’ experience in environmental/energy industry
	Senior Consultant Environmental Engineer	25 years’ experience in environmental/energy industry

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NON-TECHNICAL SUMMARY

This summary outlines the findings of the Environmental Impact Assessment (EIA) conducted by Spirit Energy Resources Limited and Spirit Energy North Sea Limited (Spirit Energy), for the proposed development of the Pegasus field via tie-back of the Pegasus West well (43/13b-7) to the Neptune E&P (UK) Limited (Neptune Energy) operated Cygnus gas development.

The purpose of this Environmental Statement (ES) is to record and communicate the findings of the EIA, which assesses the potential for environmental impacts as a result of project activities. A number of studies and surveys were undertaken to support the proposed development and these have been considered during the EIA, as appropriate.

The ES is a supporting document to the Pegasus West Field Development Plan and will be submitted to the Department for Business, Energy and Industrial Strategy (BEIS) for consideration under the regulatory approval process.

Background to the Project

The Pegasus field was discovered in 2010 and spans several licences in Quadrant 43 for which Spirit Energy is the operator. Drilling of the Pegasus West 43/13b-7 appraisal well confirmed commercial gas reserves in 2014.

The proposed Pegasus West Development will require the installation of a *c*. 56.8 km production pipeline connecting the Pegasus West well, in Block 43/13b - and then traversing Blocks 43/14, 43/15, and 44/11 - to the Cygnus development in Block 44/12 of the Southern North Sea (SNS). Cygnus is a gas development that includes the Cygnus Alpha (A) hub, comprising three bridge-linked platforms and Cygnus Bravo. Cygnus B is an unmanned satellite drill centre c. 7 km north of Cygnus A. Pegasus West production will be routed to the Cygnus Alpha process and utilities platform, then exported with Cygnus gas for processing at the Bacton terminal on the Norfolk coast.

The proposed development, situated on the United Kingdom Continental Shelf (UKCS), is *c*. 107 km north-east of Flamborough Head on the North Yorkshire coast at the Pegasus West well location, and *c*. 35 km from the UK/NL jurisdictional median line at Cygnus.

In accordance with the Petroleum Act 1998, as operator of the Pegasus field licences, Spirit Energy is applying to BEIS to obtain approval for development of Pegasus West as detailed in Section 2 of this document.

An ES was previously submitted to BEIS (Reference No. D/4227/2018), however sanctioning of the Project was deferred resulting in a shift to the project schedule and consequent changes to the projected first hydrocarbon date included in an update to the Field Development Plan (FDP). This ES reflects the changes in the FDP and is aligned with the new Offshore Oil and Gas Exploration, Production, Unloading and Storage (Environmental Impact Assessment) Regulations 2020 (hereafter referred to as the 2020 Offshore EIA Regulations) that came into force on January 2021.

Project Activities

Spirit Energy plan to re-enter and complete the suspended Pegasus West well using a jack up drilling rig (JUDR). The well will be flowed for a period during well clean-up and testing, displacing completion fluids which will be discharged to sea and flaring produced hydrocarbons. The JUDR will install a subsea wellhead system including a Xmas tree with a wellhead protection structure (WPS).

It is proposed that the Pegasus West well will be tied back to Cygnus via a new *c*. 56.8 km long 10” carbon steel production pipeline. A new umbilical, also *c*. 56.8 km in length, will provide transportation of hydraulic power, electrical power, communications and injection chemicals from Cygnus to the Pegasus West well. The pipeline and umbilical will be laid on the seabed before being jet trenched for the majority of the pipeline route. A *c.* 4 km section (between KP4.35 and KP8.383) will remain surface laid and protected with rock. Surface lay of this section of the production pipeline and umbilical is driven by a combination of geotechnical (the very stiff nature of the shallow soil (clay)), and operational safety reasons (the shallow water depth and high wire loading).

Where the pipeline route is required to cross the two existing disused third party pipelines, these will be constructed using concrete mattresses and deposited rock.

A combination of rock cover, concrete mattresses and grout bags will be installed to protect infrastructure at the Pegasus West and Cygnus ends of the pipeline within the Pegasus West and Cygnus 500 m safety zones. It is possible that spot rock cover will be required to protect and stabilise sections of the pipeline that may not remain buried.

At Cygnus, the Pegasus West pipeline spools and umbilical will cross the Cygnus infield pipeline and umbilical between the pipeline and a new Subsea Isolation Valve (SSIV) structure. Following production pipeline and umbilical installation, pre-commissioning tests will be performed to ensure system integrity. These will include pressure and leak testing, and transit of a gauge pig through the pipeline to confirm pipeline shape, propelled with chemically treated, dyed seawater injected from a surface vessel and discharged subsea at a pig receiver at Cygnus.

Reception facilities will be installed at the Cygnus topsides providing tie-ins to the Cygnus processing facilities, flare and drains systems, metering, dedicated electrical and hydraulic control to the Pegasus West well, and a chemical storage and injection system. During the production phase, hydrocarbons flowing from the Pegasus reservoir will be routed, via the reception module, through the existing Cygnus processing facilities. Pegasus West inputs will use available Cygnus gas processing capacity (ullage).

Existing power generation facilities are sufficient to meet the power requirements of the Pegasus West Development such that it will not result in any changes to combustion emissions at Cygnus. Any Pegasus West produced water will be separated on Cygnus and processed by the existing produced water management system. It is expected that quantities of produced water from Pegasus West will be very small, although there is a possibility of formation water breakthrough in later field life. Apart from mono-ethylene glycol (MEG), chemicals injected at the Pegasus West well, and returned to Cygnus will be discharged to sea with produced water if they partition in to the water phase, rather than the hydrocarbon phase during separation. Meg will be regenerated in a closed loop.

Environmental Baseline

The environmental sensitivities at the Pegasus West well, along the pipeline route, at Cygnus and in the surrounding areas are identified. An understanding of the baseline environment is required in order to identify project interactions with the environment, and to provide a basis for assessing the environmental impacts of the development.

The Pegasus West Development project area is largely defined by the Dogger Bank, a geological formation that is significantly shallower than the surrounding seabed. Water depths along the pipeline route range between 17.2 m lowest astronomical tide (LAT) and 36.2 m LAT. From the Pegasus West well at 27.8 m LAT the seabed undulates for approximately 7.5 km along the pipeline route towards Cygnus to the east, after which it gently shoals on to the Dogger Bank in to water less than 20 m deep for much of the rest of the route to Cygnus, at approximately 22.6 m LAT.

The peak current speed of a mean spring tide is 0.52 ms^{-1} at Pegasus West, and tidal current speeds gradually reduce along the pipeline route from west to east, along with tidal range, with a peak mean spring tidal current speed of 0.37 ms^{-1} at Cygnus. Extreme current speeds, driven by storm systems, are greatest in winter months and can be much stronger. However, wave motion is the most erosive force acting on seabed sediments. The annual mean significant wave height ranges between 1.75 m at Pegasus West to 1.80 m at Cygnus, but storm waves can cause sediment erosion, suspension and resettlement throughout the development area, and particularly in shallower areas.

Seabed sediments in the Pegasus West well location comprise gravelly sand, with areas of sand and sandy gravel. The seabed along the pipeline route is predominantly sand and shell fragments with areas of coarser sandy gravel with shell fragments and cobbles/pebbles, occurring intermittently along the route. The proportions of silt and clay is generally low. Sand ripples and megaripples were recorded throughout the pipeline route.

Areas of sandy seabed that intermittently shoal at <20 m LAT along pipeline route are consistent with features of the EU Habitats Directive Annex I habitat 'sandbanks which are slightly covered by seawater all of the time'. The proposed development is located within the Dogger Bank Special Area of Conservation (SAC) which is designated due to the presence of this habitat.

Sediment concentrations of some heavy metals are above background, but most are below the concentration above which biological impacts might expected and comparable to the range recorded from other surveys in the area. Sediment hydrocarbon concentrations are generally below the SNS average. One sampled location on the pipeline route, approximately 7.85 km east of Pegasus West, had hydrocarbons concentrations within the range normally observed at oil and gas installations, possibly due to historical activity around a nearby well. No hydrocarbon concentrations sufficiently high to have toxic effects were recorded in the development area.

The phytoplankton community is dominated by diatoms from November to May when mixing is at its greatest and by from June to October. Phytoplankton production on the Dogger Bank occurs throughout the year supporting a high biomass of species at higher trophic levels year-round and creating a region that is biologically unique in the North Sea. The zooplankton community is dominated by copepod species.

Visible seabed species observed included annelid worms, bivalve molluscs, crabs including the brown crab and hermit crabs, echinoderms including the common starfish, sand starfish, sea potato, and brittlestars. On occasional hard surfaces, hornwrack and the soft coral *Alcyonium digitatum* were common. Tube-building annelid worms were the most commonly observed group. Of the animals living in seabed sediments, polychaete worms were the most abundant taxanomic group recorded in the development area, followed by crustaceans, then molluscs. Heterogeneity of the faunal community along the proposed route was primarily associated with the varying proportions of sand and gravel in seabed sediments.

Seabed habitats and biological communities (biotopes) in the vicinity of the proposed development have been classified using the European Union Nature Information System (EUNIS) habitat classification system. Five distinct biotopes were identified, all of which fall under the definition of 'sandbanks which are slightly covered by seawater all of the time' Annex I habitat, particularly where they occur at depths <20 m LAT. No other Annex I habitats were identified in the project area. The large, long-lived and slow-growing bivalve mollusc *Arctica islandica*, listed on the OSPAR list of threatened and/or declining species and habitats, has also been recorded in the project area.

Predatory fish species present on the Dogger Bank include whiting, plaice, mackerel and cod with dab and grey gurnard being particularly abundant. Gobies, gurnards, and flatfish including plaice, dab, and lemon sole have been observed on the pipeline route. A number of commercially important fish species are known to spawn and have nursery grounds in the area. These include anglerfish, cod, hake, herring, ling, mackerel, plaice, sandeel, sole, sprat, and mackerel. The most vulnerable stages of the fish lifecycle to general disturbances (sediment disruption, chemical/hydrocarbon discharges) are the egg and larval stages, hence recognition of spawning and nursery grounds within the area of proposed activities is important. Species that deposit their eggs on the seabed, including herring and sandeel are susceptible to impacts resulting from oil and gas exploration and production. Herring spawning grounds have been confirmed in the Pegasus West well area, and an assessment of herring and sandeel spawning ground potential on the pipeline route has identified areas of preferred spawning habitat for both species. There is a period of concern for drilling activities in Block 43/13 (Pegasus West area), registered by the Joint Nature Conservation Committee (JNCC), related to herring spawning between August and October.

The distribution and abundance of these seabird species varies seasonally and annually. Seabirds such as Atlantic puffin use the project area in the breeding season (April – July), whereas other species such as the common guillemot and little auk are present in higher densities in the winter season (October - April). Seabird sensitivity to surface oil pollution in the vicinity of the development ranges from ‘low’ to ‘extremely high’, with ‘extremely high’ sensitivity in the months of July and December.

Harbour porpoise, white-beaked dolphin and minke whale occur in the project area. Grey seals are likely to occur at low densities (5-10 individuals per 25 km^2). The proposed Pegasus West Development is located within the Southern North Sea Special Area of Conservation (SAC), identified as an area of importance for harbour porpoise. The SAC is designated solely for the purpose of contributing to the Favourable Conservation Status (FCS) of harbour porpoise populations by avoiding significant disturbance to harbour porpoise or deterioration their habitats. Harbour porpoise densities vary seasonally and across the Southern North Sea SAC, the highest densities occur during the summer period in the project area, with estimated densities greater than 3.0 per km^2.

Commercial fishing effort is higher at the Cygnus end of the pipeline route, but is low compared to other areas of the UKCS, and dominated by demersal trawling. Similarly, shipping density increases along the length of the pipeline route from ‘low’ at the Pegasus West well end (Blocks 43/13 and 43/14), increasing to ‘moderate’ where the pipeline traverses Blocks 43/15 and 44/11, then to ‘high’ around Cygnus (Block 44/12).

The consented Dogger Bank A,B and C and Sofia Offshore Wind Farm B are located to the north of the proposed Pegasus West Development, inside the Dogger Bank SAC. Construction of Dogger Bank A and B is currently underway, with main offshore construction predicted to occur in Q2 2022. Expected operational first phase of Dogger Bank A and B is to be in 2023. Dogger Bank C is considered the third phase and will be developed on a later stage timescale.

Impact Assessment

The EIA process reviews project activities to identify planned and unplanned interactions with the environment (aspects). Using baseline environmental information to identify receptors, the potential environmental and socio-economic impact of the project from both planned and unplanned activities is assessed using the method described in Spirit Energy’s Guidance for Environmental Management in Capital Projects. The Spirit Energy EIA process aims to preferentially avoid, then minimise, then restore and finally offset adverse impacts using control and mitigation measures. The significance of impacts is evaluated (on a scale of ‘low’, ‘medium’ or ‘high’ significance) given the application of inherent control and mitigation measures. Where necessary additional and supplementary control and mitigation measures are identified and applied in order to reduce any adverse impacts to a level that is ‘as low as reasonably practicable’ in line with the philosophy of the Spirit Energy Environmental Policy.

The Spirit Energy Risk Assessment Matrix is used for assessing the significance of environmental risks from unplanned events. This is based on the Spirit Energy E&P HSES Risk Assessment Matrix, and incorporates the likelihood of an event occurring, as well as the severity of the potential impacts, to determine the risk.

Physical presence

The principal sources of impacts associated with physical presence concern the use of specialist and support vessels, including the JUDR, and installed subsea infrastructure.

The physical presence of vessels may result in navigational restriction and hazard to shipping, prevention of commercial fishing, and behavioural disturbance to marine mammals and seabirds. Installed subsea infrastructure has the potential to prevent commercial fishing from its vicinity (by the use of safety exclusion zones), and/or to present a snagging hazard to fishing vessels using demersal gears.

Existing levels of shipping in the vicinity are low to moderate. Fishing effort in the project area is relatively low when compared to other areas of the UKCS. However, the fishing activity that does take place is dominated by demersal trawling, where fishing gear is towed across the seabed such that it may come in to contact with structures on the seabed. This can result in damage to seabed infrastructure, fishing gear and fishing vessels. It is likely that marine mammals will move away from the immediate vicinity of vessels, possibly in response to vessel-generated underwater sound, and that some bird species to be displaced from foraging areas where vessels are present.

Standard measures to ensure that the impacts associated with the physical presence of vessels are minimised include notifying other sea users of the timing and location of vessel activities, use of legally required navigation aids, and optimising the number of vessels required and their length of time on site. Measures to mitigate the impacts of seabed infrastructure include the use of statutory 500 m safety zones, the design of infrastructure including rock berms to minimise the risk of interactions with fishing gear and post lay surveys to ensure a safe seabed.

In summary, due to the localised and relatively short duration of vessel activities, and due to the limited unburied infrastructure on the seabed, and with the identified control and mitigation measures in place, the overall significance of physical presence is considered to be **medium**.

Energy use and atmospheric emissions

The principal sources of energy use and atmospheric emissions will arise from project vessel use during installation, flaring during well completion activities and for first gas, and from the additional power generation and compression required on Cygnus for processing and exporting Pegasus West fluids over the life of field.

Emissions will result in localised impacts to air quality which, at their peak, will be no greater than would result at Cygnus in the years leading up to Pegasus West operation.

Emissions will also make a small contribution to global warming due to emissions of greenhouse gases (GHG). Power on Cygnus is provided by two dual fuel gas turbine generators (GTG) operating one on one off. Based on annual figures for 2019, 600 te diesel was used and 6,279 te fuel gas. Power requirements are not linked directly to the production throughput and a small incremental increase in power demand is anticipated to accommodate operation of Pegasus West. The impact of Pegasus West on export gas compression requirements at Cygnus is more complex and will result in a small increase in fuel gas consumption in aggregate over life of field. In total, the Pegasus West project is estimated to give rise to approximately 70,000 Te of CO_2e. Approximately 28,000 Te of CO_2e of the total will be a result of production, approximately 14,000 Te of CO_2e from vessels used during installation and approximately 28,000 Te of CO_2e due to well clean up and first opening of the well.

The increase in GHG emissions at Cygnus as a result of Pegasus West is estimated to be between

8% and 10%, while significantly increasing gas production by between 37% and 47%. Pegasus West offers very low GHG emissions per barrel of oil equivalent produced when compared to the average across the UK Continental Shelf and also when compared to imported gas to the UK from Norway.

Underwater sound

The principal sources of underwater sound arise from the use of vessels (including the JUDR) for subsea infrastructure installation and well completion activities. These have the potential to impact marine mammals and certain species of fish.

The project sources of underwater sound are not deemed capable of causing any physical injury to fish or marine mammals. As a worst case, fish and marine mammals may be temporarily displaced from, or reduce foraging effort in, areas in close proximity to vessels, but this would not be significant given to the area of similar available habitat.

In summary, due to the localised and short duration, or intermittent nature of activities, and with the identified control and mitigation measures in place, the overall significance of the impact of underwater sound is considered to be **low**.

Seabed disturbance

The principal source of seabed disturbance associated with project activities concern the positioning (jacking-up) of the JUDR, and the installation of infrastructure and associated stabilisation features. Of these, the largest area of impact will be from temporary disturbance associated with trenching and burial of the production pipeline and umbilical. The largest area of permanent seabed disturbance will be from the *c.* 4 km rock berm, installation of pipeline crossings and spot rock cover. These activities will result in the redistribution of sediments, potentially resulting in mortality or physical injury to benthos and eggs laid on the seabed, and in some locations, the permanent replacement of the natural seabed habitat with a stable, hard substrate.

Standard measures to control disturbance include operational planning and equipment selection.

The species and habitats recorded in the vicinity of the Pegasus West Development are relatively widespread in the SNS. The area anticipated to be permanently disturbed represents a very small percentage of the extent of these habitats in the region and in the Dogger Bank SAC. The area that would be impacted by temporary disturbance, although larger, also represents a very small percentage of the extent of these habitats in the region and in the Dogger Bank SAC. Furthermore, the environment is subject to natural disturbance by waves and currents, and anthropogenic disturbance such as from trawling. None of the seabed communities identified in the project area has a high sensitivity to temporary seabed disturbance. Recovery would be expected to commence, through species recruitment from adjacent undisturbed areas, as soon as activities are completed. Project sources of seabed disturbance have the potential to impact herring and sandeel spawning, particularly if they take place during and shortly after the spawning seasons. Given the small area of seabed disturbance, relative to the extent of suitable spawning and nursery habitat in the SNS, any local mortality is unlikely to have an impact on populations as a whole.

In summary, due to the localised and relatively short duration of project activities, the limited footprint of infrastructure that will be installed on the seabed, and with the identified control and mitigation measures in place, the overall significance of the impact associated with seabed disturbance is considered to be **medium**.

Discharges and releases to sea

The principal sources of discharges and releases to sea concern the use project vessels, well completion, the installation of subsea infrastructure, and the production of hydrocarbons through the Cygnus host facility.

The vessels' work programme comprises a total of approximately 438 individual vessel days spread over a period of several months. Discharges from vessels during this time are expected to be rapidly dispersed and diluted under prevailing metocean conditions.

During well completion and subsea infrastructure installation chemicals that pose the minimum risk to the environment will be, where possible, selected. All planned chemical use and discharge will be risk assessed and permitted under the OCR, and the chemicals that will be discharged are routinely used in offshore oil and gas operations. All discharges would be expected to rapidly disperse and dilute under prevailing metocean conditions.

Similarly, planned hydrocarbon discharges will be minimised, but where necessary they will be permitted under the OPPC Regulations. Pegasus West production is not expected to substantively increase discharges of produced water and associated dispersed oil at Cygnus and even under the worst case, increases will be small and of limited duration. Hydrocarbon discharges are also expected to rapidly disperse and dilute under prevailing metocean conditions.

In summary, due to the localised and short duration, or intermittent nature of activities, and with the identified control and mitigation measures in place, the overall significance of the impact of discharges and releases to sea is considered to be **low**.

Waste

The quantities of waste produced will be limited. All wastes returned to shore will be handled and disposed of in accordance with legislation, Waste Management Plans (WMPs) and the waste management hierarchy. Only fully permitted waste management facilities will be used.

Given the limited quantities of waste that will be produced and the application of identified control and mitigation measures, the overall significance of the impact of the management of project waste is considered to be **low**.

Large release to sea

Sources of a potential unplanned large volume release to sea are associated with a loss of diesel containment from a vessel (including the JUDR), or a loss of reservoir hydrocarbons (condensate) from the Pegasus West well as a result of a well blowout or from the Pegasus West pipeline as a result of a rupture. Of these, the worst case in terms of the volume and duration of release would be a well blowout.

Condensate does not persist in the marine environment. Spill modelling shows that the extent of surface oiling, and of seabed sediment contamination, would be relatively small and that the probability of condensate reaching shore is low.

The area potentially impacted by a release coincides with areas of very high seabird sensitivity to surface oil pollution in the month of June, and extremely high sensitivity in the month of July and between the months of November and January. Impacts on the conservation features of the Dogger Bank SAC and the Southern North Sea SAC are possible.

Spill modelling suggests that, for a worst case, a relatively small area of seabed could be contaminated with hydrocarbons at concentrations just above the threshold above which toxic effects on benthic fauna may begin to be discernible. Many of the most abundant benthic species in the project area have low sensitivity to hydrocarbon contamination, but some species may be impacted. The area of potential impacts on benthos following the modelled worst case hydrocarbon release is approximately 56 km^2, if inside the Dogger Bank SAC, equivalent to 0.45% of its area.

Harbour porpoise are present at relatively high densities in the project area during the summer period. Mortality of marine mammals as a direct result a project-related large hydrocarbon release is unlikely but there is potential for sub-lethal impacts on individuals as a consequence of inhaling or ingesting hydrocarbons. However, in the unlikely event of a large hydrocarbon release, it would be unlikely to have a significant impact on the achievement of the Conservation Objectives of the Dogger Bank SAC or the Southern North Sea SAC.

When all receptors are taken into account the worst case environmental impact associated with a large release to sea is considered to be **medium**.

A large hydrocarbon release is considered to be 'unlikely' owing to the procedural (the JUDR's management systems) and operational controls that will be applied. The blowout frequency for a gas well completion operation to a North Sea standard is one in every 1.4×10^{-4} operations (equivalent to one blowout for every 7,143 completion operations), and a blowout during production would be much less likely.

Given the low likelihood of such a release, and following the application of control and mitigation measures, the overall risk of impacts from a large hydrocarbon release is considered to be **medium** and 'as low as reasonably practicable'.

Summary of Control and Mitigation Measures

Project specific commitments and mitigation measures to minimise the impact of the proposed Pegasus West Development project on the environment are highlighted throughout the ES and are summarised in Table 1. These will be documented in the project environmental management plan, which includes roles and responsibilities for their implementation.

ASPECT	COMMITMENTS
Physical Presence	• Consultation with the NFFO; • The fishing industry will be informed of relevant vessel activities and locations using Kingfisher Information Services; • A Notice to Mariners will be circulated prior to JUDR mobilisation; • Notice will be sent to Trinity House of any movements associated with the mobilisation and demobilisation of the JUDR; • All vessels will adhere to COLREGS and will be equipped with navigational aids, including radar, lighting and AIS (Automatic Identification System) etc.; • Vessel use will be optimised by minimising the number required, and their length of time on site; • The JUDR will abide by CtL conditions; • The JUDR will be equipped with navigational aids and aviation obstruction lights system, as per the Standard Marking Schedule for Offshore Installations; • An ERRV will patrol the Pegasus West area for the duration of well completion activities; • The pipeline and umbilical will be trenched and buried for the majority of their length to minimise interactions with fishing gear; • Guard vessels will be in deployed for the period when the pipeline and umbilical are on the seabed prior to burial or covering with rock; • All permanently unburied subsea infrastructure will be located within the existing Cygnus 500 m safety zone, or that which will be established at the Pegasus West well, and will be designed to be 'fishing friendly' or over-trawlable; • All subsea infrastructure installed out with 500 m safety zones will either be buried or designed to be over-trawlable (surface laid sections or third party pipeline crossings); and • The requirement for pipeline protection and stabilisation features will be minimised through project design & installation in accordance with industry best practice.

ASPECT	COMMITMENTS
Energy Use and Atmospheric Emissions	• The JUDR and other project vessels will be subject to audits ensuring compliance with UK legislation and the Spirit Energy Marine Operations and Vessel Assurance Standard (SPT-MAL-GEN-STA-0010); • Vessel use will be optimised where possible by minimising the number of vessels required, and their length of time on site; and • Vessels will be operated where possible in modes that allow for economical fuel use. Neptune will incorporate the impact of the Pegasus West production within developing controls including: • Asset GHG Emission Reduction Action Plans; • Flaring and venting reviews to identify/action zero routine flaring by 2030; • Active flare reduction strategy; • Active vent reduction strategy; • Emission key performance indicators and targets; • Industry level benchmarking of flaring and venting; and • Asset Methane Action Plan.
Underwater Sound	• Machinery, tools and equipment will be in good working order and well-maintained (as required under the contract with the subcontractor); and • Vessel use will be optimised where possible by minimising the number of vessels required, and their length of time on site.
Seabed Disturbance	• All activities which may lead to seabed disturbance will be planned, managed and implemented in such a way that disturbance is minimised; • Project vessels will utilise dynamic positioning systems for station keeping rather than anchors; • Rig site surveys will be completed before locating the JUDR at Pegasus West; • If possible, the JUDR will be positioned so that spud cans line up with existing spud can depressions; • The production pipeline and umbilical tie-back route length will be minimised; • The area of drag of the initiation anchor, used to lay the pipeline, will be minimised; • The use of protection and stabilisation features will be optimised; and • Spot rock deposits will be installed in a controlled manner using a fall-pipe and ROV.
Discharges and Releases to Sea	• The JUDR and other project vessels will be subject to audits ensuring compliance with UK legislation and the Spirit Energy Marine Operations and Vessel Assurance Standard (SPT-MAL-GEN-STA-0010); • All project vessels used will be MARPOL-compliant; • Procedures and systems for the minimisation of waste and effluent generation from vessels (maintained as required under the contract with the subcontractor) will be implemented; • Procedures and systems for the management of ballast and bilge water from vessels (maintained as required under the contract with the subcontractor) will be implemented; • Accident prevention measures will be in place on vessels in order to minimise the potential for accidental spillages of hydrocarbons or other polluting materials; • Vessels will have an approved SOPEP in place; • Vessels will be selected and audited to ensure that effective operational systems

ASPECT	COMMITMENTS
	and onboard control measures are in place; • Vessel use will be optimised by minimising the number required, and their length of time on site; • Where technically feasible the selection of PLONOR chemicals, or chemicals with a low HQ or RQ will be prioritised, and the use of chemicals with a substitution warning will be avoided; • Discharges to sea will be conducted in compliance with regulations and permit conditions; and • Lessons learnt from previous project scopes will be reviewed and implemented with regards to discharges to sea.
Waste	• The volume of waste produced will be minimised by the use of appropriate procurement controls; • The principles of the waste management hierarchy will be applied during all activities; • Existing Cygnus and vessel WMPs will be strictly followed; • All waste will be properly segregated to avoid cross-contamination; • Only licenced waste management facilities will be used; and • Monthly reporting of waste sent to shore will be undertaken.
Large Release to Sea	• Activities will be carried out by trained and competent offshore crews and supervisory teams; • An approved OPEP to manage releases, including large hydrocarbon releases, will be in place prior to any activities being undertaken; • A co-ordinated industry oil spill response capability will be available; Well completion-specific measures: • A robust BOP pressure and functional testing regime will be in place as well as visual integrity checks; • A TOOPEP or an update to the existing Cygnus OPEP for Pegasus West well completion will be in place covering well completion operations; Subsea infrastructure installation-specific measures: • All vessel activities will be planned, managed and implemented in such a way that vessel durations in the field are minimised; • Spirit Energy's existing marine procedures will be adhered to minimise risk of hydrocarbon releases; and • Shipboard Oil Pollution Emergency Plans (SOPEPs) will be in place for project vessels. Commissioning and production-specific measures: • A DHSV will enable isolation of the reservoir; • Cygnus facilities will be protected by a combination of a topside Emergency Shutdown Valve (ESDV) and a SSIV; • The production pipeline will be protected by pressure alarms which can assist leak detection; and • Releases, including large hydrocarbon releases associated with Pegasus West production, will be managed under the Cygnus OPEP.

Table 1 Summary of proposed control and mitigation measures

Conclusion

Overall, the EIA concludes that the significance of impacts as a consequence of the proposed Pegasus West Development project activities is generally **low**, but is **medium** for activities that disturb the seabed and where fishing will be excluded from the Pegasus West 500 m safety zone due to the physical presence on installed subsea infrastructure. The risk of impacts from a worst case large hydrocarbon release is considered to be **medium** and 'as low as reasonably practicable'. Generally, the impacts identified are considered localised and short term with low potential for long term or transboundary and cumulative impacts. The proposed Pegasus West Development does not contradict any marine planning objectives or marine planning oil and gas policies.

ACRONYMS AND ABBREVIATIONS

ACRONYM	DESCRIPTION
"	Inch (25.4 mm)
°C	Degrees Celsius
%	Percentage/parts per hundred
μPa	Micro-Pascal
AET	Apparent Effects Threshold
AHT	Anchor Handling Tug
BAC	Background Assessment Criteria
BAT	Best Available Technique
BAOAC	Bonn Agreement Oil Appearance Code
BBL	Barrel
BC	Background Concentration
BCF	Billion cubic feet
BEIS	The Department of Business, Energy and Industrial Strategy
BEP	Best Environmental Practice
BoD	Basis of Design
BOE	Barrels of Oil Equivalent
BOP	Blowout Preventer
BRC	Background Reference Concentration
CAPEX	Capital Expenditure
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
CGR	Condensate Gas Ratio
CH_4	Methane
CHARM	Chemical Hazard and Risk Management
CNS	Central North Sea
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
CoP	Cessation of Production
COLREGS	Convention on the International Regulations for Preventing Collisions at Sea
cSAC	Candidate Special Area of Conservation
CSV	Construction Support Vessel
CtL	Consent to Locate
dB	Decibel

ACRONYM	DESCRIPTION
DCO	Development Consent Order
DepCon	Deposit Consent
DEFRA	Department for Environment, Food and Rural Affairs
DHSV	Downhole Safety Valve
DP	Dynamic Positioning
DSV	Diving Support Vessel
EBS	Environmental Baseline Survey
EC	European Commission
EDR	Effective Deterrent Radius
EEMS	Environmental Emissions Monitoring Scheme
EHC	Electro-Hydraulic-Chemical
EIA	Environmental Impact Assessment
ELV	Emission Limit Values
EoFL	End of Field Life
EPS	European Protected Species
ERRV	Emergency Response and Rescue Vessel
ES	Environmental Statement
ESAS	European Seabirds at Sea
ESDV	Emergency Shutdown Valve
ETS	Eagles Transportation System
ETSWAP	Emissions Trading Scheme Workflow Automation Project
EU	European Union
EU ETS	European Union Emissions Trading Scheme
EUNIS	European Union Nature Identification System
FCS	Favourable Conservation Status
FDP	Field Development Plan
FEPA	Food and Environmental Protection Act
GHG	Greenhouse Gas
GIS	Geographic Information System
GJ	Gigajoules
GCR	Gas Condensate Ratio
GTG	Gas Turbine Generators
HLV	Heavy Lift Vessel
HP	High Pressure

ACRONYM	DESCRIPTION
HQ	Hazard Quotient
HSE	Health and Safety Executive
HSES	Health, Safety, Environment and Security Policy
HYCOM	Hybrid Co-ordinated Ocean Model
Hz	Hertz
IBCAO	International Bathymetric Chart of the Atlantic Ocean
ICES	International Council for the Exploration of the Sea
IMO	International Maritime Organisation
IoP	Institute of Petroleum
IUCN	International Union for Conservation of Nature
JCP	Joint Cetacean Protocol
JNCC	Joint Nature Conservation Committee
JUDR	Jack-Up Drilling Rig
KCl	Potassium Chloride
KHI	Kinetic Hydrate Inhibitor
kHz	Kilohertz
kg	Kilogram
km	Kilometre
KP	Kilometre Point
L	Length
LAT	Lowest Astronomical Tide
LP	Low Pressure
LTOBM	Low Toxicity Oil Based Mud
m	Metre
MA	Major Accident
MAH	Major Accident Hazard
MarESA	Marine Evidence based Sensitivity Assessment
MARPOL	International Convention for the Prevention of Pollution from Ships (MARPOL)
MAT	Master Application Template
MBES	Multi Beam Echo Sounder
MCA	Maritime and Coastguard Agency
MCAA	Marine and Coastal Access Act
MCZ	Marine Conservation Zones
MEG	Monoethylene Glycol
MEI	Major Environmental Incident

ACRONYM	DESCRIPTION
mg	Milligram
mm	Millimetre
MMBOE	Million Barrels of Oil Equivalent
MMO	Marine Management Organisation
mmscf	Million Standard Cubic Feet
MODU	Mobile Offshore Drilling Unit
MP	Medium Pressure
MPS	Marine Policy Statement
MTe	Million Tonnes
MU	Management Unit
MW	Megawatts
MW(th)	Megawatts thermal
NaCl	Sodium Chloride
NAO	North Atlantic Oscillation
NB	Nominal Bore
NCMPA	Nature Conservation Marine Protected Area
NFFO	National Federation of Fishermen's Organisations
NL	Netherlands
nm	Nautical Mile
NMPi	National Marine Plan Interactive
NNS	North North Sea
NOEC	No Observed Effect Concentration
NOx	Oxides of Nitrogen
N_2O	Nitrous Oxide
NSTD	North Sea Transition Deal
NUI	Normally Unattended Installation
OBM	Oil Based Mud
OCR	Offshore Chemicals Regulations
OD	Outer Diameter
OGA	Oil and Gas Authority
OGP	Oil and Gas Producers
OGUK	Oil and Gas UK
OPEP	Oil Pollution Emergency Plan
OPEX	Operating Expenditure
OPPC	Oil Pollution Prevention and Control
OPRED	Offshore Petroleum Regulator for Environment and Decommissioning

Acronyms and Abbreviations

ACRONYM	DESCRIPTION
OSCAR	Oil Spill Contingency and Response
OSPAR	OSlo and PARis Convention
OVI	Oil Vulnerability Index
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PETS	Portal Environmental Tracking System
PL	Pipeline Identification Number
PLONOR	Pose Little Or No Risk to the environment
pMCZ	Proposed Marine Conservation Zone
PNEC	Predicted No Effect Concentration
ppb	Parts Per Billion
PPC	Pollution Prevention and Control
PTS	Permanent Threshold Shift
pSPA	Potential Special Protection Area
PWA	Pipeline Works Authorisation
P10	10% probability that the quantities recovered will equal or exceed the high estimate
P50	50% probability that the volumes recovered will equal or exceed the best estimate
P90	90% probability that the volumes recovered will equal or exceed the low estimate
RBA	Risk-Based Approach
RFC	Remote Flooding Console
ROV	Remotely Operated Vehicle
RQ	Risk Quotient
SAC	Special Area of Conservation
SAT	Subsidiary Application Template
SBES	Single Beam Echo Sounder
SCANS	Small Cetaceans in the European Atlantic and North Sea
SCI	Site of Community Importance
SCM	Subsea Control Module
SCR	The Offshore Installations (Offshore Safety Directive) (Safety Case etc) Regulations
SEAL	Shearwater Elgin Area Line
SINTEF	The Foundation for Scientific and Industrial Research
SIP	Self-Installing Platform
SNCB	Statutory Nature Conservation Bodies

ACRONYM	DESCRIPTION
SNS	Southern North Sea
SOPEP	Shipboard Oil Pollution Emergency Plan
SOSI	Seabird Oil Sensitivity Index
SO2	Sulphur Dioxide
SPA	Special Protection Area
SPL	Sound Pressure Level
SSIV	Subsea Isolation Valve
SSS	Single Scan Sonar
SSSI	Sites of Special Scientific Interest
SUTU	Subsea Umbilicals Termination Unit
Te	Tonne (1,000 kg)
TEG	Tri-Ethylene Glycol
TH	Trinity House
THC	Total Hydrocarbon Concentration
TOOPEP	Temporary Operations Oil Pollution Emergency Plan
TPH	Total Petroleum Hydrocarbons
TUTU	Topside Umbilical Termination Unit
UHB	Upheaval Buckling
UK	United Kingdom
UKCS	United Kingdom Continental Shelf
UKOOA	United Kingdom Offshore Operators Association (now OGUK)
VMS	Vessel Monitoring System
VOCs	Volatile Organic Compounds
W	Width
WMP	Waste Management Plan
WPS	Wellhead Protection Structure

GLOSSARY

TERM	DESCRIPTION
Approach	Initial or final stretch of pipeline (or umbilical) as it leaves its point of origin or reaches its destination.
Backfill	The replacement of excavated sediment into a trench.
Benthos	The community of organisms that live on, or in, the seabed.
Biotope	A biotope is an area of uniform environmental conditions providing a living place for a specific assemblage of plants and animals.
Carboniferous	A geological period (and system of derived rock layers) that spans 60 million years from the end of the Devonian Period 358.9 million years ago to the beginning of the Permian Period, 298.9 million years ago.
Circalittoral	A marine biological zone defined by depth and related factors including the amount of wave energy experienced at the seabed; the degree of thermal stability; and the proportion of surface light reaching the sea floor. The circalittoral is defined at its upper limit as the depth at which 1% light reaches the seabed, and its lower limit by the maximum depth to which the passage of a wave causes motion in the water column. The deep circalittoral zone extends deeper than this, to the 200m depth contour.
Deltaic	An area of deposition, or the deposit formed by a flowing sediment-laden current as it enters an open or standing body of water, such as a river spilling into a gulf.
Demersal gear	Fishing gear that is operated on or close to the seabed.
Epifauna	Animals living on the surface of the seabed or a riverbed, or attached to submerged objects or aquatic animals or plants.
Grey water	Non-industrial wastewater generated from domestic processes such as washing dishes, laundry and bathing.
Habitat	A place where plants or animals normally live, characterized primarily by its physical features (topography, plant or animal physiognomy, soil characteristics, climate, water quality etc.) and secondarily by the species of plants and animals that live there.
Holocene	The current geological epoch. It began approximately 11,650 years before present, after the last glacial period.
Impact	Any change to the environment wholly or partially resulting from an operational activity environmental aspect. (ISO 14001:2015).
Infauna	Animals living in the sediments of the ocean floor or river or lake beds.
Infralittoral	A marine biological zone defined by depth and the proportion of surface light reaching the sea floor. The infralittoral is defined at its upper limit by mean low water, and its lower limit by the depth to which 1% of light reaches the seabed.
Infrastructure	General term to describe any of platform (jackets, topside), template/manifold, well, wellhead, Xmas tree, pipeline, umbilical, stabilisation and protection features.
Jack-up	A self-contained combination drilling rig and floating barge, fitted with long support legs that can be raised or lowered independently of each other.
Major Environmental Incident	An incident which results, or is likely to result, in significant adverse effects on the environment in accordance with Directive 2004/35/EC of the European Parliament and of the Council on environmental liability with regard to the prevention and remedying of environmental damage. A Major Environmental

TERM	DESCRIPTION
	Incident (MEI) must have another safety related major accident as a precursor.
Megaripples	Large sandwaves or ripple-like features having wavelengths greater than 1m or a ripple height greater than 10cm.
Metocean	A contraction of the words 'meteorology' and 'oceanology' referring to the wave, wind and current conditions that affect offshore operations.
Sessile	Fixed in one place and immobile.
Siphon	A siphon is an anatomical structure which is part of the body of some aquatic molluscs. Siphons in molluscs are tube-like structures in which water flows. The water flow is used for one or more purposes such as locomotion, feeding, respiration, and reproduction.
Spirit Energy	Spirit Energy Resources Limited.
Spool(s)	Short sections of pipe that are typically flanged and bolted together (also known as spool pieces).
Upheaval Buckling (UHB)	During operation, due to high pressures and high temperatures of the fluid flow in pipelines, pipelines can expand resulting in buckling. Buried pipelines are restrained from moving but when the force exerted by the pipeline exceeds the vertical restraint that resists the uplift movement the pipeline will move upward, known as upheaval buckling, and potentially resulting in sections being exposed above seabed level.

1. INTRODUCTION

Spirit Energy Resources Limited and Spirit Energy North Sea Limited (both referred to as Spirit Energy going forward), as operator, and its partner Neptune E&P UK Limited (Neptune Energy), propose to develop the Pegasus field via a tie-back of the existing Pegasus West appraisal well (43/13b-7) to the existing Neptune Energy-operated Cygnus gas development in Block 44/12 in the Southern North Sea (SNS) (Figure 1-1).

The proposed Pegasus West Development Project is *c.* 107 km north-east of Flamborough Head on the North Yorkshire coast at the Pegasus West well location, and approximately 35 km from the UK/NL jurisdictional median line at Cygnus.

The proposed Project will require the installation of a *c.* 56.5 km production pipeline (does not include length of tie-in spools) connecting the well, in Block 43/13b - and then traversing Blocks 43/14, 43/15, and 44/11 - to the Cygnus development. The installation of additional supporting subsea infrastructure, and modifications to the topside facilities at Cygnus, will also be required.

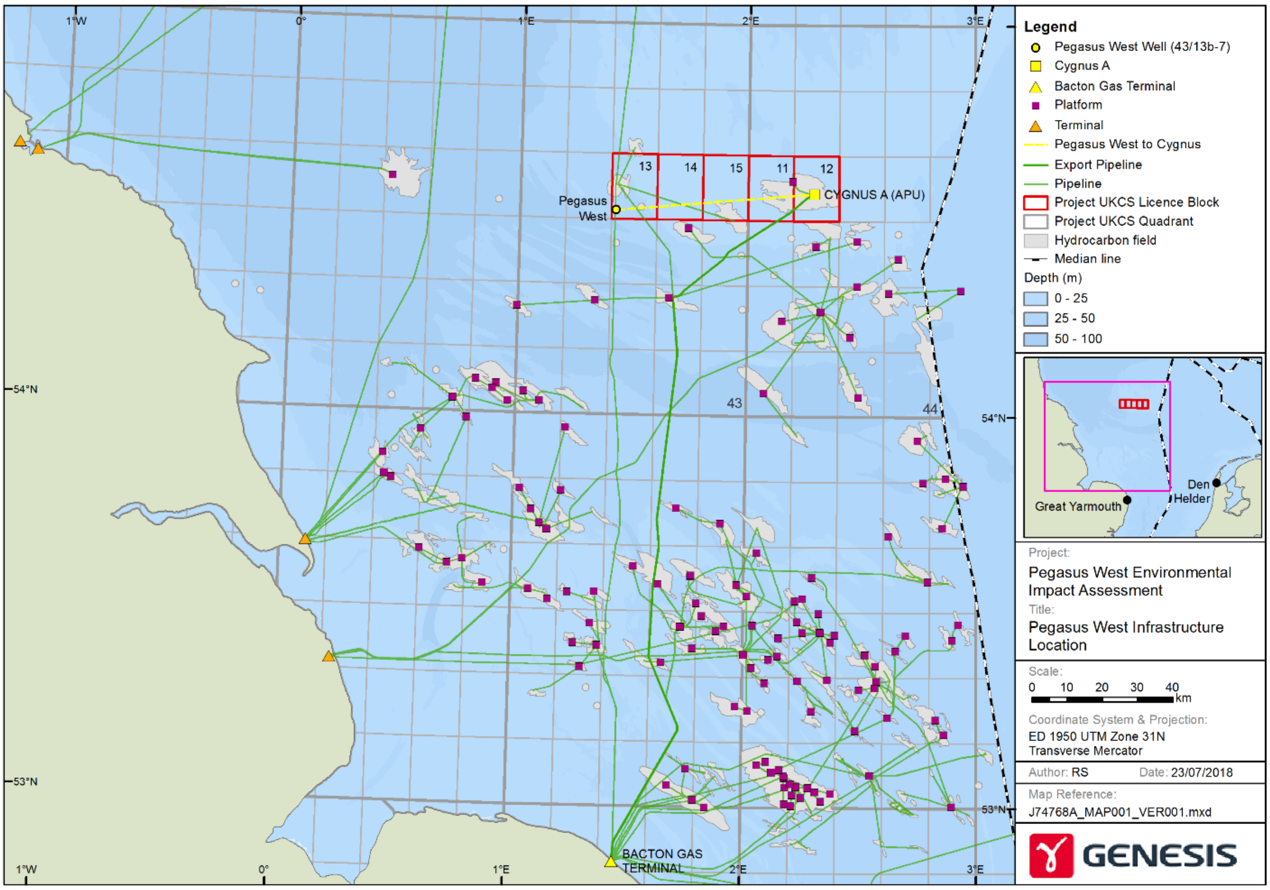


Figure 1-1 Pegasus West Development location

The Pegasus field was discovered in 2010 and spans several licences in Quadrant 43 for which Spirit Energy is the operator. Drilling of the Pegasus West 43/13b-7 appraisal well confirmed commercial gas reserves in 2014. Pegasus West is associated with licence numbers P1724, P1727 and P2128 for which ownership is summarised in Table 1-1.

EQUITY HOLDER	% HOLDING		
	P2128	P1724	P1727
Spirit Energy Resources Limited	61.25%	-	-
Spirit Energy Resources North Sea Limited	-	61.25%	61.25%
Neptune E&P UK	38.75%	38.75%	38.75%

Table 1-1 Licence interests in Pegasus West

An Environmental Statement (ES) for the Pegasus West Development Project was previously submitted to the Department for Business, Energy and Industrial Strategy (BEIS) (Reference No. D/4227/2018). However following submission of the ES, sanctioning of the Project was deferred resulting in a shift to the project schedule and consequent changes to the projected first hydrocarbon date included in an update to the Field Development Plan (FDP). This ES reflects the changes in the FDP and is aligned with the new Offshore Oil and Gas Exploration, Production, Unloading and Storage (Environmental Impact Assessment) Regulations 2020 (hereafter referred to as the 2020 Offshore EIA Regulations) that came into force on January 2021.

The UK Government's Energy White Paper explicitly recognises that the UK's domestic oil and gas industry has a critical role in maintaining the country's energy security and is a major contributor to the UK economy. Pegasus West supports the UK Government's statutory objective to maximise the value of economically recoverable hydrocarbons. The Development will support increased longevity of its host, the Cygnus facility, and in doing so, sustain key existing infrastructure which will support the future development of oil and gas discoveries in the Southern North Sea.

1.1 Overview of the Pegasus West Development

The proposed Pegasus West Development comprises:

- The completion for production of the existing Pegasus West appraisal well (43/13b-7);
- The installation of a 10" nominal bore (NB) carbon steel production pipeline (approximately 56.5 km in length) and associated tie-in spools, and a 119 mm outer diameter (OD) electro-hydraulic-chemical (EHC) umbilical (approximately 57.0 km in length), between Pegasus West and the existing Cygnus development;
- The installation of a Xmas tree and wellhead protection structure (WPS) at the Pegasus West well, and a subsea isolation valve (SSIV) at Cygnus; and
- Modifications to Cygnus topside facilities.

1.2 Purpose of the Environmental Statement

The 2020 Offshore EIA Regulations require the undertaking of an EIA and production of an Environmental Statement (ES) for certain types of offshore oil and gas projects likely to have a significant effect on the environment. The Regulations set trigger levels (Section 1.5.1) for a mandatory ES based on new or increased oil and gas production.

The purpose of this ES is to report on the EIA process undertaken to meet both statutory and Spirit Energy internal project requirements. The ES provides a public consultation document which supports consultees in the decision making process. It is therefore required to be a comprehensive report. The ES also provides an opportunity to assure the Regulator and consultees that Spirit Energy is informed and understands:

- The likely consequences of the activities, emissions, discharges and physical presence of the project;
- The local environment; and

- The nature of the environmental and socio-economic issues arising from other users of the sea.

The ES has been prepared in accordance with the 2020 Offshore EIA Regulations, and with the Guidance from BEIS (BEIS, 2021).

1.3 Scope of the Environmental Statement

The scope of the EIA and resultant ES includes the following activities:

- Completion of the Pegasus West well ready for production;
- Installation and commissioning of subsea infrastructure;
- Modifications to Cygnus topside facilities;
- Additional hydrocarbon production at Cygnus (relative to operation without Pegasus West); and
- Decommissioning at End of Field Life (EoFL).

The Spirit Energy Guidance for Environmental Management in Capital Projects defines the Spirit Energy requirements for EIA to support consistent delivery of the operations in line with the Spirit Energy Health, Safety, Environment and Security (HSES) Policy. In accordance with BEIS guidance and Spirit Energy's HSES policy, this ES therefore:

- Provides a comprehensive description of the environment in the proposed project location;
- Identifies project activities and aspects, and assesses the significance of impacts;
- Addresses stakeholder concerns regarding the project;
- Identifies design solutions and control and mitigation measures to avoid significant environmental impacts;
- Identifies residual impacts and assesses their significance; and
- Assesses any cumulative and transboundary impacts.

The proposed Pegasus West Development is within the Dogger Bank Special Area of Conservation (SAC) and the Southern North Sea SAC . The impacts of the proposed development in these areas are considered in detail.

1.4 Document Layout

Table 1-2 summarises the full structure of this ES.

SECTION		CONTENTS
	Non-Technical Summary	A summary of the ES.
1	Introduction	Introduction to the project and scope of the ES. This section also includes a summary of applicable legislation, Spirit Energy’s Management System, areas of uncertainty and the consultation process to date.
2	Project Description	A description of Pegasus West well completion, subsea infrastructure installation, Cygnus topside modifications and Pegasus West production with anticipated production profiles.
3	Environmental Baseline	A description of the environmental and socio-economic receptors in the area.
4	EIA Method	Description of the method used to assess the significance of impacts from planned activities and the significance of environmental risks from unplanned events.
5-10	Assessment of Impacts	Detailed assessment of Physical Presence (Section 5); Energy Use and Atmospheric Emissions (Section 6); Underwater Sound (Section 7); Seabed Disturbance (Section 8); Discharges and Releases (Section 9); and Waste (Section 10).
11	Large Release to Sea	Detailed assessment of the risk of, and impacts of, an unplanned (accidental) large release to sea.
12	Conclusions	Key findings including a register of commitments.
13	References	Sources of information drawn upon throughout the ES.
Appendix A	East Offshore Marine Plan	Assessment of the project against the East Offshore Marine Plan.
Appendix B	Environmental Assessment and Management Workshop Results	Summary of the results of the workshop.
Appendix C	Oil Spill Modelling	Modelling of the impacts of a large hydrocarbon release in the event of a well blowout.

Table 1-2 Structure of the ES

1.5 Regulatory Context

This section provides an overview of environmental legislation applicable to the project.

1.5.1 Environmental Impact Assessment

Offshore environmental control has developed significantly over the past thirty years and is continuing to evolve in response to increasing awareness of potential environmental impacts. Strands of both primary and secondary legislation, voluntary agreement and conditions in consents granted under the petroleum licensing regime and international conventions have all contributed to the current legislative framework.

The main controls for new oil and gas projects are EIAs, which became a legal requirement of offshore developments in 1998. Current requirements are set out in the 2020 Offshore EIA Regulations and with accompanying guidance (BEIS, 2021).

Under the 2020 Offshore EIA Regulations the Pegasus West Development requires a mandatory ES for production of 500,000 m^3 or more of gas per day and installation of a pipeline of more than 40 km in length.

Following submission of the ES, a period of formal public consultation is required under both the EIA Regulations and European Directive 2003/35/EC (Public Participation Directive).

The EIA needs to consider the impact on the surrounding environment including any protected areas. Many protected areas have been designated in the UK under the European Union (EU) Nature Directives, in particular the Habitats Directive (92/43/EEC) and the Birds Directive (2009/147/EC). Since January 2021 these are now maintained and designated under the Habitats Regulations for England and Wales, Scotland and Northern Ireland. Amendments to the Habitats Regulations mean that the requirements of the EU Nature Directives continue to apply to how European sites (Special Areas of Conservation (SACs) and Special Protection Areas (SPAs)) are designated and protected. The Habitats Regulations also provide a legal framework for species requiring strict protection, e.g. European Protected Species (EPS). The Marine and Coastal Access Act 2009 enables the designation of marine conservation zones (MCZs) in English and Welsh waters and the designation of nature conservation marine protected areas (NCMPAs) in Scotland.

1.5.2 Habitats and species of conservation concern

All offshore projects or developments must demonstrate that they are not “likely to have a significant impact on the integrity of the conservation objectives for the protected site” or “significantly disturb European Protected Species (EPS)” either alone or in combination with other plans and projects.

The Conservation of Offshore Marine Habitats and Species Regulations 2017 have a revised definition of ‘disturbance’ to EPS. It is now an offence to:

- Deliberately capture, injure, or kill any wild animal of a EPS (termed ‘the injury offence’); and/or to
- Deliberately disturb wild animals of any such species (termed ‘the disturbance offence’).

  Disturbance of animals includes any event that is likely to:
- Impair their ability to survive, breed or reproduce, or to rear or nurture their young, or (in the case of animals hibernating or migratory species), to hibernate or migrate; or to
- Affect significantly the local distribution or abundance of the species to which they belong.

1.5.3 Discharges to sea

1.5.3.1 Oil discharges

In accordance with the Oslo/Paris Convention (OSPAR) Recommendation (2001/1), the UK through OPRED has introduced regulatory requirements which reduce the permitted average monthly oil in water discharge concentration to a maximum of 30 mg/l. OSPAR Recommendation 2001/1 also required contracting parties to reduce the total discharge of oil in produced water by 15% by 2006 measured against a 2000 baseline. The permits replaced the granting of exemptions under the Prevention of Oil Pollution Act 1971 and are issued under the Offshore Petroleum Activities (Oil Pollution Prevention and Control) Regulations 2005 (as amended 2010 and 2011).

1.5.3.2 Chemical discharges

In June 2000, the OSPAR Convention for the Protection of the Marine Environment in the North East Atlantic made a decision requiring a mandatory system for the control of chemicals (OSPAR Decision 2000/2 on a Harmonised Mandatory Control System for the Use and Reduction of the Discharge of Offshore Chemicals). This decision operates in conjunction with two OSPAR Recommendations:

- OSPAR Recommendation 2000/4: The application of a Harmonised Pre-Screening Scheme for Offshore Chemicals to allow authorities to identify chemicals being used offshore; and
- OSPAR Recommendation 2000/5: The application of a Harmonised Offshore Chemical Notification Format for providing data and information about chemicals to be used and discharged offshore.

The UK Government's offshore oil and gas regulator (BEIS) implemented OSPAR Decision 2000/2 on the control of chemical use offshore, through the Offshore Chemicals Regulations (OCR) (2002, as amended 2005, 2010, 2011, 2017 and 2018). The regulations require offshore operators to apply for permits for the use and/or discharge of chemicals in the course of all relevant offshore energy activities, including well operations, production operations, pipeline operations, and decommissioning operations. The 2011 Amendment Regulations extended the provisions to take enforcement action in the event of any unintentional offshore chemical release.

1.5.3.3 Risk Based Approach

OSPAR Recommendation 2012/5 for a Risk-Based Approach (RBA) to the Management of Produced Water Discharges from Offshore Installations aims to produce a method for prioritising mitigation actions for those discharges and substances that pose the greatest risk to the environment. The objective is that by 2020 all offshore installations with produced water discharges in the OSPAR maritime area will have been assessed to determine the level of the risk and that, where appropriate, measures will have been taken to reduce the risk posed by the most hazardous substances. BEIS has issued guidance on the RBA for UK installations (BEIS, 2020).

1.5.4 Atmospheric emissions

Combustion installations on oil and gas platforms with a rated thermal input of 20 MW(th) or more require permitting under the UK's Emissions Trading Scheme (UK ETS). The UK ETS replaced the UK's participation in the European Union ETS system on 1 January 2021. The EU ETS is based on Directive 2003/87EC establishing a scheme for greenhouse gas emission allowance trading within the Community (the EU ETS Directive) and the UK ETS broadly aligns with the Directive. The UK ETS is implemented by the Greenhouse Gas Emissions Trading Scheme Order 2020 (as amended). The relevant provisions of the Order include the requirement to monitor and report carbon dioxide (CO_2) emissions, surrender allowances and to notify of any changes affecting the allocation of allowances.

Combustion installations on oil and gas platforms with a rated thermal input of 50 MW(th) or more require permitting under the Offshore Combustion Installations (Pollution Prevention and Control) Regulations 2013 (as amended). This includes conditions limiting releases notably for carbon monoxide (CO), oxides of nitrogen (NO_x), sulphur oxides (SO_x), methane (CH_4) and volatile organic compounds (VOCs) and the demonstration of the use of BAT. Combustion installations with a rated thermal input of 1 MW(th) to 50 MW(th) also require permitting under Pollution Prevention and Control (PPC) regulations to comply with the emission limit values (ELV's) as stipulated in the Medium Combustion Plant directive EU 2015/2193 of 25th November 2015 for sulphur dioxide (SO_2), NOx and dust.

The revised OGA Strategy (January 2021) retains a binding obligation to secure that the maximum value of economically recoverable petroleum is recovered from the strata beneath relevant UK waters. The Strategy also states that in doing so, appropriate steps must be taken to reducing greenhouse gas emissions and assist in meeting the UK net zero target. The Strategy is supported by Stewardship Expectations. The OGA 'Stewardship Expectation 11 – Net Zero' (March 2021) sets out the OGAs expectations of the steps that should be taken across the exploration and production lifecycle, to reduce emissions and promote CCS and Hydrogen.

1.5.5 Marine and Coastal Access Act

The Marine and Coastal Access Act (MCAA) came into force in November 2009. The Act covers all UK waters except Scottish internal and territorial waters which are covered by the Marine (Scotland) Act (2010), which mirrors the MCAA powers. The MCAA provides the legal mechanism to help ensure clean, healthy, safe, productive and biologically diverse oceans and seas by putting in place a new system for improved management and protection of the marine and coastal environment. It replaces and merges the requirements of the Food and Environmental Protection Act (FEPA) Part II (environment) and the Coastal Protection Act (navigation).

The MCAA has enabled:

- Establishment of the Marine Management Organisation (MMO) to operate as the competent marine planning authority in English territorial waters and UK offshore waters (for matters that are not devolved) such as marine licensing and enforcement of marine legislation;
- A strategic marine planning system to agree marine objectives and priorities and establish a series of marine plans to implement marine policy (Section 1.5.5.1 and Appendix A);
- A new marine licensing system for marine activities; and
- Powers enabling the designation of Marine Conservation Zones (MCZ) in the territorial waters adjacent to England and Wales and UK offshore waters.

However, the following are exempt from the MCAA as they are regulated under different legislation:

- Activities associated with exploration or production/storage operations that are authorised under the Petroleum Act; and
- Additional activities authorised solely under the BEIS environmental regime, e.g. chemical and oil discharges.

Therefore, activities which are not regulated by the Petroleum Act or under the BEIS environmental regime require an MCAA licence.

1.5.5.1 Marine planning

The UK Marine Policy Statement (MPS) provides the policy framework for the marine planning system and marine plans put into practice the policies identified in the MPS, informing decision-making for any activity or development which is in, or impacts on, a marine area. The UK is divided into marine planning regions, 11 in English waters, and the proposed Pegasus West Development is located in the East Offshore Marine Plan area. Objectives for the East Inshore and East Offshore

Marine Plans are listed in Table 1-3.

OBJECTIVE	DETAILS
1	To promote the sustainable development of economically productive activities, taking account of spatial requirements of other activities of importance to the East marine plan areas.
2	To support activities that create employment at all skill levels, taking account of the spatial and other requirements of activities in the East marine plan areas.
3	To realise sustainably the potential of renewable energy, particularly offshore wind farms, which is likely to be the most significant transformational economic activity over the next 20 years in the East marine plan areas, helping to achieve the United Kingdom's energy security and carbon reduction objectives.
4	To reduce deprivation and support vibrant, sustainable communities through improving health and social well-being.
5	To conserve heritage assets, nationally protected landscapes and ensure that decisions consider the seascape of the local area.
6	To have a healthy, resilient and adaptable marine ecosystem in the East marine plan areas.
7	To protect, conserve and, where appropriate, recover biodiversity that is in or dependent upon the East marine plan areas.
8	To support the objectives of Marine Protected Areas (and other designated sites around the coast that overlap, or are adjacent to the East marine plan areas), individually and as part of an ecologically coherent network.
9	To facilitate action on climate change adaptation and mitigation in the East marine plan areas.
10	To ensure integration with other plans, and in the regulation and management of key activities and issues, in the East marine plans, and adjacent areas.
11	To continue to develop the marine evidence base to support implementation, monitoring and review of the East marine plans.

Table 1-3 Objectives for the East Inshore and East Offshore Marine Plans (MMO, 2014)

These objectives are to be achieved through the application of 38 plan policies, some of which apply to specific sectors. The proposed development as described in this ES have been assessed against the East Offshore Marine Plan objectives and oil and gas planning policies (Appendix A).

1.6 Spirit Energy Management System

Spirit Energy is committed to conducting activities in compliance with all applicable legislation and in a manner that will minimise impacts on the environment. The proposed Pegasus West Development will be delivered in compliance with the Spirit Energy Health, Safety, Environment and Security (HSES) Policy (Figure 1-2) and the Spirit Energy Environmental Management System, which has been developed in line with the principles of the International Standard for Environmental Management Systems (ISO14001:2015).

HEALTH, SAFETY, ENVIRONMENT AND SECURITY POLICY

At Spirit Energy creating an incident free workplace is our top priority. All employees and business partners are required to comply with this policy and our commitments outlined below.

We are committed to:

- **Assessing**, understanding and managing our HSES risks and impacts
- **Enabling** the creation of a positive culture holding each other accountable, helping us to: achieve our HSES goals; support business growth; and realise our vision of an incident free workplace
- **Proactively** supporting employee health and safety, seeking ways to protect the environment, including the prevention of pollution, efficient use of resources and the reduction of waste and carbon emissions
- **Empowering and encouraging** personnel to work in a safe way
- **Intervening** if we believe that the work environment or task is unsafe or may cause environmental damage, or we see an unsafe act
- **Learning** from our successes and incidents, and freely sharing lessons with business partners
- **Working with stakeholders**, suppliers and business partners in the pursuit of good practice in HSES
- **Continually improving** and setting measurable objectives and targets in business plans to enhance HSES performance
- **Developing** and testing prioritised incident response and recovery plans to protect our people, the environment and minimize business impact
- **Ethically conducting our business** and complying with regulatory and other applicable requirements

Our HSES management system enables the delivery of these policy commitments, is structured in line with recognised good practice, and is routinely assured. Independent certification to ISO 14001 shall be maintained for our environmental material operations.

Our performance is reviewed regularly and relevant results published.

Chris Cox
CEO
August 2018

SPIRIT ENERGY

Figure 1-2 Spirit Energy HSES Policy

1.7 Areas of Uncertainty

This EIA has been undertaken during the Define phase of the project. Where engineering detail was not available certain assumptions were required to be made. Where uncertainty existed the environmental worst case option has been assessed. The key assumptions and uncertainties are outlined below.

1.7.1 Protection and stabilisation features

A combination of rock and concrete mattresses will be required to be deposited/installed for the protection and stabilisation of the installed subsea infrastructure. The estimated quantities of these materials used in the impact assessment are maximums in order that the worst case area of seabed disturbance may be determined. The actual quantities required will be confirmed during detailed engineering and will feature in Pipeline Works Authorisation (PWA) and associated Deposit Consent (DepCon) applications that will be submitted for approval to the OGA during the Execute phase of the project.

1.7.2 Production profiles

The production profiles presented in this ES are derived from computer simulations and therefore have a range of uncertainty associated with them. They represent annual averages of projected high case production rates.

1.8 Consultation Process

Table 1-4 details the consultations carried out with OPRED and the JNCC in August 2021 to support the EIA process. In addition, Table 1-4 details the comments received from a number of stakeholders following issue of a Scoping Report in September 2018 supporting the initial Pegasus West Development Environmental Statement. The Scoping Report informed stakeholders of the proposed development and the proposed content and extent of the EIA, including the initial identification of environmental impacts, areas of key concern, and the identification of relevant sources of environmental data.

The process of consultation will continue throughout the development project.

As required by the 2020 Offshore EIA Regulations guidance (BEIS, 2021), a copy of the ES and the public notice has been made publicly available on the Company's website at the time of submission: www.spirit-energy.com/pegasuswest.

CONSULTEE	COMMENT	SPIRIT ENERGY RESPONSE
Workshop held with OPRED and JNCC on 5/8/21		
Joint Nature Conservation Committee (JNCC)	JNCC provided reference to the Marine Management Organisation Public Registers as a source of information for permit applications relating to Offshore Wind Developments in the wider area. Informed of permits submitted to support surveys for UXOs at these locations.	Information incorporated into Section 8.
	JNCC requested that the impact on the seabed (especially in relation to pipeline protection materials) is minimised.	Cognisance of this request has been taken account of through all phases of the project.
Offshore Petroleum Regulator for Environment and Decommissioning (OPRED)	OPRED enquired if any further environmental data was available that could support the view that the information gathered in the 2018 survey is still representative of the environment.	Spirit Energy were advised by Neptune that no further environmental sampling has taken place at the Cygnus platform.
	OPRED referred to previous issues with laying lines approaching the Cygnus platform and how due to soil types, more rock was required than initially applied for. OPRED requested that lessons learned from this experience should be fully understood and implemented.	Spirit Energy can confirm this is not expected to be an issue at the Cygnus approach for this project.
	OPRED advised of the importance to importance of considering the Project in terms of Net Zero.	Addressed in Section 7
	OPRED requested increased flaring associated with start-up is addressed in the ES. Acknowledged that no anticipated increase during production.	Addressed in Section 7
Response to Scoping Report issued in September 2018 in support of initial Pegasus West Development ES		
OPRED	OPRED supports the environmental impacts that have been identified for detailed assessment during the EIA, but would highlight the importance of cumulative impact as part of the ES.	Addressed in Sections 5.2.4; 6.2.2; 7.2.3; 8.3.2; 9.2.5; 10.3.2 and 11.3.
	OPRED stated that details of installation methods should be addressed and assessed appropriately, with protection/trenching being proportional and to BAT/BEP. In addition, option selection and criteria used should be clear.	Addressed in Sections 2.5.3 and 8.4.
JNCC	The proposed development is within the Dogger Bank SAC, a static sandbank system. We recommend that all material removed during this process is kept within the system (i.e. not deposited far away) as removal of volume from the system is likely to result in impact to the sandbank feature of this site. We also recommend that, where practical, deposition of stabilisation materials (e.g. concrete mattresses and deposited rock) are kept to a minimum and that infrastructure is not placed on seabed features or habitats of conservation importance.	Addressed in Section 8.
	The proposed development is within the Southern North Sea SCI designated on the basis of its long-term, preferential use by harbour porpoise. Piling is currently not being considered for this project however we highlight that activities such as pre-sweeping, trenching, dredging, deposits, discharges and disposal activities have the potential to impact the achievement of Conservation Objective 3: the supporting habitats and processes relevant to harbour porpoises and their prey are maintained. Impacts from the proposed works in relation to all COs should be considered within the ES.	Addressed in Section 8.

CONSULTEE	COMMENT	SPIRIT ENERGY RESPONSE
	As per DECC 2015, the environmental description should focus on that of the actual area to be developed and not just provide a generic description of the local environment. Evidence should be presented within the ES confirming that the data are still relevant. • Survey data should at least include the area of proposed operations. • Survey data should provide adequate evidence that habitats and species of nature conservation concern, including Annex I habitats, are or are not present. • It is good practice to include a diagram indicating the surveyed area in the context of the proposed activities and to identify any sample points or the location of photographic evidence. Data provided should also include high resolution acoustic data, video and/or still images.	Addressed in Section 3.2.3.4, 3.3.2 and 3.4.1.
	When considering the marine mammal environmental baseline, we highlight that results from the third Small Cetaceans in Europe Atlantic waters and the North Sea survey (SCANS III) are now available. We also highlight that data associated with the revised Phase III report of the Joint Cetacean Protocol (JCP) is now available.	Addressed in Section 3.3.5.2.
	We note the inclusion of data from the Seabird Oil Sensitivity Index (SOSI) and commend Spirit on their presentation of this data. When assessing the impacts of accidental events on seabird populations, inclusion of this information is appropriate. We recommend consideration of other data sources when describing the baseline biological environment in the ES, e.g. Kober *et al*., 2010.	Addressed in Section 3.3.4.
	JNCC considers it best practice to consider the full worst-case scenario in order to enable a meaningful assessment of the full environmental impacts of a project.	Worst case scenarios have been considered throughout the ES.
	There is a requirement for assessing the cumulative effects of a project under the EIA Directive. JNCC suggests that the proposed operations are assessed alongside approved developments under construction, approved developments that have not yet commenced construction, developments submitted for approval but not yet approved, as well as any other significant appropriate development for which some realistic figures are available.	Addressed in Section 3.2.3.2.
Marine Management Organisation (MMO)	MMO advised of the publication of the East Inshore and Offshore marine plans and requirements to consider them in the ES. They advised that further information on how to apply the East Inshore and Offshore Plans is available oat their Marine Information System.	Addressed in Section 1.5.5.1 and Appendix A.
Maritime & Coastguard Agency (MCA)	The MCA would expect to see a full Shipping & Navigation chapter in the Environmental Statement. This should include the use of appropriate data to consider local marine traffic, including commercial, fishing and recreational vessels and appropriate collision risk management plans, etc. The proximity to other developments, including windfarms, should also be explored further so that any potential safety risks can be identified and addressed with appropriate mitigation.	Addressed in Section 3.5.5 and Section 5.
National Federation of Fishermen's Organisations (NFFO)	No comments received.	

Table 1-4 Summary of consultation responses

2. PROJECT DESCRIPTION

This section provides a technical summary of the proposed Pegasus West Development project, including the required project infrastructure (Figure 2-1) and the required activities and methods to install, commission and produce hydrocarbons from this infrastructure.

Figure 2-1 Schematic showing the proposed Pegasus West Development project infrastructure in relation to existing Cygnus infrastructure

2.1 Nature of the Reservoir

The Pegasus field was discovered in 2010 (exploration well 43/13b-6z) and a commercial gas discovery was confirmed in 2014 by appraisal well 43/13b-7 (Pegasus West). Following three well tests, the Pegasus West well was suspended for future production.

PROPERTY	VALUE
Reservoir type	Gas
Reserves	14.5 MMBOE (83 BCF)
Gas Condensate Ratio (GCR) following Stock Tank Flash	4 to 6 bbl/mmscf
Gas Condensate Ratio (GCR) over Cygnus Process	8 to 10 bbl/mmscf

Table 2-1 Reservoir properties

The Pegasus gas and condensate reservoir comprises Carboniferous (Namurian - Westphalian) sandstones deposited in a deltaic environment. It is located in the SNS to the west of the Cavendish field, and to the east of the Andromeda prospect. Pegasus West gas is a high quality 'sweet' gas with low CO_2 concentrations, requiring only water and condensate removal to meet sales quality specifications. The estimated total recoverable gas volume from Pegasus West is 83 Billion Cubic Feet (BCF) (mid-case).

There are several exploration prospects in close proximity to the Pegasus West discovery which, if successful, would be candidates for further development of the Pegasus field (Figure 2-2). However, the scope of this ES is confined solely to the tie-in of the Pegasus West well to Cygnus.

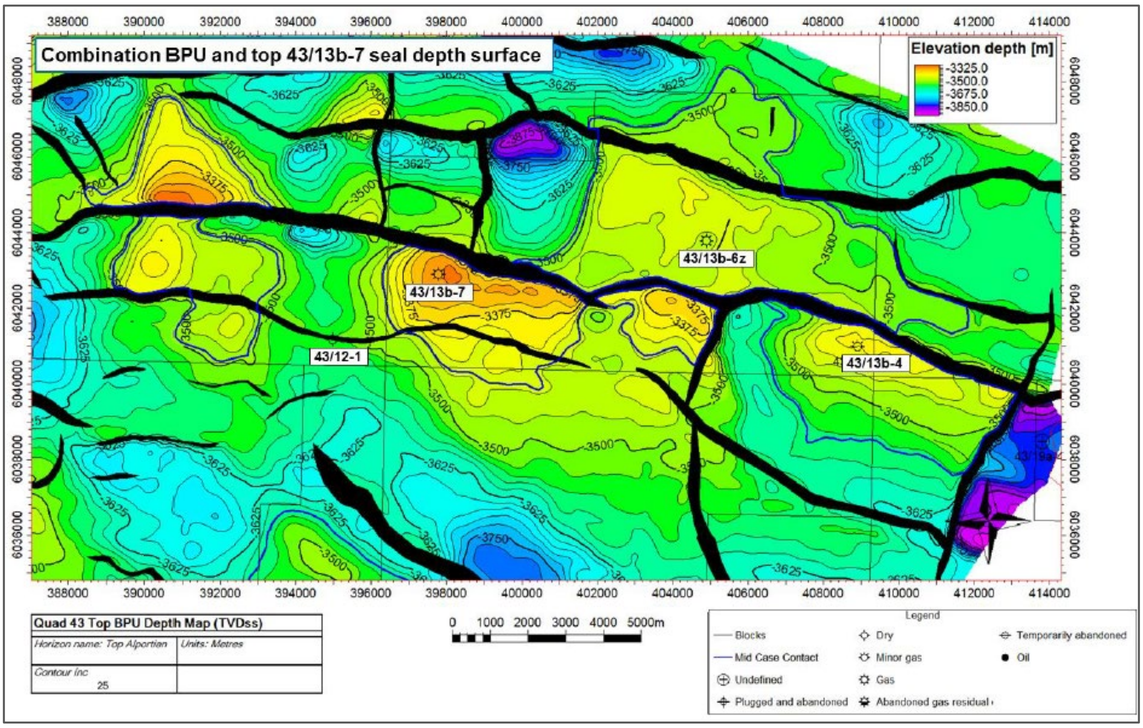


Figure 2-2 Top reservoir depth structure and well locations (including 43/13b-7 Pegasus West)

2.2 Option Selection

2.2.1 Field development options

A number of development options were considered for the Pegasus West discovery with the aim of optimising the value of the field and the use of surrounding infrastructure. Decision criteria in support of this aim are: Economic including capital expenditure (CAPEX) and operating expenditure (OPEX); Technical viability including health, safety and environmental implications; Commercial viability including potential to support future Greater Pegasus Area development; and Delivery including scheduling.

The Evaluate project phase examined and ruled out based on technical or commercial criteria:

- Subsea tie-back via 32 km pipeline to the Perenco-operated Trent facilities;
- Subsea tie-back via 17 km pipeline to the Ineos-operated Cavendish facility;
- Development of a Pegasus hub by relocation and deployment of a Self-Installing Platform (SIP) from the F3/FA field in the Dutch sector of the North Sea to Pegasus, with gas export to the Shell operated SEAL pipeline; and

- Development of a Pegasus hub by installation of a refurbished jack up drilling rig (JUDR) with processing services at Pegasus.

Four options were taken into the Select project phase for further assessment (Table 2-2).

Select phase studies screened out the options of a SIP tied in to Breagh (option 3) and a direct tie-in to the Cleeton facility (option 4) due to lower value, higher CAPEX, longer tie-in pipeline requirements, and no Spirit Energy equity in the tie-in facilities. Furthermore, Cleeton has no gas compression and is an ageing facility likely to have associated late life asset maintenance and integrity issues, along with much greater brownfield construction risks.

Of the remaining two options, a subsea tie-back via an approximately 56.8 km production pipeline to Cygnus, with onward gas export to the Bacton Gas Terminal via the Perenco-operated Eagles Transportation System (ETS) pipeline (option 1) is the selected option. Spirit Energy considered relocation and installation of the F3/FA SIP, a Normally Unattended Installation (NUI), to Pegasus with tie in to ETS at Trent Wye (option 2). However, this would have higher OPEX costs, higher safety risks associated with operating a NUI with gas processing, and higher project execution risks associated with installing a SIP in the Pegasus West area, where seabed suitability is not proven.

In terms of environmental impact, the comparative environmental impact evaluation and ranking determined that tie-back to Cygnus is the joint second most favourable environmental option, ranking equally with option 2. The absence of impacts associated with installation and operation of a NUI platform counted comparatively favourably in the assessment, while its requirement for a relatively long tie-back wholly within the Dogger Bank SAC counted comparatively unfavourably. Of the four options carried through to select, pipeline lengths ranged from approximately 32 km to approximately 77 km. The shortest pipeline option would require installation of a platform, introducing risks to navigation from the new surface infrastructure and a new source of emissions and discharges. The option of tie-back to Cygnus was the next shortest pipeline route considered in detail.

	OPTION	DESCRIPTION	CONSIDERATIONS
1	Subsea tie-back to Cygnus (selected option)	Subsea tie-back via a new approximately 56.5 km production pipeline (excludes tie-in spool lengths) to Cygnus located east of Pegasus West. Onward gas export via ETS to the Bacton Gas Terminal.	• Lower OPEX • No navigational risk associated with SIP installation • Larger seabed footprint than options 1,2 and 3
2	SIP to Trent Wye	The F3/FA SIP would be relocated from its current location to Pegasus West. Gas exported via a new 32 km pipeline tie-in to the Trent Wye facility to the south of Pegasus. Onward gas export via ETS to the Bacton Gas Terminal.	• Higher OPEX • Higher project execution risk of moving and installing the SIP • Navigational risk associated with SIP installation • Smaller seabed footprint than option 1, 3 and 4 • Additional atmospheric emissions from SIP including gas compression, power generation and aviation and marine support activities.
3	SIP to Breagh	The F3/FA SIP would be relocated from its current location to Pegasus West. Gas exported via a new 65km pipeline to the Breagh facility to the west of Pegasus, then onwards to the Teesside Gas Processing Plant.	• Higher CAPEX • Long export route • No Spirit Energy equity in infrastructure • Higher project execution risk of moving and installing SIP • Navigational risk associated with SIP installation • Larger seabed footprint than options 2 and 4 • Additional atmospheric emissions from SIP including gas compression, power generation and aviation and marine support activities.
4	Subsea tie-back to Cleeton	Subsea tie-back via a new 77km pipeline to the Cleeton facility to the south-west of Pegasus West. Onward gas export via the Cleeton gas export pipeline to the Dimlington Gas Terminal.	• Higher CAPEX • Long export route • No Spirit Energy equity in infrastructure • No gas compression • Ageing facility • No navigational risk associated with SIP installation

Table 2-2 Pegasus West Development options

2.2.2 Pipeline installation method

Trench and bury, and surface lay options were evaluated for the installation of the production pipeline and EHC umbilical. The option to (where possible) trench and bury the pipeline and EHC umbilical was selected in order to reduce the risk of snagging posed by them to third party users of the seabed, to reduce the risk of damage to them by these third parties, and to provide stability (reducing the likelihood of exposures above the seabed). It is accepted practice in the SNS to trench and bury rather than surface lay pipelines of the diameter selected for this project. It should be noted that a *c.* 4 km portion of the production pipeline and EHC umbilical, between KP4.350 and KP8.383, will be surface laid. Surface laying of this section is required for geotechnical (very stiff clay) and for installation safety (high loading in wires due to shallow water) reasons. The surface laid sections will be protected and stabilised using rock (Section 2.5.3).

2.3 Schedule of Activities

The activities associated with the Pegasus West Development are scheduled to commence in Q4 2022 as shown in Table 2-3. It should be noted that the schedule presented is not fixed and is liable to change as the project progresses through detailed design. First Gas is anticipated in Q1-Q3 2024.

EXECUTE PHASE	2022				2023				2024		
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3
Cygnus topside modifications, hook-up and commissioning											
Well re-entry and completion											
Installation and testing of subsea infrastructure											
First gas											

Table 2-3 Indicative schedule of activities

2.4 Well Completion

It is proposed to re-enter and complete the suspended Pegasus West 43/13b-7 appraisal well using an as-yet-unassigned three-legged JUDR. A generic JUDR specification has been used for the purposes of this EIA. The operation is expected to take around 55 days and is anticipated to be carried out in Q4 2022.

2.4.1 Positioning of the jack-up drilling rig

The JUDR will locate at the Pegasus West well location (Table 2-4).

LOCATION	NORTHING/EASTING	LATITUDE/LONGITUDE
Pegasus West well (43/13b-7)	6,042,908 N 397,774 E	54° 31’ 20.102” N 001° 25’ 14.358” E
Spheroid: International 1924ED50 – Datum: ED50 Projection: UTM Zone 31N, Central Meridian 3°E		

Table 2-4 Pegasus West well co-ordinates

2.4.2 Blowout Preventer (BOP)

The JUDR will be equipped with a Blowout Preventer (BOP) which is rated for pressures beyond that of the Pegasus West reservoir. The BOP will be positioned on the rig floor.

The function of the BOP is to prevent uncontrolled flow from the well to the surface by closing in the well in the event of uncontrolled release from the reservoir into the well bore. The BOP comprises a series of hydraulically operated rams that can be closed in an emergency from the drill floor, or from a safe location elsewhere on the rig.

The integrity of the BOP will be tested prior to usage and periodically during the well completion.

Inspection and testing of the BOP will be undertaken in line with the UK legislation and Spirit Energy procedures.

2.4.3 Jack-Up Drilling Rig activities

The JUDR will re-enter the Pegasus West well and convert the jack-up mudline suspension system, left following appraisal drilling, to a 13 5/8" subsea wellhead system. It will also install downhole pressure gauge(s) in the well to enable reservoir surveillance and management from the surface.

The well will be flowed to displace the completion fluid, a brine consisting sodium chloride/potassium chloride (NaCl/KCl) with small quantities of chemicals to protect the well. These chemicals will include a corrosion inhibitor, an oxygen scavenger and a biocide. Completion fluids will be discharged to sea. This chemical discharge is covered under the Pegasus West appraisal drilling chemical discharge permit (DRA93/6). Spirit Energy will apply for a new well intervention chemical permit for any chemical use and discharge by the JUDR, and for discharge of completion fluids if directed by BEIS. If there is a possibility that completion fluids will be contaminated by reservoir hydrocarbons, Spirit Energy will apply for a term oil discharge permit. Completion fluids will be tested for hydrocarbon content, treated if required, and discharged to sea in compliance with the conditions of the oil discharge permit and legislative requirements.

After completion of the well clean-up, the well may be flowed for a test period. For the duration of well clean-up and any testing, produced hydrocarbon gas will be flared. This period will be minimised as far as possible and is not anticipated to be longer than 48 hours. Based on the anticipated gas composition, a maximum of 6,767 Te of gas and 307 Te (2,500 bbl) of condensate will be flared.

Finally, the JUDR will install and test the production Xmas tree (Section 2.5.1), recover the suspension plugs and suspend the well before departing the field.

2.4.4 Jack-up drilling rig support activity

Various support vessels will be associated with the well completion operations. Table 2-5 summarises the estimated duration that each vessel will be active and their estimated fuel use. Estimates provided are based on an indicative maximum duration for well completion activities of 55 days. A total of 25 helicopter round trips are assumed, with a round trip of taking approximately 2 hours.

VESSEL TYPE	PROJECT DAYS	FUEL CONSUMPTION (Te/day)[1]	TOTAL FUEL USE (Te)
Jack-Up Drilling Rig (JUDR)	55	10	550
JUDR Tow Vessel	14	21	294
Anchor Handling Tug (AHT)	10	21	210
Emergency Response and Rescue Vessel (ERRV)	55	1.5	82.5
Supply vessel (in transit)	12	10	120
Supply vessel (working)	8	1.5	12
Helicopter	2.083	12 (0.5 Te/hour)	25
Total Fuel Use			**1,293.5**
[1]Source: The Institute of Petroleum (2000).			

Table 2-5 Vessel type and fuel usage during Pegasus West well completion activities

2.4.5 Relief well

The location of a relief well will be identified in advance of well re-entry. It is anticipated that the total time to plan and drill a relief well would be approximately 95 days.

2.5 Subsea Infrastructure Installation

This section describes the subsea infrastructure to be installed as part of the proposed Pegasus West Development project and its relationship to existing infrastructure at Cygnus (Figure 2-1). Table 2-6 summarises the required subsea infrastructure including its dimensions.

ITEM	DESCRIPTION
1	Vertical Xmas tree and WPS including SUTU and SCM (*c*. 6.94 m (L) x 5.20 m (W)).
2	Connection tee and 10” (NB) production tie-in spools at Pegasus West (*c*. 62.0 m x 0.273 m OD) between connection tee and 10” pipeline.
3	10” (NB) pipeline between Pegasus West and Cygnus (*c*. 56,512 m x 0.273 m OD).
4	Electro-hydraulic-chemical EHC umbilical between Pegasus West and Cygnus J tube J4 (*c*. 56,982 m x 0.119 m OD).
5	10” (NB) production tie-in spools at Cygnus (*c*. 150.0 m x 0.273 m OD) between 10” production pipeline and Subsea Isolation Valve (SSIV).
6	SSIV at Cygnus (8.40 m (L) x 6.90 m (W)). This will be a gravity-based structure.
7	10” production tie-in spools at Cygnus (*c*. 110.0 m x 0.273 m OD) between Cygnus 12” R4 riser flange and SSIV.

Table 2-6 Subsea infrastructure required for the Pegasus West Development

2.5.1 Xmas tree and wellhead protection structure

A shallow water vertical Xmas tree with a wellhead protection structure (WPS) will be installed at the Pegasus West well and installed as a single unit by the JUDR. The Xmas tree will include an integrated Subsea Control Module (SCM). A Subsea Umbilical Termination Unit (SUTU) will be positioned underneath the WPS and it will distribute electrical, hydraulic and chemical and services from the EHC umbilical to the well. Electrical jumpers will relay power and signalling from the SUTU to the SCM. Similarly, hydraulic jumpers will relay hydraulic power and chemical services from the SUTU to the Xmas tree stab plate.

The Xmas tree will have an arrangement of hydraulically operated valves, with manual back-up valves, and the well will have a hydraulically operated Downhole Safety Valve (DHSV), to shut in production and isolate the reservoir.

Chemicals will be continuously injected at the Xmas tree, as necessary, to prevent the formation of hydrates, corrosion, and wax deposition (Section 2.7.4).

2.5.2 Connection tee and spools at Pegasus West

The Pegasus West Xmas tree will be connected, via a 6” spool, to a connection tee (within the WPS). From here, the well will be connected, via 10” spools, to the production pipeline. These tie-in spools, measuring approximately 62 m in total length, will be surface-laid. A Diving Support Vessel (DSV) will be mobilised to install and connect the spools and connection tee.

2.5.3 Production pipeline and EHC umbilical

The Pegasus West well will be tied back to Cygnus via a 10” NB (nominal bore) carbon steel production pipeline, approximately 56.5 km in length (without tie-in spools). A 119 mm OD (outer diameter) EHC umbilical, approximately 57.0 km in length, will provide transportation of electrical power and signals, hydraulic power, and chemicals from Cygnus to the Pegasus West well. The pipeline and EHC umbilical will each be laid, trenched and buried in parallel, approximately 30 m apart, along the majority of their length.

References to positions on the production pipeline route are made in kilometre points (KPs) from KP0 (zero) at the Pegasus West end of the pipeline to KP56.512 at the Cygnus end.

2.5.3.1 Production pipeline and EHC umbilical laying

The base case is for a reel lay pipeline installation vessel to install the Pegasus West production pipeline on the seabed. The pipeline will be free-flooded during pipelay. Dosing of the entrained seawater with oxygen scavenger, corrosion inhibitor and biocide chemicals will prevent corrosion of the pipeline over the construction period until pipeline commissioning (Section 2.5.5).

The Pegasus West EHC umbilical will be installed on the seabed using the reel lay method, starting at Cygnus and moving towards Pegasus West.

Where the production pipeline and EHC umbilical are required to be surface-laid (4.033 km between KP4.350 to KP8.383) they will be installed parallel to each other, approximately 1 m apart, such that their protection and stabilisation can be achieved with a single rock berm, approximately 7.5 m in width, over the majority of the surface laid section. Where the pipeline route is required to cross the existing Esmond to Bacton pipeline, the production pipeline and EHC umbilical will require a larger spacing to allow the construction of a separate crossing for each (Section 2.5.3.3).

For the period when the pipeline and EHC umbilical are on the seabed, estimated at up to one week, guard vessels will be in deployed to ensure the safety of other seabed users from the risk of snagging.

2.5.3.2 Production pipeline and EHC umbilical trenching

As discussed in Sections 2.2.2 and 2.5.3.1, the majority of the production pipeline and EHC umbilical will be trenched and buried. However, it will be necessary to surface lay the length of the pipeline between KP4.350 to KP8.383. Trenching and burying this section of the lines is not possible for a combination of geotechnical (the very stiff nature of the shallow soil (clay)), and installation safety (the shallow water depth and high wire loads) reasons.

The base case is to separately trench and bury the production pipeline and EHC umbilical by jetting. With jetting, high pressure water and air is used to fluidise seabed sediments beneath the laid pipeline or EHC umbilical to trench and bury them without significant spoil mounds. The pipeline will be buried to a minimum of approximately 1.0 m below seabed level, (depth of covering), and the EHC umbilical will be buried to a minimum of approximately 0.6 m below seabed level (depth of covering).

The ends of the pipeline and EHC umbilical, inside the Pegasus West and Cygnus 500 m safety exclusion zones, will initially be left exposed for later tie-in. Where the pipeline route is required to cross the third-party Esmond to Gordon pipeline, upon approach from each side the lines will remain surface laid and protected with mattresses and rock cover (Sections 2.5.3.3 and 2.5.3.4).

The worst case in terms of excavation and disturbance of sediment is to trench and bury the Pegasus West pipeline and EHC umbilical separately in parallel trenches that are approximately 30 m apart along the entirety of the route.

The possibility of installing the pipeline and EHC umbilical together in a single trench for the majority of the route will continue to be investigated however during detailed design. Co-location would in any case require to commence at a point far enough from the Pegasus West well such that reservoir fluids in the pipeline would have cooled sufficiently to avoid thermal impacts on EHC umbilical performance, estimated at approximately 10 km.

2.5.3.3 Pipeline crossings

The production pipeline and EHC umbilical will require to cross three existing pipelines as summarised in Table 2-7.

NO.	KP	INTERNAL DIAMETER	NAME	LAY	STATUS
1	5.7	24 inch	Esmond to Bacton pipeline	Surface (no protection)	Disused
2	19.4	12 inch	Esmond to Gordon pipeline	Buried	Disused
3*	*c.* 56.7 (within Cygnus 500 m zone)	12 inch	Cygnus B to Cygnus A infield production pipeline and EHC umbilical	Surface (with protection)	Active
*In this instance the infield pipelines will be crossed by the new Pegasus West tie-in spools and the EHC umbilical.					

Table 2-7 Pipeline crossings

The crossing of the Esmond to Bacton pipeline will occur at KP5.7, which occurs within the section of the Pegasus West production pipeline and EHC umbilical that will be surface laid. The crossings will be constructed from a combination of rock and concrete mattresses. In order to make the crossing, the Pegasus West production pipeline and EHC umbilical will require to be separately routed (and protected) for a length of *c.*300 m. Mattresses will be laid from a DSV and a rock lay vessel will be used to lay the rock.

The crossing of the Esmond to Gordon pipeline will occur at KP19.4, which occurs within the section of the production pipeline and EHC umbilical that will be trenched and buried. The buried production pipeline and EHC umbilical will require to transition to the surface at each side of the Esmond to Gordon pipeline to enable the crossings to be made. For both the production pipeline and EHC umbilical crossing a *c.* 100 m section (including both the transitions and the crossing) will require to be protected with deposited rock. These crossings will comprise a combination of rock and concrete mattresses.

Within the Cygnus A 500 m exclusion zone the Pegasus West production pipeline tie-in spools and EHC umbilical will cross the surface-laid section of the Cygnus B to Cygnus A infield production pipeline and EHC umbilical at three separate locations.

Table 2-8 summarises the quantity of concrete mattresses and deposited rock that will be required for the construction of the pipeline crossings.

2.5.3.4 Subsea infrastructure protection (excluding pipeline crossings)

A combination of rock, concrete mattresses and grout bags will be deposited/installed within the Pegasus West 500 m safety exclusion zone to protect the surface-laid production tie-in spools, and the surface-laid ends of the production pipeline and EHC umbilical[1]. The production pipeline and the EHC umbilical have separate approaches to Pegasus West. An approximately 75 m length of production pipeline/spools, and an approximately 150 m length of EHC umbilical will require to be protected with deposited rock.

A combination of rock, concrete mattresses and grout bags will also be laid within the Cygnus 500 m safety exclusion zone to protect the surface-laid production tie-in spools, and the surface-laid ends of the production pipeline and EHC umbilical. The production pipeline and EHC umbilical routes will join at a point approximately 50 m from the SSIV and continue side-by-side from the SSIV to the Cygnus platform, allowing the same features and materials to protect them (and the SSIV). A *c*. 60 m length of production pipeline/spools, and *c*. 230 m of EHC umbilical will require to be protected with deposited rock.

It is possible that spot rock cover will be required to remediate free spans and areas of potential upheaval buckling (UHB) on the production pipeline or EHC umbilical.

2.5.3.5 Summary of protection and stabilisation features and materials

Table 2-8 summarises the maximum quantities of deposited rock, concrete mattresses and grout bags required for the protection and stabilisation of subsea infrastructure.

[1] The requirement for rock to be laid within the 500 m exclusions zones is driven by the local weather conditions. For example, the extreme weather conditions at the Cygnus platform, have previously resulted in a requirement for remedial work (rock placement) where mattresses have been removed by storm conditions. Also an unstable mattress damaged the fibre optic cable for the Cygnus platform requiring a dedicated intervention. Rock has a higher tolerance than flexible concrete mattresses for extreme environmental events which is likely to require fewer remedial interventions over the field life.

ITEM	NUMBER/MASS (Te)
Deposited Rock	
Mass of deposited rock on surface laid production pipeline and EHC umbilical (KP4.3 to KP8.3)	39,000
Mass of spot rock cover on the production pipeline and EHC umbilical (free span and UHB remediation)	10,000
Mass of rock cover at Esmond to Bacton pipeline crossings	5,000
Mass of rock cover at Esmond to Gordon pipeline crossings (including trench transitions)	3,000
Mass of rock cover at Cygnus approach (including crossings of the existing Cygnus A to Cygnus B tie-in spools)	3,000
Mass of rock cover at Pegasus West approach	1,500
Concrete Mattresses	
Number of mattresses at approach to Pegasus West	23
Number of mattresses at approach to Cygnus platform (excluding those associated with pipeline crossings)	63
Number of mattresses at pipeline crossings	59
Grout Bags	
Number of 25 kg grout bags at approach to Pegasus West Xmas tree	240
Number of 25 kg grout bags at the Cygnus platform	2,160
Quantities presented include contingency e.g. 50% added to the quantity of concrete mattresses and grout bags.	

Table 2-8 Anticipated maximum quantities of protection and stabilisation features and materials

2.5.3.6 Pipeline and EHC umbilical connection at Cygnus

The production pipeline will be connected to the existing 12” R4 riser at Cygnus. The EHC umbilical will be pulled up the existing J-tube J4 on the north side of the Cygnus platform, and connected to a Topside EHC umbilical Termination Unit (TUTU).

To provide the most direct route, the production pipeline and EHC umbilical will approach Cygnus from the south-west, running approximately parallel with and to the north of the existing 24” Cygnus gas export pipeline (PL3088).

Inside the Cygnus 500 m safety exclusion zone, the surface laid end of the production pipeline will be connected with *c*. 150 m of 10” tie-in spools to a Subsea Isolation Valve (SSIV) located *c*. 100 m from Cygnus. The SSIV will be connected to the Cygnus riser with a further *c*. 110 m 10” tie-in spools (Table 2-6).

The EHC umbilical will also connect to the SSIV and between the SSIV and the Cygnus J-tube J4, the EHC umbilical will be laid parallel to the Pegasus West production pipeline tie-in spools.

2.5.4 Production pipeline and EHC umbilical testing and commissioning

Following installation of the production pipeline and EHC umbilical, commissioning tests will be performed to ensure system integrity, including:

- Gauge pigging to confirm pipeline shape. A pre-installed magnetic gauge pig will be propelled through the pipeline from the Pegasus end of the pipeline with chemically treated, dyed seawater injected from a surface vessel. Chemical dosing of the seawater, using a mixture of oxygen scavenger, corrosion inhibitor and biocide, will prevent corrosion and the dye will be used to identify and locate any leaks during subsequent hydrostatic testing;
- Hydrostatic pressure testing (strength test) of the installed pipeline undertaken by a surface vessel to verify the integrity of the welded joints within the 'as-installed' pipelines; and
- Hydrostatic pressure testing (leak test) undertaken from Cygnus after pipeline spool tie-in to prove the integrity of the tie-in connection points. The EHC umbilical chemical and hydraulic cores will also be pressurised from Cygnus. A Remotely Operated Vehicle (ROV) deployed from a surface vessel will inspect pipeline flange connections and EHC umbilical end connections for leaks.

On completion of these activities, the treated seawater will be displaced from the production pipeline by dewatering pigs, launched from a DSV and propelled the length of the pipeline to a pig receiver at the Cygnus, and discharged to sea. A dose of monoethylene glycol (MEG) will be injected ahead and between each pig to inhibit hydrate formation when production from Pegasus West commences.

The permitted discharge of chemicals to the marine environment is a routine part of subsea installation operations. The quantities of chemicals to be used, and whether or not they are to be discharged, will be determined during the project detailed design stage. Wherever possible, chemicals will be chosen that are PLONOR (Pose Little Or No Risk to the environment) or are of Hazard Quotient (HQ) <1. Chemical use and discharge will be subject to a pipeline chemical discharge permit with an environmental risk assessment prior to execution.

2.5.5 Post-lay survey

A post-lay survey of the production pipeline and EHC umbilical will be conducted to confirm burial and identify any free spans and areas of UHB requiring spot rock cover.

2.5.6 Subsea installation support vessels

Various support vessels will be associated with the subsea installation activities. Typical vessel use, duration and fuel usage by vessels during installation are provided in Table 2-9.

VESSEL TYPE	PROJECT DAYS	FUEL CONSUMPTION (Te/day)[1]	TOTAL FUEL USE (Te)
Survey Vessel	40	10	400
Rock Installation Vessel	12	15	180
Pipeline Installation Vessel	28	23	644
Supply Vessel	21	1.5	31.5
Trenching Vessel	31	17	527
Construction Support Vessel (CSV)	21	18	378
Diving Support Vessel (DSV)	24	18	432
Guard Vessel (3 of)	100	0.8	80
Total Fuel Use			**2,672.5**
[1]Source: The Institute of Petroleum (2000).			

Table 2-9 Vessel type and fuel usage during subsea installation activities

2.6 Cygnus Overview and Topside Modifications

Cygnus is a gas development, located in UKCS Block 44/12, and includes the Cygnus A hub, consisting of three bridge-linked platforms (Figure 2-1):

- Process and utilities platform;
- Production wellhead platform; and
- Utilities and accommodation platform.

In addition, the Cygnus B wellhead platform, which is a NUI, is tied back to the Cygnus A process and utilities platform.

Gas from Cygnus is exported through a 24” pipeline which connects to the ETS pipeline at the Wye tie-in point, approximately 1 km north-east of the Perenco-operated Trent platform. From here gas is exported via the approximately 165 km long, 24” ETS pipeline for processing at the Perenco-operated terminal at Bacton on the Norfolk coast.

The proposed Pegasus West production pipeline and EHC umbilical will tie into the Cygnus A process and utilities platform (Section 2.5.5) which has facilities for separation, gas compression and dehydration, and produced water processing and discharge. The utility systems will include chemical injection, instrument air supply, fuel gas, flare and gas compression.

Cygnus has a total gas processing capacity of 300 mmscf per day. Increased inputs from Pegasus West will not exceed the existing Cygnus gas processing capacity and will fill available ullage in the system.

Any Pegasus West produced water will be separated on Cygnus and processed by the existing produced water management system. It is expected that the only water produced from Pegasus West will be saturation water. Formation water breakthrough is a possibility in later field life, as illustrated in Section 2.7.3, but is not expected. Produced water at Cygnus is discharged to sea under the conditions of the installation Oil Discharge Permit. Any increase in produced water as a result of the Pegasus West tie-back will be within the capacity of the existing produced water management system.

The Cygnus power generation system comprises two 3.1 MW dual fuel turbine generators using export gas as fuel under normal operating conditions and low sulphur diesel when gas is not available. The design philosophy is for one of the turbines to be operational while the other is maintained on standby. There is also a backup 0.8 MW emergency diesel generator. The existing power generation facilities are sufficient to meet the power requirements of the Pegasus West Development.

2.6.1 Topside modifications

A reception module will be installed at Cygnus as part of the proposed Pegasus West Development that may require to provide some, or all of, the following facilities:

- A reception separator;
- An emergency shutdown valve;
- Piping to gas, condensate and water tie-in points to the Cygnus processing facilities;
- Tie-ins to Cygnus flare and drain systems;
- Allocation metering;
- A condensate heater;
- A master control station, enabling electrical signalling and hydraulic control of the Pegasus West well via the EHC umbilical to the SCM and receive data from various subsea instruments;
- An electrical power unit to supply power, via the EHC umbilical, to the Pegasus West well SCM;
- A hydraulic power unit to service the subsea control system;
- A TUTU, the interface between the topside facilities and the subsea infrastructure; and
- A dedicated chemical injection system delivering required chemicals to the Pegasus West well.

Given that the Pegasus field ownership is now aligned with the Cygnus field ownership (Section 2.2.1.2), Pegasus West gas will now be able to gain access to certain existing facilities on Cygnus that was not possible under historical field ownership.

The following simplification opportunities, the adoption of which will be confirmed during detailed engineering, have as a result been identified; route Pegasus West gas for processing through the existing Bravo train (removing the need for a large reception module); use, by Pegasus West, of the existing MEG package on Cygnus (removing the need for a dedicated package); and metering package revised to an allocation standard as opposed to a fiscal standard.

2.6.2 Topside modification support vessels

A Heavy Lift Vessel (HLV) may be required to install the reception module at Cygnus. The estimated duration of this activity and fuel usage by the HLV is provided in Table 2-10.

VESSEL TYPE	PROJECT DAYS	FUEL CONSUMPTION (Te/day)[1]	TOTAL FUEL USE (Te)
Heavy Lift Vessel (HLV)	7	50	350
[1]Source: The Institute of Petroleum (2000).			

Table 2-10 Vessel type and fuel usage during Cygnus topside modification activities

2.7 Production Phase

Production profiles have been developed for the Pegasus West Development project, assuming earliest First Gas in 2024. These forecast the likely volumes of gas, condensate and water that will be produced. Anticipated high case forecasts are presented here because the environmental impacts associated with the production of these volumes are likely to be greatest with respect to, for example, atmospheric emissions, discharges to sea etc.

The window for first gas is estimated to be between January 1st 2024 and September 30th 2024. The production profiles presented, assume a mid-point within this window of May 2024 for first gas.

2.7.1 High case gas production

Table 2-11 and Figure 2-3 show the anticipated high case gas production rates from Pegasus West in the context of Cygnus mid-case production. Maximum Pegasus West gas production of approximately 1,982,000 m^3/d is anticipated in 2025.

YEAR	GAS PRODUCTION RATE (Thousand m³/d)		
	Cygnus without Pegasus West	Pegasus West (High Case)	Cygnus with Pegasus West
2021	6,600	0	6,600
2022	7,312	0	7,312
2023	5,749	0	5,749
2024	5,173	1,321	6,494
2025	3,986	1,982	5,968
2026	2,898	1,890	4,788
2027	2,226	1,265	3,491
2028	1,464	783	2,247
2029	852	498	1,350
2030	599	321	920
2031	503	210	713
2032	326	151	477
2033	284	113	397
2034	76	85	161

Table 2-11 Anticipated Pegasus West high case gas production rates

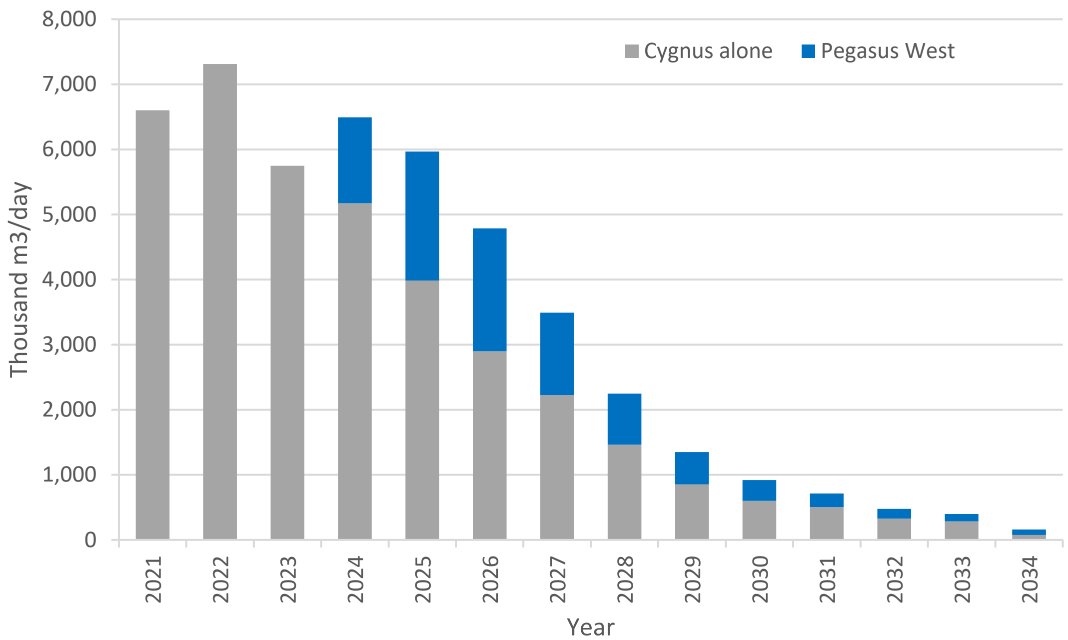


Figure 2-3 Anticipated Pegasus West high case gas production rates

2.7.2 High case condensate production

Table 2-12 and Figure 2-4 show the anticipated high case condensate production rates from

Pegasus West in the context of Cygnus mid-case production.

YEAR	CONDENSATE PRODUCTION RATE (Te/d)		
	Cygnus[1] without Pegasus West	Pegasus West[1] (High Case)	Cygnus with Pegasus West
2021	50.0	0.0	50.0
2022	53.2	0.0	53.2
2023	39.6	0.0	39.6
2024	36.5	48.1	84.6
2025	28.3	71.0	99.2
2026	20.5	66.7	87.2
2027	15.8	43.3	59.0
2028	11.0	25.7	36.7
2029	6.5	15.4	21.8
2030	4.5	9.0	13.5
2031	3.8	5.2	9.0
2032	2.5	3.0	5.5
2033	2.2	1.9	4.0
2034	0.6	1.3	1.9
[1]Based on a condensate specific gravity of 0.75			

Table 2-12 Anticipated Pegasus West high case condensate production rates

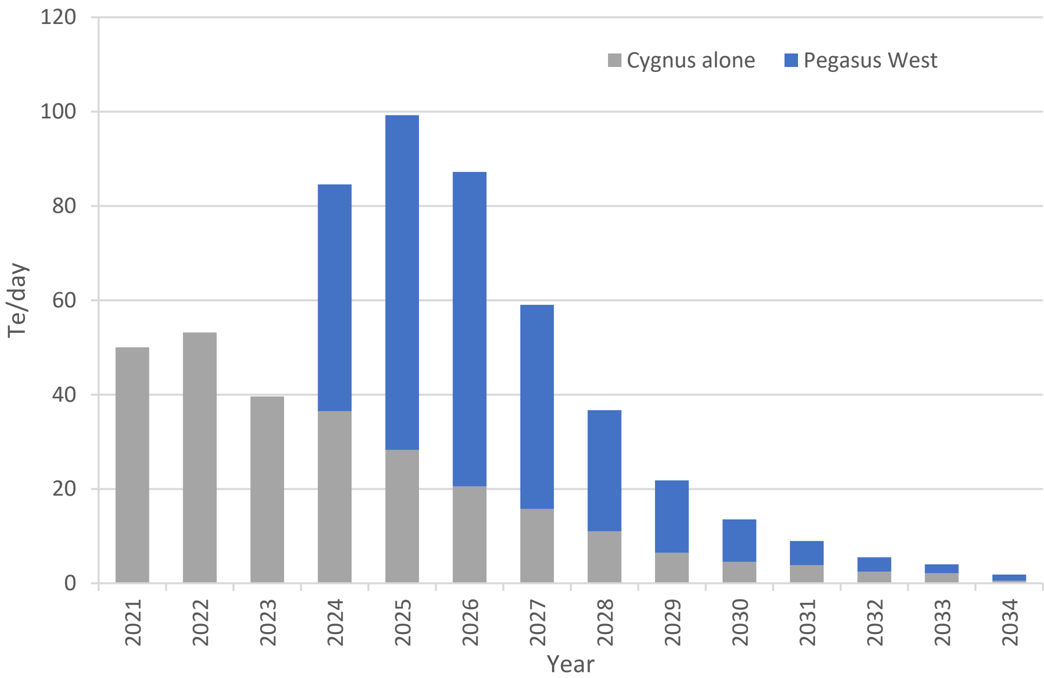


Figure 2-4 Anticipated Pegasus West high case condensate production rates

2.7.3 High case water production

Table 2-13 and Figure 2-5 show the anticipated high case water production rates from Pegasus West in the context of Cygnus mid-case production.

YEAR	WATER PRODUCTION RATE (Te/d)		
	Cygnus[1] without Pegasus West	Pegasus West[1] (High Case)	Cygnus with Pegasus West
2021	12.93	0.00	12.93
2022	18.22	0.00	18.22
2023	19.77	0.00	19.77
2024	27.82	0.00	27.82
2025	61.93	5.52	67.46
2026	70.76	38.64	109.39
2027	10.98	5.22	16.20
2028	12.03	0.00	12.03
2029	14.60	0.00	14.60
2030	26.55	0.00	26.55
2031	53.39	0.00	53.39
2032	46.28	0.00	46.28
2033	0.09	0.00	0.09
2034	0.03	0.00	0.03

[1]Based on a formation water specific gravity of 1.1

Table 2-13 Anticipated Pegasus West high case water production rates

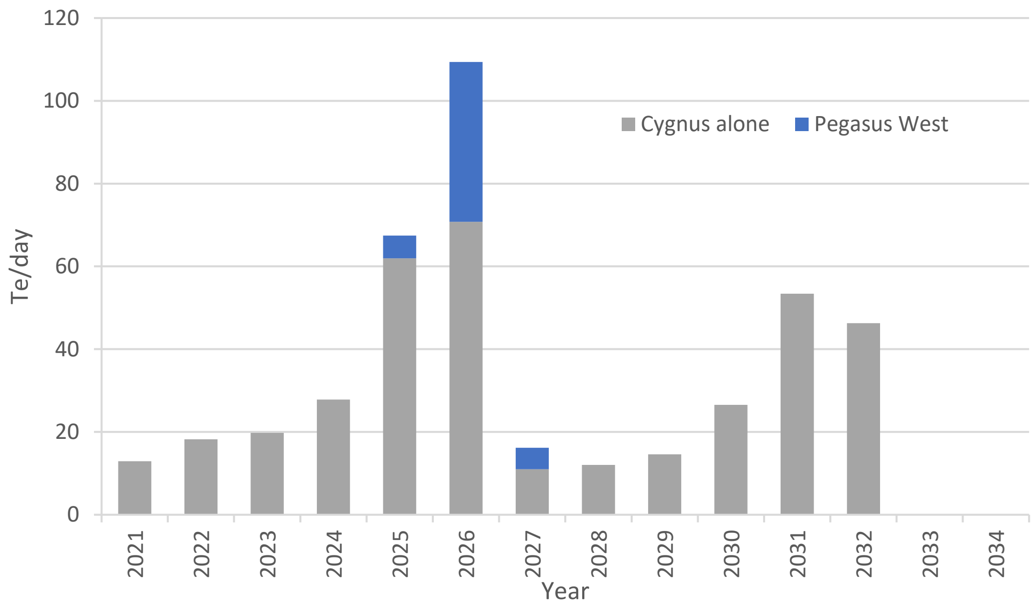


Figure 2-5 Anticipated Pegasus West high case water production rates

2.7.4 Production chemical use

Chemicals are used during the production of hydrocarbons to maintain process efficiency. Hydrocarbons flowing from the Pegasus reservoir will be treated with several chemicals, injected at the Pegasus West well, and returned to Cygnus. The Pegasus West Development chemical requirements will include:

- MEG for opening the downhole safety valve and for low temperature protection and hydrate mitigation during well start-up;
- MEG for continuous hydrate inhibition;
- Corrosion inhibitor for continuous corrosion inhibition;
- Wax inhibitor (contingency use); and
- Potable water/scale wash water (at later field life).

It is currently anticipated that demulsifiers will not be required. However, in the unlikely event that it is, it would be injected at the host facilities rather than subsea.

Hydraulic fluid will also be used for control of the Pegasus West well, supplied via the EHC umbilical to the well SCM.

Based on current methodologies there are no chemicals planned for use and/or discharge that significantly differ from those routinely used for production activities. Pegasus West chemical use and discharge will be included in a variation to the existing Cygnus production chemical permit prior to First Gas.

2.8 Key Permits and Consents

The Portal Environmental Tracking System ('PETS') is BEIS's environmental permitting system accessed via the UK Energy Portal. PETS integrates permits and consents under one centralised Master Application Template (MAT). There are six types of MAT available on the PETs system:

- Drilling Operations;
- Pipeline Operations;
- Production Operations;
- Decommissioning Operations;
- Well Intervention Operations; and
- A Standalone application.

Once a MAT has been created it can support various types of Subsidiary Application Templates (SATs). The following types of SATs are available:

- EIA Direction;
- Chemical Permit;
- Consent to Locate;
- Oil Discharge Permit;
- Offshore Combustion Installations Permit;
- Marine Licence, EPS Disturbance Licence; and
- Marine Survey.

UK Emissions Trading Scheme (ETS) Permits are submitted via the ETS Workflow Automation Project (ETSWAP) portal.

2.8.1 Pollution Prevention and Control (PPC)

It should be noted that Pegasus West requires no changes to the Cygnus power generation equipment. However, the existing PPC permit will be reviewed and any changes to fuel use as a result of the Pegasus West Development project will be captured in a variation.

2.8.2 EU Emissions Trading Scheme (EU ETS)

No new Greenhouse Gas (GHG) permit under the UK Emissions Trading Scheme will be required; however, the description of the installation in the existing Cygnus permit application will be updated to reflect the Pegasus West Development coming online.

2.8.3 Oil Pollution, Prevention and Control (OPPC)

Discharges of oil to sea are controlled under The Petroleum Activities (Oil Pollution, Prevention and Control) Regulations 2005. The existing Cygnus oil discharge life permit will be updated to include Pegasus West production. In addition, oil discharge term permits will be obtained for the well completion activities.

2.8.4 Chemical use and discharges to sea

The relevant permits to use and discharge chemicals offshore will be obtained in accordance with the Offshore Chemicals Regulations (OCR). All offshore activities are covered by the Regulations including oil and gas production, drilling of wells, discharges from pipelines and discharges made during decommissioning. Chemical use and discharge permits will be obtained for well completion and pipeline commissioning activities. The Cygnus production chemical permit will be varied to reflect changes to chemical use and discharge associated with Pegasus West production.

2.8.5 Oil Pollution Emergency Plan (OPEP)

A Temporary Operations OPEP (TOOPEP) or update to the existing Cygnus OPEP will be obtained for the completion of the Pegasus West well. The Cygnus OPEP will be updated to incorporate production from Pegasus West.

2.8.6 Consent to Locate (CtL)

Where applicable, Spirit Energy will obtain the following CtLs:

- Mobile Installation, e.g. mobile offshore drilling units (MODUs);
- Permanent/Fixed Structure, e.g. Xmas tree;
- Pipeline or Cable System, e.g. gas flowline, and control EHC umbilical; and
- Other Operation, e.g. Installation of surface buoys and moorings.

2.8.7 Pipeline Works Authorisation (PWA) and Deposit Consent (DepCon)

A PWA and Deposit Consent will be obtained from the Oil and Gas Authority (OGA) to allow the production pipeline, EHC umbilical and associated protection features to be installed.

2.9 Decommissioning

At Cessation of Production (CoP) the Pegasus West infrastructure will be decommissioned in line with legislation and practices in force at that time. In 2021, this would constitute the following:

- The Petroleum Act 1998 (as amended);
- BEIS Decommissioning Guidance Notes (November 2018);
- The UK Guidelines for Suspension and Abandonment of Wells (2015);
- The Pipeline Safety Regulations 1996 requiring the safe decommissioning of pipelines; and
- Any other agreements with OPRED and relevant regulatory bodies.

2.9.1 Subsea infrastructure

In line with current guidelines and legislation the decommissioning of the production pipeline and EHC umbilical would be subject to a Comparative Assessment and Decommissioning Programme. It is expected that the pipeline and connecting spools will be cleaned, that accessible infrastructure on the seabed will be removed and recovered to shore for preferential reuse, then recycling, and finally disposal in accordance with the waste hierarchy, and that a seabed clearance campaign would be conducted. However, this would be subject to future legislative requirements and guidance.

2.9.2 Well

All well decommissioning programmes will be subject to a well notification assessed by the Health and Safety Executive (HSE) under the Offshore Installations (Offshore Safety Directive) (Safety Case etc). Wells will be plugged and permanently abandoned in accordance with the Oil and Gas UK (OGUK) Guidelines for the Abandonment of wells (OGUK, 2015) (or applicable guidance at that time). All well programmes will have been reviewed by the HSE Offshore Safety Department as required under the Design and Construction Regulations.

On completion of the well abandonment programme each conductor and internal tubing will thereafter be cut 3 m below the seabed. The subsea wellheads will then be recovered.

Nearer the time of CoP, a full decommissioning plan will be developed in consultation with the relevant statutory authorities. The plan will be designed to ensure that potential effects on the environment resulting from the decommissioning of the facilities are considered and minimised.

2.10 Summary of Principal Planned Activities and Aspects

General use of vessels (including the JUDR)

- Use of specialist vessels for the installation of subsea infrastructure, well completion, and surveying;
- Use of guard vessels to protect third parties from the snagging risk associated with the exposed production pipeline and EHC umbilical prior to their trenching and burial; and
- Use of support vessels (ERRV, supply etc.).

Positioning of vessels

- Use of dynamic positioning systems; deployment of the JUDR.

Well completion

- Pegasus West well re-entry (chemical use and discharge, hydrocarbon discharge); and
- Well clean-up and testing (chemical discharge and flaring).

Subsea infrastructure installation

- Laying, trenching and burial of the production pipeline and EHC umbilical;
- Installation of the Xmas tree and WPS at the Pegasus West well;
- Installation of pipeline tie-in spools, and the SSIV at Cygnus;
- Construction of production pipeline and EHC umbilical crossings; and
- Deployment of subsea infrastructure protection and stabilisation features.

Subsea infrastructure commissioning

- Testing and commissioning of the production pipeline (chemical use and discharge).

Production of hydrocarbons

- Energy use, chemical use and discharges, and hydrocarbon discharges and releases associated with production from the Pegasus West well.

3. ENVIRONMENTAL BASELINE

3.1 Introduction

This section describes the current nature and status of the environment in the vicinity of the proposed Pegasus West Development. An understanding of the baseline environment is required in order to identify project interactions with the environment, and to provide a basis for assessing the environmental impacts of the development.

This section has been prepared with reference to available literature and site-specific survey data. Table 3-1 summarises the most recent environmental surveys that have been completed in the vicinity, while Figure 3-1 shows the spatial extent and coverage of each survey. A combination of seabed samples and seabed imagery were acquired during these survey campaigns to determine the physio-chemical status of the seabed, as well as the typical biological communities in the region. The presence of potentially sensitive species and habitats was also ascertained.

SURVEY	DATE OF SURVEY	REPORT NAME/SUMMARY	REPORT REFERENCE
Pegasus Pipeline Route Survey - Blocks 43/13b, 43/4, 43/15, 44/11, and 44/12	April and May 2018	**Environmental Baseline Survey (EBS) Report.** Geophysical and environmental survey utilising side scan sonar (SSS), single beam echo sounder (SBES) and multi-beam echo sounder (MBES), magnetometer, cone penetrometer testing and vibrocorer. 21 stations were physically sampled using 0.1m^2 grabs for physico-chemical and macrofaunal analysis. All stations were investigated with a digital still camera system, and 14 camera transects were used to investigate possible sensitive habitats and magnetic anomaly.	Gardline, 2018a
		Habitat Assessment and Herring Spawning Ground Survey Report. Interpretation of survey data to identify and delineate potential sensitive habitats, if present, including potential herring and sandeel spawning grounds.	Gardline, 2018b
		Pipeline Route Survey (Geophysical survey). The main objective of the survey was to acquire bathymetry, seabed, sub-bottom, geotechnical and environmental data to determine the water depths, seabed obstructions and seabed/sub-seabed lithology along the proposed pipeline route.	Gardline, 2018c
		Pegasus Pipeline Route Survey – Marine mammal observer report. A total of 118 hours and 45 minutes of dedicated marine animal monitoring was carried out by the mitigation personnel on 15 days between 23-Apr-2018 and 15-May-2018. This includes a total of 46 hours and 2 minutes of visual pre-shoot monitoring undertaken over 77 pre-shooting searches, resulting in an average pre-shooting search duration of 36 minutes.	Gardline, 2018d
Pegasus West Rig Site Survey - Block 43/13b	November 2011; January – February 2012	**Environmental Baseline Report.** Geophysical and environmental survey utilising SSS, SBES and MBES, two sub-bottom profilers (a pinger and a mini sleeve gun) and a magnetometer. Nine stations were physically sampled using a 0.1 m^2 Hamon grab for physico-chemical and macrofaunal analysis. All stations were investigated with a camera system, and 3 camera transects were used to investigate seabed features. The survey covered a 3.4 km x 2.0 km area encompassing the Pegasus West well location.	Fugro, 2012

SURVEY	DATE OF SURVEY	REPORT NAME/SUMMARY	REPORT REFERENCE
Pegasus Site Survey - Block 43/13b	June 2010	**Environmental Baseline Report.** Geophysical and habitat assessment site survey utilising SSS, SBES and MBES, pinger, boomer, vibrocorer, cone penetrometer testing, environmental grab and camera system, and high resolution seismic equipment. The survey covered a 2 km x 2 km area around the Pegasus West well location.	Gardline, 2010

Table 3-1 Environmental surveys undertaken in the project area

3.2 Physical Environment

The type and distribution of marine life is influenced by the physical conditions of the surrounding environment, biological interactions and anthropogenic activities. These physical factors, which include, currents and tides, wave, temperature, salinity and wind also help set the design parameters for offshore facilities and influence the fate and behaviour of any emissions and discharges from an installation and the impacts associated with them.

3.2.1 Hydrology

3.2.1.1 Bathymetry

Water depths throughout the SNS are shallow when compared to the whole North Sea region, with water depths generally increasing in a northerly direction. The bathymetry of the proposed Pegasus West Development project area is largely defined by the Dogger Bank, a geological formation up to 42 m thick that was deposited at a glacial margin during the last glacial maximum (Cameron *et al.,* 1992). This bank is significantly shallower than the surrounding seabed. The southern part of the bank lies in water less than 20 m deep, gradually extending into deeper water with the greatest slope change around the 45-50 m depth contour (JNCC, 2011).

Water depths along the proposed pipeline route range between 17.2 m lowest astronomical tide (LAT) at approximately KP48.6 to 36.2 m LAT at KP7.5 (Gardline, 2018a).

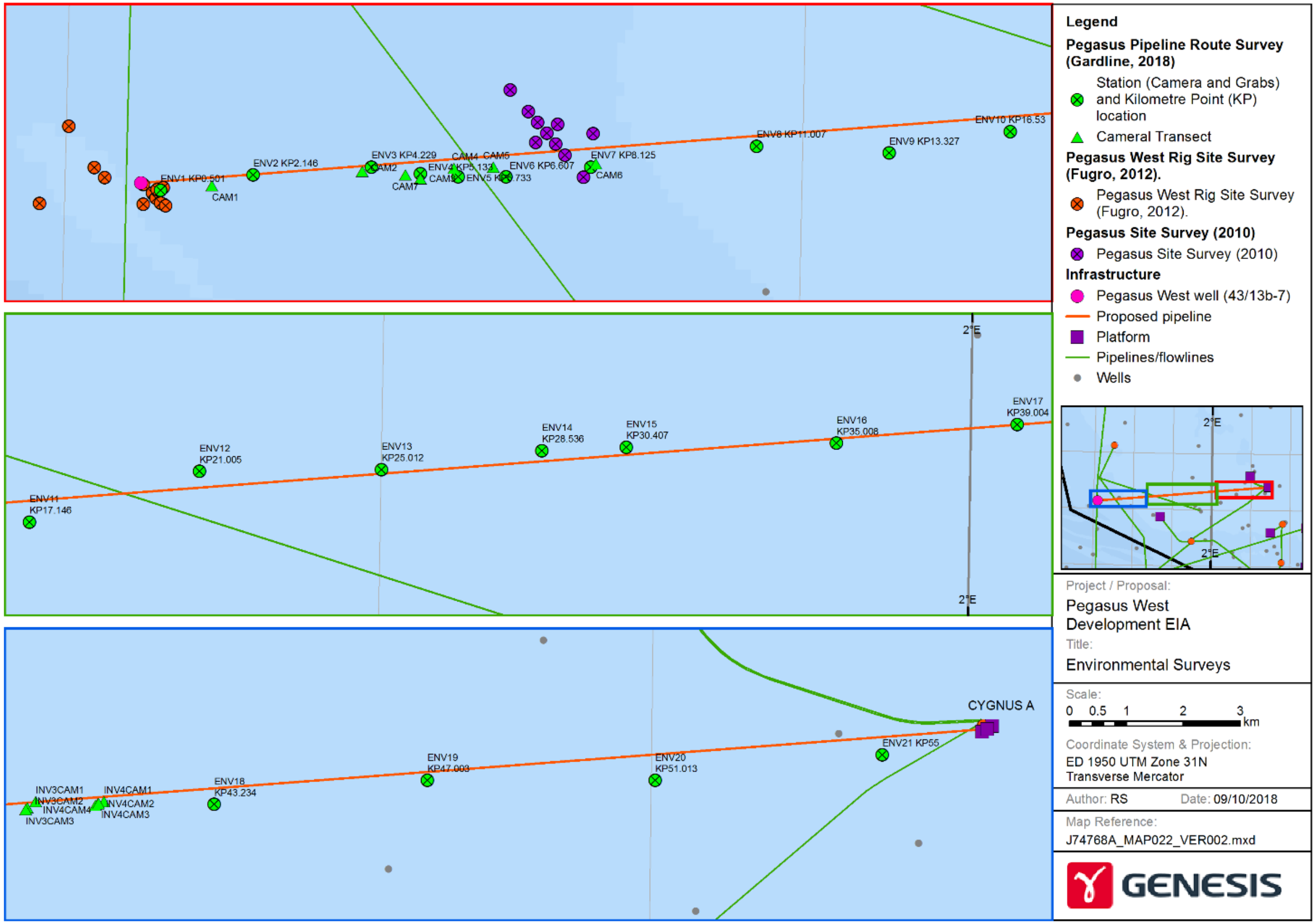


Figure 3-1 Environmental surveys undertaken in the project area

From the Pegasus West well (approximately KP0.0) at 27.8 m LAT to approximately KP7.5, the seabed is characterised by the presence of a number of broad erosional features or furrows locally up to 7 m deep, leading to a route maximum water depth of 36.2 m LAT being observed at KP7.574. These undulations are regional scale features and seabed gradients are low, typically less than 2° (Gardline, 2018c).

From KP7.5, the seabed gently shoals on to the Dogger Bank into water less than 20 m deep where the seabed is generally smooth and featureless except for occasional furrows that occur between KP13.7 and KP51. Where these are present, gradients can be locally in excess of 20°, such as that at KP50.8 (Gardline, 2018c). The pipeline route ends at Cygnus at approximately 22.6 m LAT (GDF SUEZ, 2011).

Bathymetry profile along the proposed pipeline route is illustrated in Figure 3-2.

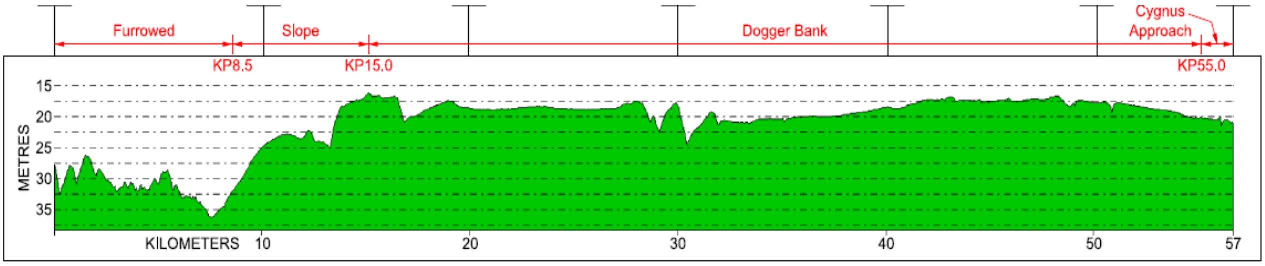


Figure 3-2 Bathymetry of the proposed pipeline route (Gardline, 2018c)

3.2.1.2 Water masses, currents and tides

The North Sea has a predominantly tidal current regime, supplemented periodically by storm surge currents. Tidal current velocities tend to decrease with depth and distance from the UK coastline. There is also a weak residual current, caused by a water mass moving south along the English coastline and then east towards the project area, which contributes a small eastward drift (Figure 3-3). The tides are semi-diurnal with tidal streams running east-south-east and west-north-west. Generally, in the SNS, storm surge currents tend to move in a southerly direction parallel to the English Coast and can exceed the speeds associated with tides.

Currents are influenced by the presence of the Dogger Bank, which alters the properties of the tidal currents moving over and around it. Tidal current velocities tend to be stronger to the west and south-west of the Bank, reduced over the shallower top. Eddies are also likely to be formed, adding to the reduction of current velocity and increasing sedimentation over the bank (Kroncke and Knust, 1995). Wave motion is the most erosive force acting on seabed sediments (see Section 3.2.1.3) as past research has shown that tidal currents on the Dogger Bank are generally insufficient to transport sediments (von Haugwitz *et al*. 1988).

The peak current speed of a mean spring tide is 0.52 ms^{-1} at Pegasus West, and tidal current speeds gradually reduce along the pipeline route from west to east, with a peak mean spring tidal current speed of 0.37 ms^{-1} at Cygnus. Similarly, tidal range decreases along the pipeline route, with the mean spring tidal range reducing from 2.61 m at PW to 1.87m at Cygnus (ABPmer, 2008). Extreme current speeds, driven by storm systems, are greatest in winter months, reaching 1.25 ms^{-1} near the surface and 0.81 ms^{-1} near the seabed (1-year return period) at Cygnus (Fugro, 2008).

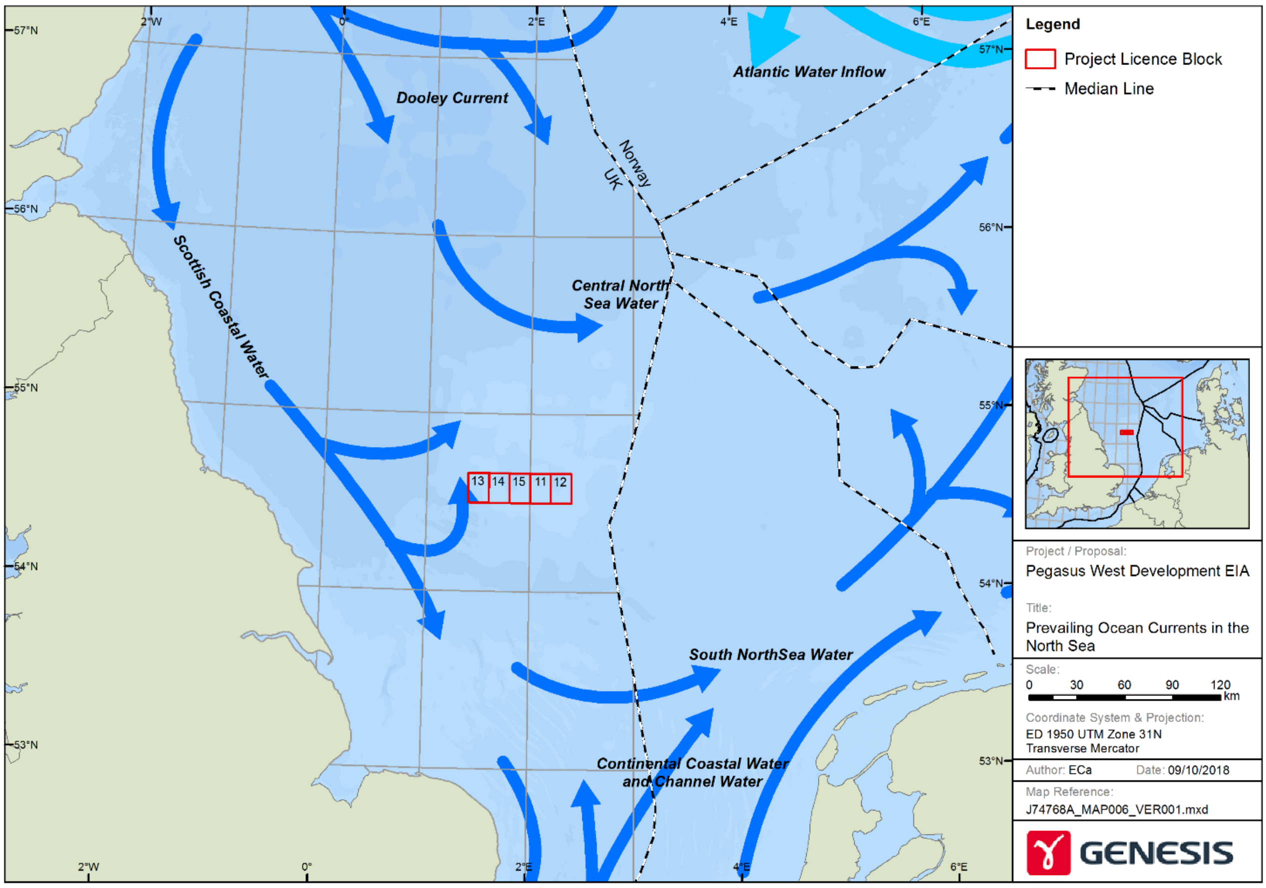
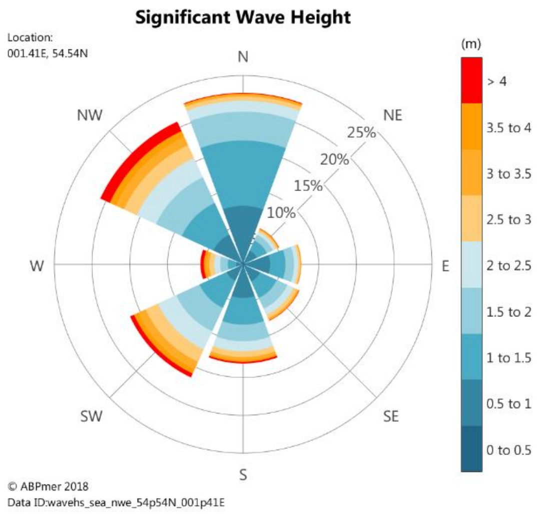


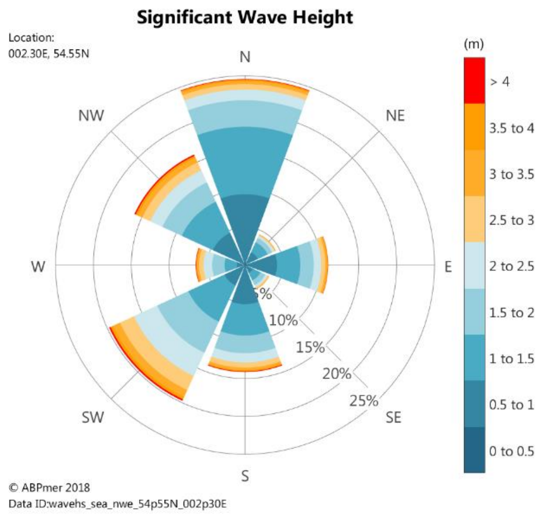
Figure 3-3 Schematic of ocean circulation in the North Sea (Turrell *et al.*, 1992)

3.2.1.3 Waves

Waves are the result of wind action on the sea surface and wave size is dependent on the distance of water, or fetch, over which the wind blows. Waves tend to be smaller, on average, in the SNS than the northern North Sea (NNS) or west of Shetland. The annual mean significant wave height ranges between 1.75 m at Pegasus West, increasing slightly to 1.80 m at Cygnus (Scottish Government NMPi). In the proposed project area, waves propagate most frequently from the north, but larger waves are more frequent from the north-west and south-west (Figure 3-4) (Data Explorer, 2018).



(A)



(B)

Figure 3-4 Operational significant wave height at Pegasus West (A) and Cygnus (B) (Data Explorer, 2018)

Large parts of the Dogger Bank are above the storm-wave base, meaning that wave action can cause sediment erosion, suspension and resettlement. Its exposed location in open waters means it is subjected to substantial wave energy, which prevents the colonisation of the sand by vegetation on the top of the bank. Klein *et al*. (1999) estimated that during a storm event, sediment up to the size of medium sand was mobilised in 60 m water depth at the northern slope of the Dogger Bank (JNCC, 2011). This suggests that sediment transport due to wave action is greater in shallower areas of the pipeline route.

3.2.1.4 Temperature and salinity

The temperature of the sea affects both the properties of the seawater and the fates of discharges and releases (spills) to the environment. Seawater temperatures vary with season, depth and proximity to land. Temperatures at the seabed and surface are fairly constant ranging between 9°C and 10°C, respectively (Scottish Government NMPi). In winter, the waters in the northern parts of the SNS are some of the coldest areas of the UK (Jones *et al*. 2004); however, sea-surface temperatures increase southwards (from 5 to 7ºC) in February. This is a result of a wedge of relatively warm water extending up from the English Channel which prevents water temperatures dropping below 5ºC (BEIS, 2016).

Fluctuations in salinity are largely caused by the addition or removal of freshwater to or from seawater through natural processes such as rainfall and evaporation. The SNS receives significant freshwater input from the rivers along its eastern boundary and is, as a consequence, less saline than the NNS. Saline water of North Atlantic origin enters the SNS via the Dover Straits, and this tends to lead to generally more salty water in the most southerly parts of the North Sea (BEIS, 2016).

Salinity increases with water depth and distance from shore. Salinity of seawater around an installation has a direct influence on the initial dilution of aqueous effluents such that the solubility of effluents increases as the salinity decreases. Salinity in the area of the blocks show little variation with season and water depth. The annual mean salinity throughout the water column is approximately 34.7 ‰ (Scottish Government NMPi).

3.2.1.5 Water quality

Regional inputs from coastal discharges and localised inputs from existing oil and gas developments may affect water quality in different areas of the SNS. Fundamentally, water samples with the highest levels of contaminants are found at inshore sites prone to high levels of industrial usage. High hydrocarbon concentrations in offshore locations are normally in the immediate vicinity of installations, originating primarily from the discharge of produced water and contaminated drill cuttings.

Hydrocarbon inputs from drill cuttings has been essentially eliminated due to Low Toxicity Oil Based Mud (LTOBM) no longer being discharged directly to sea; implemented by the OSPAR Convention 2000/3. However, there is a legacy of contamination which remains in the form of historic cuttings piles around some installations, which can release hydrocarbons if disturbed by subsea works or trawling (OSPAR Commission, 2010). Concentrations of contaminants generally fall to background levels within a very short distance of the point of discharge (Cefas, 2001).

Polycyclic Aromatic Hydrocarbons (PAHs) generally adsorb to particulate matter / suspended solids as they have low water solubility and are hydrophobic. Background water concentrations of PAHs are therefore often below the limit of detection. Similarly, due to their low solubility, Polychlorinated Biphenyl (PCB) concentrations in water are usually extremely low (<1 ng/l) and difficult to detect.

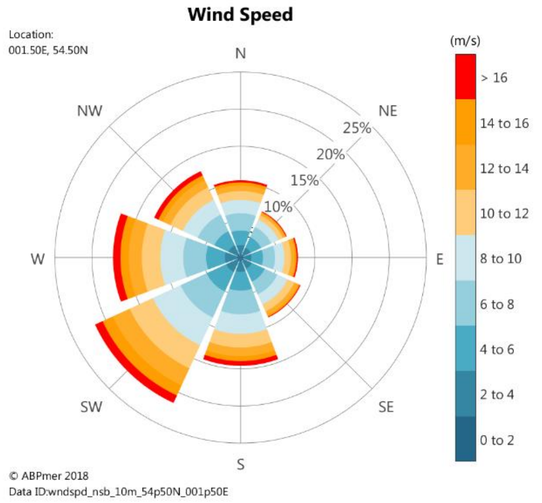
There is limited data on the levels of contaminants in north-east Atlantic waters (OSPAR, 2000). However, water quality around the proposed Pegasus West Development is predicted to be good with contaminants being close to background levels due to the distance from anthropogenic inputs and prevailing ocean current systems which disperse and dilute pollutants.

3.2.2 Meteorology

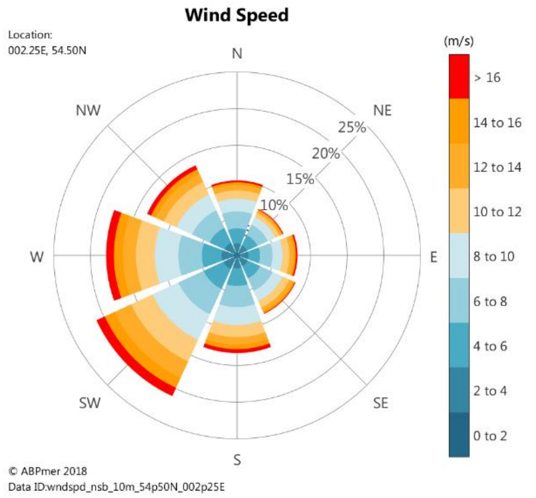
Wind direction and speed directly influence the transport and dispersion of atmospheric emissions from an installation. These factors are also important for the dispersion of marine discharges, including oil spills, influencing the movement, direction and break up of substances on the sea surface.

Average wind speeds between 1984 – 2014 were between 10.26 and 10.50 m/s in the region of the proposed Pegasus West Development (BEIS, 2016).

Site specific wind roses show the occurrence of winds from all directions, although winds from the south-west and west dominate in the vicinity of Pegasus and Cygnus (Figure 3-5). (Data Explorer, 2018).



(A)



(B)

Figure 3-5 Wind speed rose and directional distribution at Pegasus West (A) and Cygnus (B) (Data Explorer, 2018)

Air temperatures offshore are generally at their lowest in January and February (mean 4°C to 6°C) and highest in July and August (up to 16°C) (BEIS, 2016). The highest air temperatures in the Cygnus area are during summer months, with a mean peak of 15.9°C in August (Fugro, 2008).

3.2.3 The seabed

3.2.3.1 Seabed sediments

The characteristics of the local sediments and the amount of sediment transport within a project area are important factors in determining the potential effects of possible developments (drill cuttings, installation of pipelines, anchor scouring) on the local seabed environment.

Seabed sediments comprising mineral and organic particles occur commonly in the form of mud, sand or gravel and are dispersed by processes driven by wind, tides and density driven currents. The distribution of seabed sediments within the SNS is determined by a combination of hydrographic conditions, bathymetry and sediment supply.

The sediments on the surface of the Dogger Bank mainly consist of fine sands with mud content below 5%. In terms of Folk's (1954) classification, they can be described as sand, slightly gravelly sand, gravelly sand, slightly gravelly muddy sand and muddy sand. Mud content slightly increases towards deeper water (Diesing *et al*., 2009). Coarser gravelly sand and sandy gravel substrates together with isolated patches of larger pebble and cobble-sized particles have been recorded in southern and western sections of the bank (JNCC, 2011 and references therein).

The seabed broad scale sediment distribution in the Pegasus West Development area and the wider region is illustrated in Figure 3-6. Shallow sublittoral sands cover most of the project area, with areas of coarser sediments also evident (EMODnet, 2018).

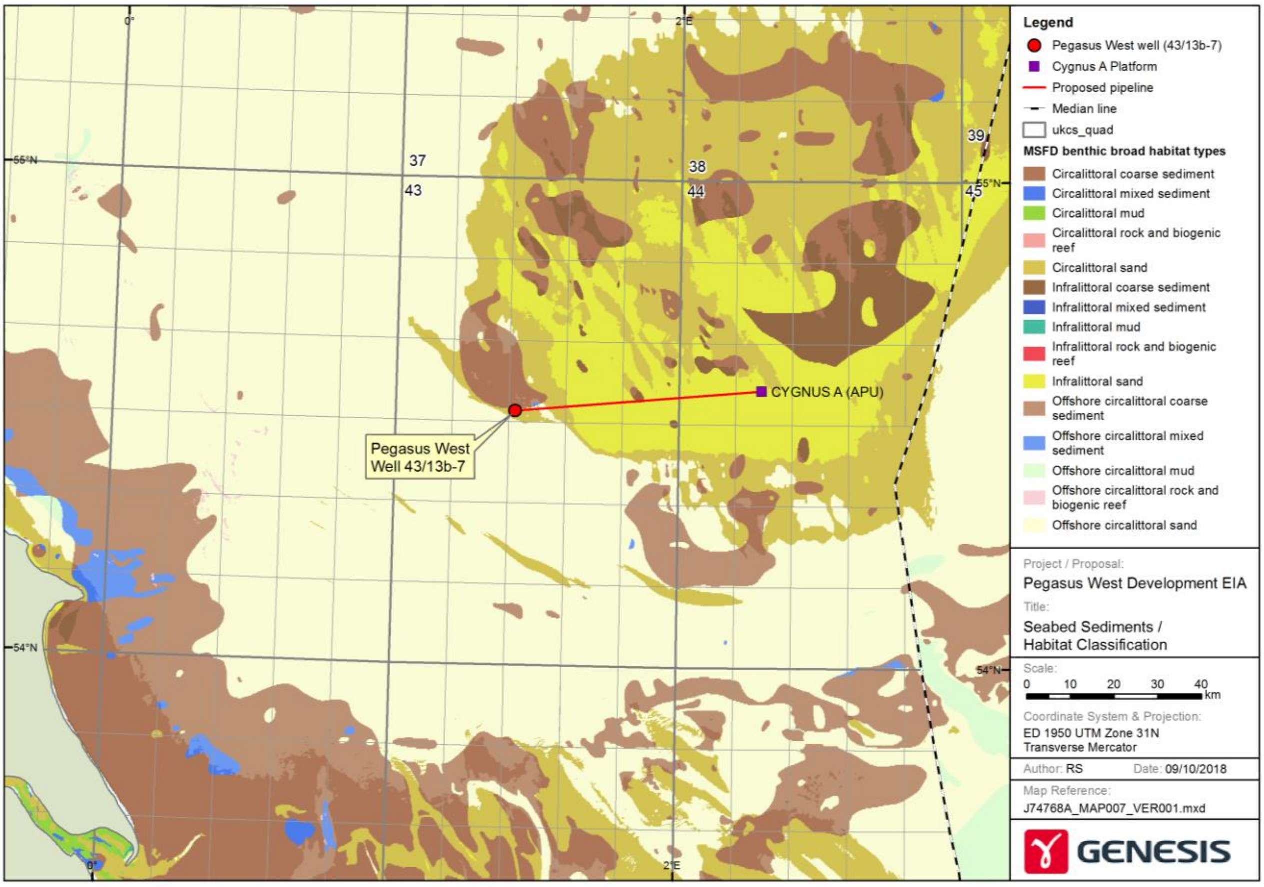


Figure 3-6 Sediment distribution (Marine Strategy Framework Directive (MSFD) predominant habitat classification) (EMODnet, 2018). Note KP0.0 is at Pegasus West, KP56.7 is at Cygnus

Seabed sediments in the Pegasus West well location comprise gravelly sand, with areas of sand and sandy gravel (Gardline 2010; Fugro, 2012). The seabed along the pipeline route is predominantly sand and shell fragments with areas of coarser sediment (Gardline, 2018a). These areas of coarser sediment comprise sandy gravel with shell fragments and cobbles/pebbles, occurring intermittently along the route but concentrated at the Pegasus West end where there are a series of furrows, and around KP15 and KP30 (Figure 3-7). The proportions of fine material (<63µm; silt and clay) were generally low at all stations (≤6.4%), with the exception of Station ENV4 which recorded a percentage fines content of 47.7% (Gardline, 2018a).

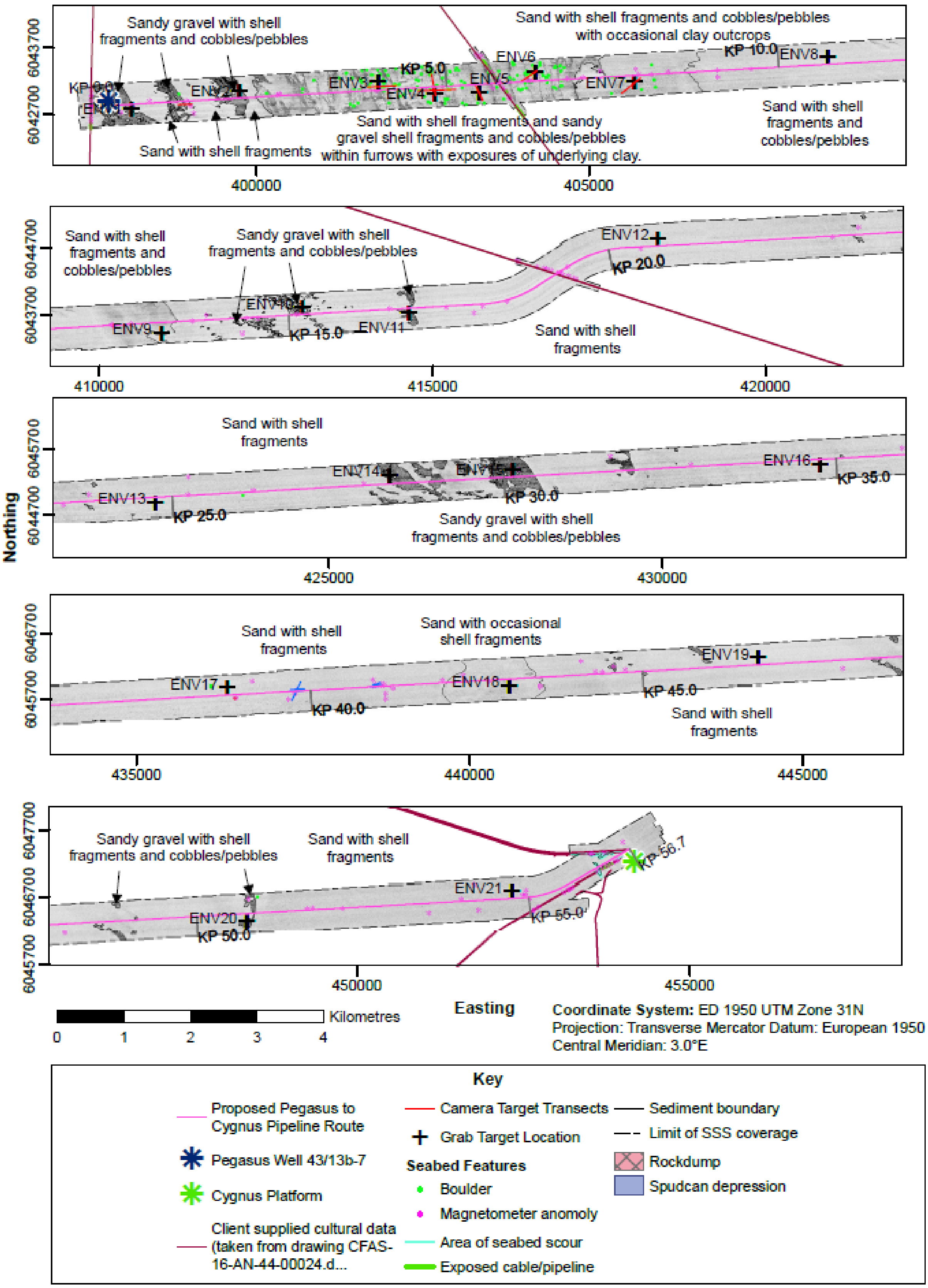


Figure 3-7 Seabed features and sediments on the proposed pipeline route (Gardline, 2018a)

3.2.3.2 Seabed features and shallow geology

Sand ripples and megaripples were recorded throughout the proposed pipeline route with occasional trawling scars indicative of fishing activities. The western part of the pipeline route from KP0 to KP7.830 has a concentration of sandbanks, furrows, sand ridges and megaripple features. There is also a concentration of boulders between approximately KP3 and KP7 (Gardline, 2018a) (Figure 3-7).

Seabed sediments in the SNS are mostly relict, with the distribution of gravelly sediments reflecting glacial, fluvial and coastal processes which have now ceased (Cameron *et al.* 1992). Surface deposits of loose, becoming dense sand, with shell fragments and gravel identified as the Holocene formation covers the majority of the proposed pipeline route with the exception of approximately KP3.0 to KP8.5, where only a veneer of Holocene sediments remains (Gardline, 2018c). The surface Holocene deposit also includes occasional gravel layers.

The Bolders Bank clay formation underlies the Holocene surface deposits on the western end of the pipeline route, as far east as approximately KP12.5. Outcrops of this clay layer are present at the seabed surface in furrowed areas from approximately KP4.6 to KP8.6 (Gardline, 2018c).

3.2.3.3 Seabed chemistry

Deep-water marine environments generally show relatively low levels of contamination compared to coastal waters and industrialised estuaries.

Exposure of marine organisms to contaminants can occur either through uptake of dissolved fractions across the gills or skin or direct digestion of the pollutant. Organisms spending the majority of their lifecycle in the water column are likely to receive the highest exposure to contaminants that remain in solution, though some will also accumulate sediment bound contaminants indirectly through their diet (i.e. digestion of animals that have accumulated the contaminants in their tissues). Organisms associated with the seabed (benthic organisms) are more exposed to particle bound contaminants with the main exposure route being either directly through ingestion of contaminated sediments or through their diet. Benthic organisms can also absorb contaminants through the surface membranes as a result of contact with interstitial water.

Elevated levels of contaminants can affect organisms (flora and fauna) in a variety of ways, ranging from cellular effects in individuals to ecosystem effects resulting from changes in population sizes or even the loss of an entire species (UK Marine SACs Project, 2001).

Heavy metals

Several metals are found in high concentrations in drilling muds and produced water, and therefore elevated concentrations can be associated with oil and gas activities. Those metals most characteristic of contamination of the sediment with drilling muds or cuttings are barium, chromium, lead and zinc (Neff, 2005).

UKOOA (2001) recorded a concentration of various contaminants in sediments more than 5km from installations south of latitude 55°N in the SNS. A threshold was set at the concentration where 95% the stations were below the threshold (and 5% above) for each contaminant (the 95^{th} percentile). For barium, mean concentrations in the SNS are typically in the region of 218µg/g with 95% of stations investigated having concentrations ≤303µg/g (UKOOA, 2001). Several locations on the proposed pipeline route had barium concentrations above the UKOOA SNS mean, and six locations (Stations ENV1, ENV2, ENV4, ENV5, ENV11 and ENV15) also exceeded the 95th percentile threshold (Gardline 2018a). Barium is a major constituent of drilling mud; hence sediment barium concentrations may be elevated in an area which has previously been subject to drilling discharges. Elevated barium concentrations at stations ENV1 and ENV2 may be explained by their proximity to the Pegasus West well. Station ENV5 is approximately 1.7km from an exploration well (43/13b-6z) drilled in 2010.

Metal concentrations were also compared to OSPAR (2005) Background Concentration (BC) values which represent the concentrations of certain hazardous substances that would be expected in the North-east Atlantic if certain industrial developments had not happened. Values were also compared to OSPAR ‘Background Assessment Criteria’ (BACs), a set of statistical tools that enable testing of whether mean observed concentrations (i.e. collected during a seabed survey) can be considered to be near background concentrations. Where these are not available, sediment sample concentrations were compared to OSPAR (1997) Background Reference Concentrations (BRC).

Concentrations of cadmium were above the BC value at all stations and arsenic and copper concentrations were above their BC values at the majority of stations, with the mean concentration also above their respective BAC thresholds. Normalised concentrations of chromium, nickel, lead and zinc also exceeded their respective BC values at a number of stations. Finally, vanadium was found to be above the BRC at several stations across the EBS area (Gardline 2018a) (Table 3-2).

Therefore, the sediment concentrations of most metals analysed for the EBS are above what would be expected in areas where certain activities, such as oil and gas exploration, are absent (Gardline, 2018a). However, OSPAR (2015) acknowledge that the current BACs may be inappropriate for application throughout the North-east Atlantic, and as such, comparison with OSPAR (2005) BC and BAC values for the predominantly sand and sandy gravelly sediments across the EBS area should be treated with some caution (Gardline, 2018a).

Despite elevated concentrations of some heavy metals, most were below their respective Apparent Effects Threshold (AET) concentrations. AET represents the concentration above which biological impacts might expected (Buchman, 2008). AETs were exceeded, however, for vanadium at Stations ENV1, ENV2, ENV4, ENV6, ENV12 and ENV15; and tin Station ENV19 (Gardline 2018a). Higher concentrations at stations ENV1 and ENV2 may be attributed to previous Pegasus West well drilling discharges.

Overall, concentrations of all metals analysed were comparable to the range recorded from other surveys in the area, suggesting they are typical for heterogeneous sand and sandy gravel sediments in the region. The concentration of metals in samples was positively correlated with the proportion of gravel in seabed sediments (Gardline, 2018a).

Station	Designation[1]	Aluminium	Arsenic	Barium	Cadmium	Chromium	Copper	Iron	Mercury[2]	Nickel	Lead	Tin	Vanadium	Zinc
ENV1	76m S KP0.255	32700	30.4	307	0.7	37.4	16.6	29200	0.01	29.6	14.4	2.3	69.5	57.8
ENV2	103m N KP1.893	32100	29.4	310	0.7	52.5	12.7	34500	<0.01	30.5	10.9	1.5	77.8	49.6
ENV3	122m N KP3.975	12300	4.7	233	0.3	12.8	5.5	6740	<0.01	4.4	6.3	<0.5	24.2	18.0
ENV4	101m S KP4.823	30400	8.4	307	0.5	39.7	13.5	18500	0.01	22.0	10.4	0.9	62.7	36.0
ENV5	135m S KP5.487	27200	12.6	524	0.5	37.8	15.1	17700	<0.01	21.8	11.8	2.0	45.8	43.3
ENV6	141m N KP6.349	17700	19.7	196	0.4	27.5	8.5	20300	<0.01	14.0	8.6	0.5	58.8	33.4
ENV7	101m S KP7.830	21300	13.8	267	0.4	24.4	8.1	21200	0.01	13.1	7.8	0.5	51.6	31.1
ENV8	99m N KP10.753	11900	3.6	152	0.3	19.2	6.3	8180	<0.01	4.1	5.5	<0.5	28.3	16.2
ENV9	153m S KP13.079	12100	4	164	0.2	9.0	5.3	6170	<0.01	3.6	4.7	<0.5	19.1	15.1
ENV10	100m N KP15.219	17000	9.7	184	0.3	13.8	9.5	12000	<0.01	7.1	5.5	<0.5	32.3	23.1
ENV11	73m S KP16.806	33400	18.6	306	0.6	24.8	10.3	21000	<0.01	15.0	8.6	0.8	51.9	31.3
ENV12	107m N KP20.753	12700	4.1	151	0.7	33.5	5.9	24900	<0.01	5.3	10	0.6	62.0	20.1
ENV13	80m S KP24.743	13300	3.6	166	0.7	24.6	4.9	15000	<0.01	5.0	6.0	<0.5	38.9	18.7
ENV14	130m N KP28.285	14900	9.6	158	0.5	22.2	7.2	16300	0.01	11.1	5.7	<0.5	39.9	24.9
ENV15	102m N KP30.141	35300	15.2	320	0.6	30.0	8.8	23200	<0.01	16.0	8.9	1.7	58.2	32.9
ENV16	74m S KP34.758	13100	3.1	178	0.6	19.3	7.4	11200	<0.01	3.6	6.2	<0.5	30.5	17.5
ENV17	110m N KP38.751	13200	2.8	178	0.3	15.8	5.0	8490	<0.01	3.8	5.6	<0.5	25.4	15.9
ENV18	99m S KP42.985	13000	6.7	155	0.3	11.2	6.2	8280	0.01	5.0	4.6	0.7	24.1	18.8
ENV19	107m N KP46.749	12600	4.6	221	0.4	17.5	44.5	11500	0.01	4.9	23.8	4.5	26.1	103.1
ENV20	122m S KP50.746	23600	19.1	246	0.3	13.1	16.8	14100	0.01	7.8	13.2	2.3	28.9	57.2
ENV21	100m N KP54.751	13000	3.6	203	<0.2	12.6	3.8	8170	0.01	3.0	6.2	0.5	22.2	13.9
This Study	Minimum	11900	2.8	151	<0.2	9.0	3.8	6170	<0.01	3.0	4.6	0.5	19.1	13.9
	Maximum	35300	30.4	524	0.7	52.5	44.5	34500	0.01	30.5	23.8	4.5	77.8	103.1
	Mean	19657	10.8	235	NC	23.7	10.6	16030	NC	11.0	9.0	NC	41.8	32.3
	±SD	8561	8.49	90	NC	11.4	8.7	7785	NC	8.7	4.5	NC	17.7	21.2

Concentrations expressed as $\mu g\ g^{-1}$ dry weight sediment.
Unless specified, concentrations determined following HF sediment digestion.
Cells in grey highlight where concentrations were below the LOD.
1 Station designation is the distance and direction from the proposed Pegasus pipeline.
2 Concentrations determined following nitric acid digest preceded by digestion of organic matter with hydrogen peroxide.
3 Buchman (2008) Apparent effects threshold (AET) correspond to the highest concentration at which no toxic effects were observed on the tested fauna: B – bivalve, N – *Neanthes*, M – microtox, O – oyster, I – infauna community, E – echinoderm larvae, L – larval bioassay.
NC Not calculated due to one or more values below the LOD.
NR Not reported.
Result in blue are from comparable surveys, see Section 1.3
Cells highlighted in red correspond to mean survey concentrations above the upper limit of the OSPAR (2005) BAC after normalisation to 5% Al.
Cells highlighted in blue correspond to concentrations above the OSPAR (2005) BC after normalisation to 5% Al
Cells highlighted in purple correspond to concentrations above the Background Reference Concentration – OSPAR (1997) after normalisation to 5% Al.

Table 3-2 Sediment metal concentrations (Gardline, 2018a; Buchman, 2008)

Hydrocarbons

Hydrocarbons have the potential to accumulate in the tissues of marine organisms, and to concentrate in the tissues of predators at the top of the marine food chain. For every link in the food chain, approximately 10% of the matter consumed is converted into the tissues of the consumer. If a contaminant passes from one level to another without being broken down, its concentration in the living matter multiplies nearly ten times at each link in the chain, a process termed bioaccumulation. Organisms at the top of the food chain can therefore be exposed to detrimentally high concentrations of a product which will not affect the organisms further down the chain. Many of the components of oil and petroleum products are biodegradable but some higher molecular weight molecules such as Polycyclic Aromatic Hydrocarbons (PAHs) tend to have significant bioaccumulation potential. The primary risk from these PAHs is that some are carcinogenic at higher concentrations with the impacts including acute toxicity, liver neoplasm and other abnormalities.

It has previously been shown that a Total Hydrocarbon Concentration (THC) of 50 mg per 1 kg of sediment (50 mg/kg or 50 µg/g) is the threshold above which hydrocarbons are expected to have toxic effects on benthic macrofaunal (UKOOA 1999; OSPAR, 2006).

A summary of the results of the hydrocarbon analysis from the EBS (Gardline 2018a) is presented in Table 3-3, compared to the SNS THC mean of 4.34 µg/g (UKOOA, 2001) and the typical range of THC and PAH sediment concentrations surrounding oil and gas infrastructure (Sheahan *et al*., 2001).

STATION	LOCATION	THC[1,2,3,4] (µg/g)	PAH[3] (µg/g)
ENV1 (Pegasus West end)	76m S KP0.501	1.1	0.001
ENV2	103m N KP2.146	1.8	NC
ENV3	123m N KP4.229	2.1	0.001
ENV4	47m SSE KP5.133	3.2	0.518
ENV5	135m S KP5.733	1.2	0.008
ENV6	141m N KP6.607	2.2	0.089
ENV7	100m S KP8.125	12.2	0.395
ENV8	99m N KP11.007	2.3	0.001
ENV9	152m S KP13.327	1.5	0.003
ENV10	100m N KP15.53	0.8	NC
ENV11	72m S KP17.146	0.8	NC
ENV12	108m N KP21.005	2.9	NC
ENV13	79m S KP25.012	2.6	NC
ENV14	130m N KP28.536	0.7	NC
ENV15	102m N KP30.407	0.7	0.011
ENV16	74m S KP35.008	3.4	0.004
ENV17	111m N KP39.004	4.8	0.002
ENCV18	98m S KP43.234	1.8	NC
ENV19	108m N KP47.003	3.5	0.002
ENV20	122m S KP51.013	1.0	NC
ENV21 (Cygnus end)	101m N KP55	4.4	0.011
	Minimum	0.7	NC
	Maximum	12.2	0.395
	Mean	2.6	NC

[1]Cells highlighted in green correspond to concentrations below the SNS 4.34 µg/g mean (UKOOA, 2001)

[2]Cells highlighted in yellow correspond to concentrations above the SNS 4.34 µg/g mean (UKOOA, 2001)

[3]Cells highlighted in orange correspond to concentrations within range expected around oil and gas infrastructure (Sheahan *et al*., 2001). THC 10 – 450 µg/g; PAH 0.02 – 74.7 µg/g

[4]Cells highlighted in red correspond to concentrations above 50 µg/g toxic effects threshold.

NC = Not Calculated – one or more values below Limit of Detection

Table 3-3 Summary of sediment hydrocarbon concentrations

The mean THC concentration recorded along the pipeline route is below the SNS mean. Stations ENV7, ENV17 and ENV21 featured relatively high THC concentrations. Station ENV7 had a THC concentration of 12.2 µg/g which is within the range normally observed at oil and gas installations (Sheahan *et al*., 2001). Station ENV7 is situated approximately 1 km south-east of the historical 43/13b-6 well location and it is possible the comparatively elevated THC was derived from diffuse petrogenic contamination associated with historical activity around this well. No hydrocarbon concentrations sufficiently high to have toxic effects were recorded in the development area.

3.2.3.4 Seabed habitats

Seabed habitats in the vicinity of the proposed Pegasus West Development have been classified using the European Union Nature Information System (EUNIS) habitat classification system. The EUNIS classification is hierarchical, differentiating at Level 1 between marine and terrestrial habitats, then at Level 2 between broad marine habitats. These are separated by rock and sediment habitats, and between those habitats on the shore (intertidal) and those in the subtidal or offshore (deep) area. These high-level divisions can be further subdivided to Level 3 and 4 on the basis of different types of sediment (e.g. gravel, mud), different degrees of wave exposure on rocky coasts (exposed, sheltered) and varying depth bands below the low water mark (e.g. shallow water where light penetrates, deeper water with little light). These habitats are, therefore, defined according to environmental characteristics which in turn determine, to a significant extent, their characteristic biological communities. A more detailed classification down to EUNIS Level 5, which includes biological communities, is included in Section 3.3.2.

The habitats identified by the EBS, down to level 4 of the EUNIS hierarchy, are listed in Table 3-4 (Gardline, 2018a, 2018b). Figure 3-8 and Figure 3-9 illustrate the habitats observed by the pipeline route survey. These habitats are mapped across the wider region at Level 4 of the EUNIS classification hierarchy in Figure 3-6, which shows that they cover large areas of the SNS.

<table>
<tr><th>LEVEL</th><th colspan="4">EUNIS HABITATS</th></tr>
<tr><td>1. Environment</td><td colspan="4">Marine (A)</td></tr>
<tr><td>2. Broad Habitats</td><td colspan="4">Sublittoral Sediment (A5)</td></tr>
<tr><td>3. Main Habitats</td><td colspan="2">Sublittoral coarse sediment (A5.1)</td><td>Sublittoral sand (A5.2)</td><td>Sublittoral mixed sediments (A5.4)</td></tr>
<tr><td>4. Biotope Complex</td><td>A5.13 Infralittoral coarse sediment</td><td>A5.14 Circalittoral coarse sediment</td><td>A5.23 Infralittoral fine sand</td><td>A5.44 Circalittoral mixed sediment</td></tr>
</table>

Table 3-4 EBS seabed habitats

Around the Pegasus West well, the seabed was identified as circalittoral coarse sediment and circalittoral mixed sediment. These classifications are consistent with the previous Pegasus West rig site survey (Fugro, 2012) which also identified these habitats.

The pipeline route survey habitat assessment identified areas of sandy seabed that intermittently shoaled at <20 m LAT from KP13.5 to the end of the proposed Pegasus pipeline route. These are consistent with features of the EU Habitats Directive Annex I habitat ‘sandbanks which are slightly covered by seawater all of the time’ (Gardline, 2018b). All the EUNIS Level 3 habitats identified at <20 m on the pipeline route potentially fall under the definition of this Annex I sandbank habitat (European Commission, 2013). The proposed development area is located within the Dogger Bank SAC which is designated due to the presence of this habitat, and is further discussed in Section 3.4.1.

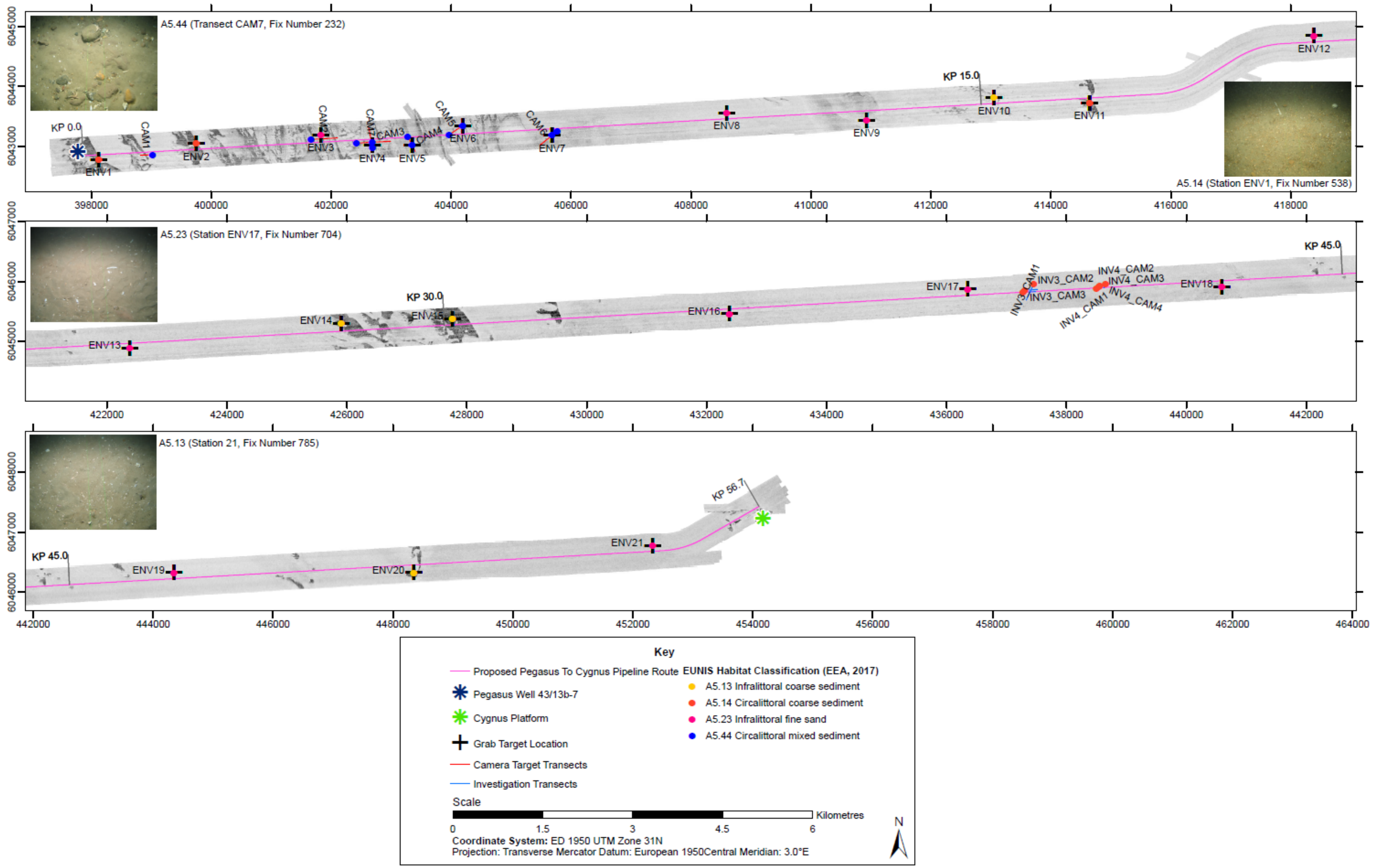


Figure 3-8 Pipeline route seabed habitats (EUNIS Level 4) (Gardline, 2018b)

Several transects and stations investigated the possible presence of biogenic reef created by the tube-building polychaete worm *Sabellaria spinulosa*. However, image analysis showed there was no evidence of the presence of biogenic reef within the pipeline route corridor. These features were observed to be due to a high abundance of the soft coral *Alcyonium digitatum* (Figure 3-9) and small areas of outcropping clay.

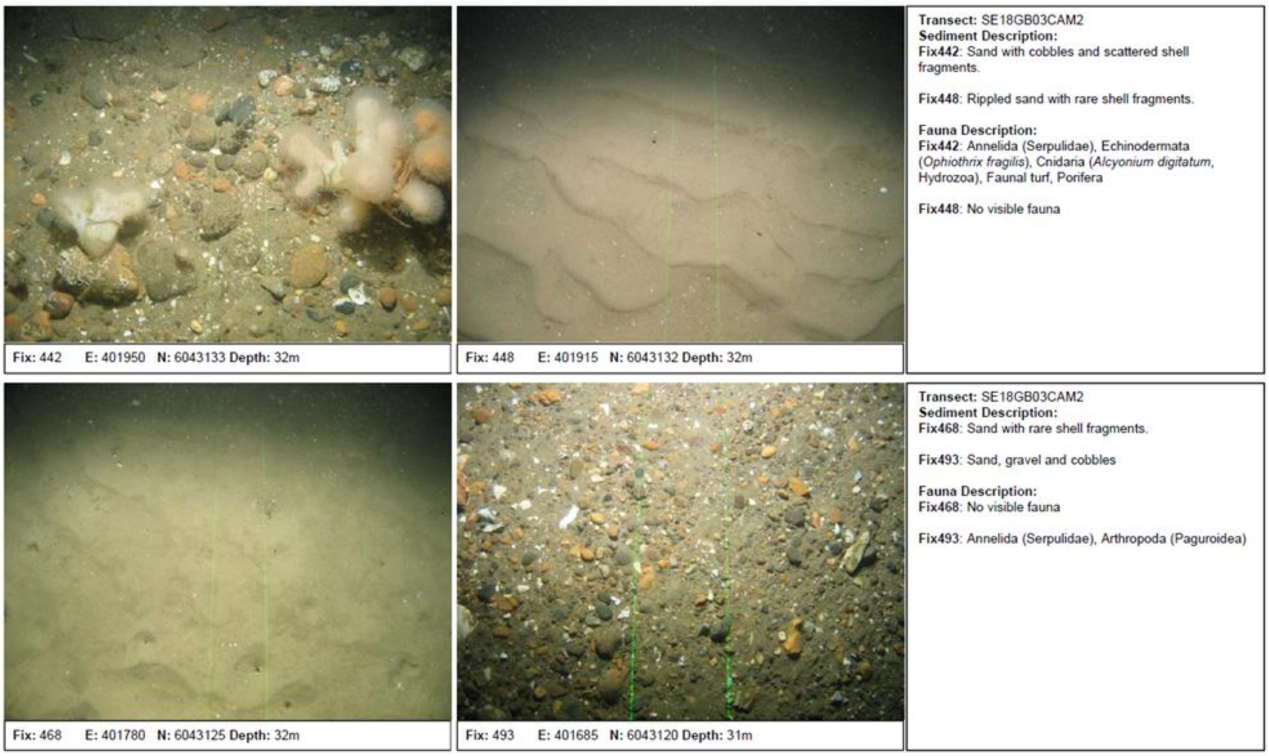


Figure 3-9 Example seabed habitats observed by the EBS (Camera transect CAM2, 57m North of KP4.142) (Gardline, 2018a)

3.3 Marine Flora and Fauna

3.3.1 Plankton

Plankton are drifting organisms that inhabit the pelagic zone of a body of water and include single celled organisms such as bacteria as well as plants (phytoplankton) and animals (zooplankton). Phytoplankton are the primary producers of organic matter in the marine environment and form the basis of marine ecosystem food chains. They are grazed on by zooplankton and larger species such as fish, birds and cetaceans. Therefore, the distribution of plankton directly influences the movement and distribution of other marine species. Population increases, known as blooms, occur in spring and autumn due to increased sunlight, temperature and nutrient availability. Meroplankton includes the eggs, larvae and spores of non-planktonic species (fish, benthic invertebrates and algae). This meroplankton population may have a very different seasonal cycle depending on the life cycle strategy of the fish species and benthic organisms which inhabit the area.

The composition and abundance of plankton communities varies throughout the year and is influenced by several factors including depth, tidal mixing, temperature stratification, nutrient availability and the location of oceanographic fronts (BEIS, 2016). The SNS is characterised by shallow, well-mixed waters, which undergo large seasonal temperature variations (JNCC

2004). The region is largely enclosed by land and, as a result, the environment here is dynamic with considerable tidal mixing and nutrient-rich run-offs from the land (eutrophication).

Under these conditions, there is relatively little stratification throughout the year and constant replenishment of the nutrients required by phytoplankton. These conditions favour diatoms, particularly the genus *Chaetoceros*, which comprise a greater proportion of the phytoplankton community than dinoflagellates from November to May when mixing is at its greatest (McQuatters-Gollop *et al*., 2007; Margalef 1973, cited in Leterme *et al*., 2006). Outside this period, the phytoplankton community is dominated by dinoflagellates of the genus *Ceratium* (*C. fusus, C. furca, C. lineatum*). Harmful algal blooms caused by *Noctiluca* sp. are often observed in the region. Phytoplankton production on the Dogger Bank occurs throughout the year supporting a high biomass of species at higher trophic levels year-round and creating a region that is biologically unique in the North Sea (Kröncke & Knust, 1995).

The zooplankton community comprises the copepods *Calanus helgolandicus* and *C. finmarchicus* as well as *Paracalanus* sp., *Pseudocalanus* sp., *Acartia* sp., *Temora* sp.; and cladocerans such as *Evadne* sp. There has been a marked decrease in copepod abundance in the SNS in recent years (Edwards *et al*. 2013), possibly linked to the North Atlantic Oscillation (NAO) index, a climate cycle that affects the sea surface temperature of the North Atlantic Ocean. This has a significant impact in the SNS, where the interface between the atmosphere and the sea is most pronounced (Harris *et al*. 2013).

3.3.2 Benthos

Bacteria, plants and animals living on or within the seabed sediments are collectively referred to as benthos. Species living on top of the sea floor may be sessile (i.e. immobile) (e.g. seaweeds) or freely moving (e.g. starfish) and collectively are referred to as epibenthic or epifaunal organisms. Animals living within the sediment are termed infaunal species (e.g. tubeworms and burrowing crabs and molluscs), while animals living on the surface are termed epifaunal (e.g. starfish, barnacles, mussels, soft corals). Semi-infaunal animals, including sea pens and some bivalves, lie partially buried in the seabed. The majority of marine benthic invertebrates exhibit a life cycle that includes a planktonic larval phase from which the bottom dwelling juvenile and adult phases recruit.

Benthic animals display a variety of feeding methods. Suspension and filter feeders capture particles which are suspended in the water column (e.g. sea pens) or transported by the current (e.g. mussels). Deposit feeders (e.g. sea cucumbers) ingest sediment and digest the organic material contained within it. Other benthic species can be herbivorous (e.g. sea urchins), carnivorous (e.g. crabs) or omnivorous (e.g. nematodes). Benthic communities show a strong correlation with habitat type, with depth mainly influencing epifauna, and sediment characteristics typically influencing the infauna (Basford *et al*., 1990). Benthic communities in deeper soft sediment habitats tend to be spatially distributed over large scales, with distinctive species assemblages associated with particular substrate types. However, depending on the intensity and spatial extent of sampling, localised community types or subtler variations may be distinguished, often associated with topographic features (BEIS, 2016).

Activities that result in the disruption of the seabed such as the deposition of discharged drill cuttings can affect the benthic fauna (Clark, 1996). The recognition that aquatic contaminants may alter benthic fauna, together with the relative ease of obtaining quantitative samples from specific locations, has led to the widespread use of infaunal communities in monitoring the long-term impact of disturbance to the marine environment. The species composition and relative abundance in a particular location provides a reflection of the immediate environment, both current and historic (Clark, 1996). Sessile infaunal species are particularly vulnerable to external influences that may alter the physical, chemical or biological community of the sediment as they are unable to avoid unfavourable conditions. Each species has its own response and degree of adaptability to changes in the physical and chemical environment.

3.3.2.1 EUNIS biotopes

The EBS classified the seabed at survey stations to biotope level (EUNIS Level 5) based on the habitat type, epifauna observed, and species identified in sediment samples (Table 3-5). Under the EUNIS system, a biotope is defined as an area "with particular environmental conditions that are sufficiently uniform to support a characteristic assemblage of organisms" (Davies *et al*., 2004). The biotope classification is more specific than habitat or biotope complex (Table 3-4).

Station	Water Depth (m LAT)	EUNIS Habitat Classification	
		BIOTOPE	CODE
ENV1	34	*Protodorvillea kefersteini* and other polychaetes in impoverished circalittoral mixed gravelly sand	A5.143
ENV2	32	*Protodorvillea kefersteini* and other polychaetes in impoverished circalittoral mixed gravelly sand	A5.143
ENV3	34	*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand	A5.233
ENV4	35	*Ophiothrix fragilis* and/or *Ophiocomina nigra* brittlestar beds on sublittoral mixed sediment	A5.445
ENV5	32	*Flustra foliacea* and *Hydrallmania falcata* on tide-swept circalittoral mixed sediment	A5.444
ENV6	37	*Flustra foliacea* and *Hydrallmania falcata* on tide-swept circalittoral mixed sediment	A5.444
ENV7	39	*Flustra foliacea* and *Hydrallmania falcata* on tide-swept circalittoral mixed sediment	A5.444
ENV8	26	*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand	A5.233
ENV9	26	*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand	A5.233
ENV10	18	*Hesionura elongata* and *Microphalmus similis* with other interstitial polychaetes in infralittoral mobile coarse sand	A5.134
ENV11	24	*Protodorvillea kefersteini* and other polychaetes in impoverished circalittoral mixed gravelly sand	A5.143
ENV12	21	*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand	A5.233
ENV13	21	*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand	A5.233
ENV14	20	*Hesionura elongata* and *Microphalmus similis* with other interstitial polychaetes in infralittoral mobile coarse sand	A5.134
ENV15	23	*Hesionura elongata* and *Microphalmus similis* with other interstitial polychaetes in infralittoral mobile coarse sand	A5.134
ENV16	22	*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand	A5.233
ENV17	21	*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand	A5.233
ENV18	19	*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand	A5.233
ENV19	20	*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand	A5.233
ENV20	21	*Hesionura elongata* and *Microphalmus similis* with other interstitial polychaetes in infralittoral mobile coarse sand	A5.134
ENV21	22	*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand	A5.233

Table 3-5 EBS survey station EUNIS biotopes (Gardline, 2018a)

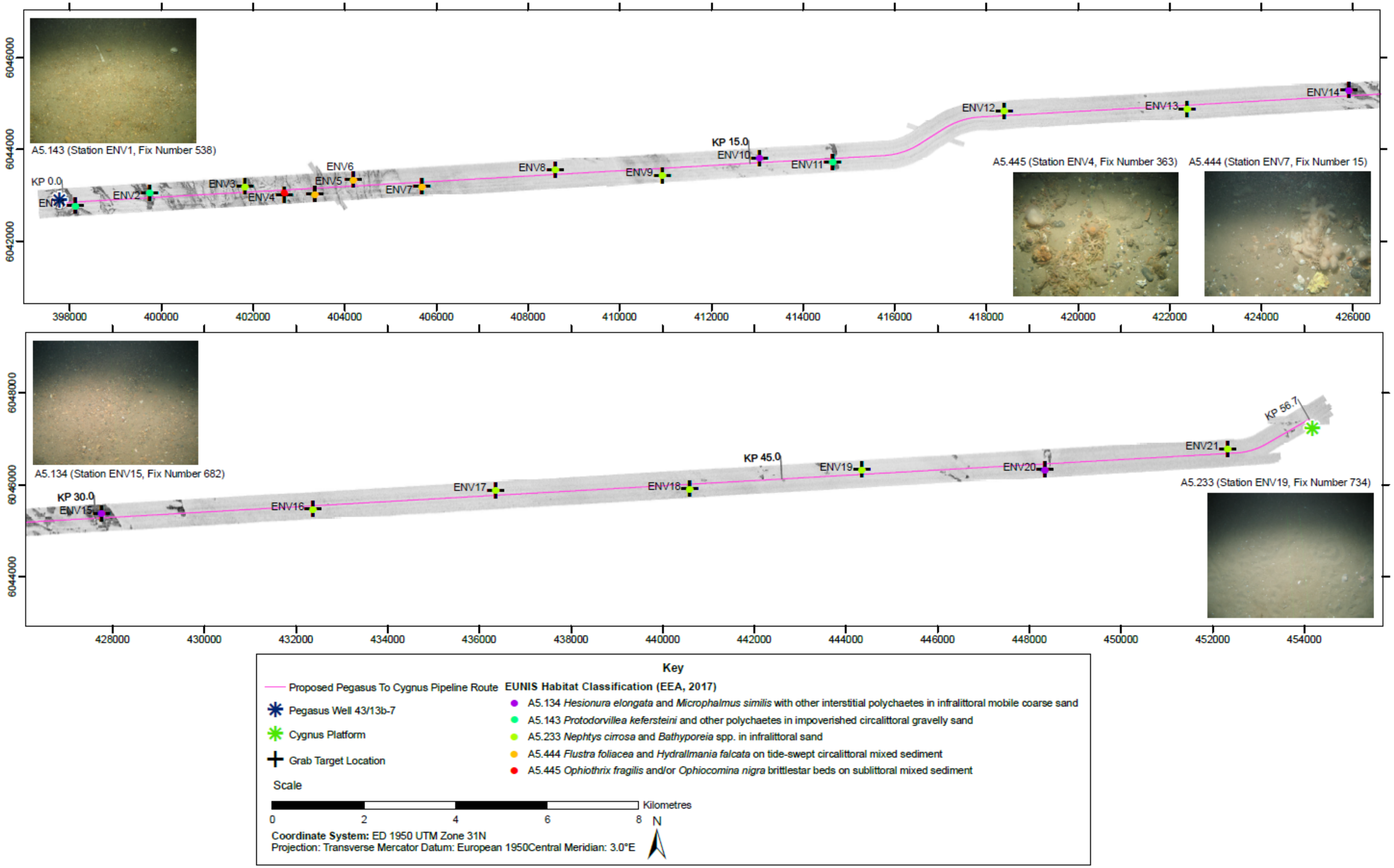


Figure 3-10 EUNIS biotopes (EUNIS Level 5) on the proposed pipeline route (Gardline, 2018a)

3.3.2.2 Epifauna

Epifaunal communities on the Dogger Bank are largely typified by communities dominated by a subset of burrowing species, including primarily the burrowing urchin *Echinocardium* sp., along with the razor shell *Ensis* sp., the sandmason worm *Lanice conchilega*, the masked crab *Corystes cassivelaunus* and sandeels. Communities associated with more gravelly sediments were distinguished from the more typical bank communities by the presence of the brittlestar *Ophiothrix fragilis* and the hermit crab *Pagurus bernhardus*. These areas of coarser sediment, along with occasional pebbles and cobbles provided a substrate for the soft coral *Alcyonium digitatum*, the bryozoan *Alcyonidium diaphanum* and Serpulid worms to colonise (Diesing *et al*., 2009).

Visible fauna was relatively sparse along the proposed pipeline route and included annelid worms, bivalve molluscs, crabs including the masked crab (*Corystes cassivalensis*), brown crab (*Cancer pagurus*), and hermit crabs (*Paguroidea*); echinoderms including the common starfish (*Asterias rubens*), the sand starfish (*Astropecten irregularis*), the sea potato (*Echinocardium cordatum*); and brittlestars (Ophiuroidea). On occasional hard surfaces, hornwrack (*Flustra foliacea*) and the soft coral *A. digitatum* were common (Gardline, 2018b). Tube-building annelid worms of the family *Serpulidae* were the most commonly observed taxon across the survey area, followed by *A. digitatum*.

3.3.2.3 Infauna

Previous surveys of the Dogger Bank area have identified a transition from a low diversity community in the shallowest areas, down to a more diverse community distributed across the main extent of the bank. In shallower regions in the south-west of the site, around Pegasus West, the community has been characterised by the presence of the polychaete *Nephtys cirrosa* and amphipods of the genus *Bathyporeia* sp. Areas to the east, including around Cygnus, have been characterised by the presence of two amphipod crustacean species, *Bathyporeia elegans* and *Bathyporeia guilliamsoniana*, the polychaete worm *Magelona mirabilis* and the burrowing bivalve *Tellina fabula.* More gravelly areas were reflected by the presence of certain fauna, such as the polychaete *Glycera lapidum* (Diesing *et al*., 2009; JNCC, 2011 and references therein).

Polychaete worms were the most abundant taxanomic group recorded by the pipeline EBS, followed by crustaceans, then molluscs. Echinoderms and other taxonomic groups were present in low numbers. The results for Stations ENV1 and ENV2 were similar to the results of a previous survey of the Pegasus West area, although the earlier survey showed a higher proportion of polychaetes (Gardline, 2018a; Fugro, 2012).

Dominant species on the proposed pipeline route were the polychaete *Spiophanes bombyx*, the amphipod *B. elegans* and the molluscs *Fabulina fabula* and *Abra alba*, ranked first, second, third and fourth respectively (Gardline, 2018a). The polychaetes *Pisione remota*, *Owenia*, *Protodorvillea kefersteini*, *Nephtys cirrosa* and *Glycera lapidum* were also common, as were juveniles of the bivalve mollusc genus *Thracia* (Gardline, 2018a). However, the distribution of these species between stations was uneven, suggesting a heterogenous community along the proposed pipeline route, which was expected given the geographical range and variation in sand and gravel recorded.

Heterogeneity of the faunal community along the proposed route was primarily associated with the varying proportions of sand and gravel recorded. For example, of the most dominant and abundant taxa, the mollusc *F. fabula* and the crustacean, *B. elegans* were found in greater abundance at the stations with higher proportions of sand, and were absent or in comparatively lower abundance at the more gravelly stations. Conversely, the polychaetes *P. remota* and *P. kefersteini* were present in greatest abundance at the gravelly stations (Gardline, 2018a).

Stations ENV4, ENV5, ENV6 and ENV7 were located in an area where exposures of the underlying

Bolders Bank Formation were observed at seabed (Gardline, 2018e), characterised as Circalittoral mixed sediment (EUNIS A5.44). Seabed imagery revealed the presence of the soft coral *A. digitatum* and overall the community was more diverse and distinct from the other stations, with characterising taxa including the polychaete *Mediomastus fragilis*, the brittlestar echinoderm *Amphiura filiformis*, the mollusc *Kurtiella bidentata.*

3.3.2.4 Arctica islandica

The proposed Pegasus West Development project is located in an area associated with *Arctica islandica* (Ocean Quahog) aggregations (Figure 3-11). *A. islandica* is a large bivalve mollusc which buries vertically in the top few centimetres of sandy and muddy sediments with its siphon protruding at the surface. It occurs from the low intertidal zone down to a water depth of approximately 400 m. Among the longest-lived and slowest growing marine bivalves and populations of 40-80 year old specimens, with a substantial proportion over 100 years old, have been recorded (OSPAR, 2009a).

The pipeline route habitat survey (Gardline, 2018b) noted several possible sightings of *A. islandica* in the form of bivalve siphons in the digital stills or video footage at Stations ENV12 and ENV21 and Transects CAM2, CAM7, INV3_CAM3, INV4_CAM2 and INV4_CAM3). Juveniles were recorded in sediment samples at three of the 21 stations (ENV6, ENV8, ENV21), one individual at each (Gardline, 2018a). Although *A. islandica* abundance is too low in the SNS to be sampled properly by means of single grab samples, their presence is indicative of general suitability of the sandy sediments within the area for *A. islandica* (Gardline, 2018b).

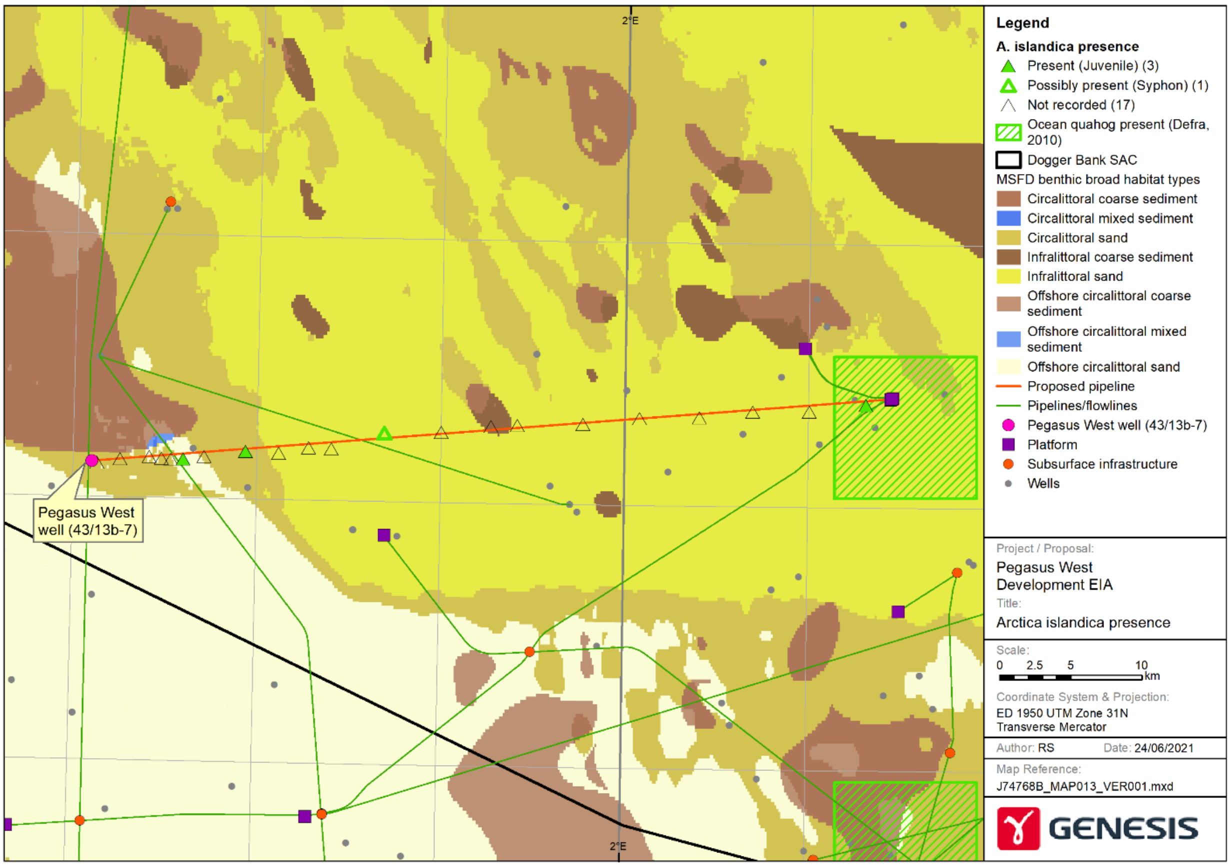


Figure 3-11 *Arctica islandica* records in the project area

The main threat to *A. islandica* is from seabed disturbance, specifically, physical change to the seabed type, physical removal of the substratum, or direct physical abrasion. Further information on *A. islandica* is provided in Section 3.4.4.3.

3.3.3 Fish

3.3.3.1 Fish species distribution

More than 330 fish species are thought to inhabit the shelf seas of the UKCS (Pinnegar *et al*., 2010). Pelagic species (e.g. herring, mackerel, blue whiting, and sprat are found in mid-water and typically make extensive seasonal movements or migrations. Demersal species (e.g. cod, haddock, sandeels, sole and whiting live on or near the seabed and similar to pelagic species, many are known to passively move (e.g. drifting eggs and larvae) and/or actively migrate (e.g. juveniles and adults) between areas during their lifecycle.

Predatory fish species present on the Dogger Bank include whiting, plaice, mackerel and cod (JNCC, 2011) with dab and grey gurnard being particularly abundant (Cefas, 2007). The pipeline route habitat survey observed gobies, gurnards, and flatfish including plaice, dab, and lemon sole (Gardline, 2018b).

Many of these species are widespread, having large extended spawning and nursery grounds. The most vulnerable stages of the fish lifecycle to general disturbances (sediment disruption, chemical/hydrocarbon discharges) are the egg and larval stages, hence recognition of spawning and nursery grounds within the area of proposed activities is important.

The proposed Pegasus West Development project is located within the International Council for the Exploration of the Sea (ICES) rectangles 38F1 and 38F2 in the SNS (see Section 3.5.1 for description of ICES rectangles). Spawning and nursery grounds of some commercially important fish known to occur in the area are listed in Table 3-6 and illustrated in Figure 3-12.

SPECIES	J	F	M	A	M	J	J	A	S	O	N	D
Mackerel [1]	J	J	J	J	S*J	S*J	S*J	SJ	J	J	J	J
Herring [1]	J	J	J	J	J	J	J	SJ	SJ	SJ	J	J
Cod [1,2]	SJ	S*J	S*J	SJ	J	J	J	J	J	J	J	J
Whiting [1,2]	NJ	SNJ	SNJ	SNJ	SNJ	SNJ	NJ	NJ	NJ	NJ	NJ	NJ
Plaice [1,2]	S*	S	S									
Sprat [1]	NJ	NJ	NJ	NJ	S*NJ	S*NJ	SNJ	SNJ	NJ	NJ	NJ	NJ
Sandeel [1,2]	SN	SN	N	N	N	N	N	N	N	N	SN	SN
Sole [1,2]			S	S*	S							
Horse mackerel	J	J	J	J	J	J	J	J	J	J	J	J
Haddock	J	J	J	J	J	J	J	J	J	J	J	J
Key: S = Spawning, * = Peak Spawning, N = Nursery Blue *highlighting indicates high intensity spawning* [2] Sources: [1] Coull *et al.,* (1998); [2] Ellis *et al.,* (2012) ; [3] Aires *et al.,* (2014)												

Table 3-6 Summary of spawning and nursery activity for some commercial fish species known to occur in ICES rectangles 38F1 and 38F2

In addition, Ellis *et al.,* (2012) have also identified the region as a high intensity nursery ground for whiting, and a low intensity nursery ground for spurdog, tope, blue whiting, ling, hake and anglerfish.

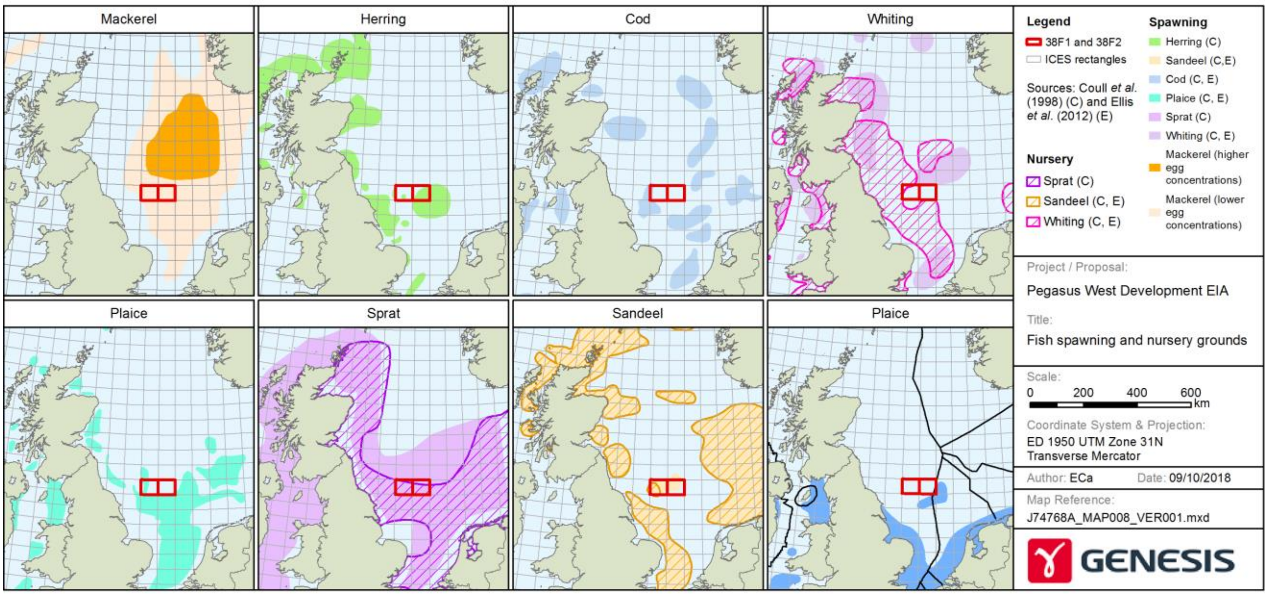


Figure 3-12 Fish spawning and nursery grounds within ICES rectangles 38F1 and 38F2

Species distribution modelling predictions of the spatial distribution of aggregations of 0-group fish (fish in the first year of their life) indicates that for the majority of commercial fish species, juveniles are unlikely to be present in the area, but the probability of juvenile whiting, herring, horse mackerel and sprat is higher, whilst probability of juvenile cod, haddock, mackerel is medium to low (Table 3-6 and Figure 3-13; Aires *et al.,* 2014).

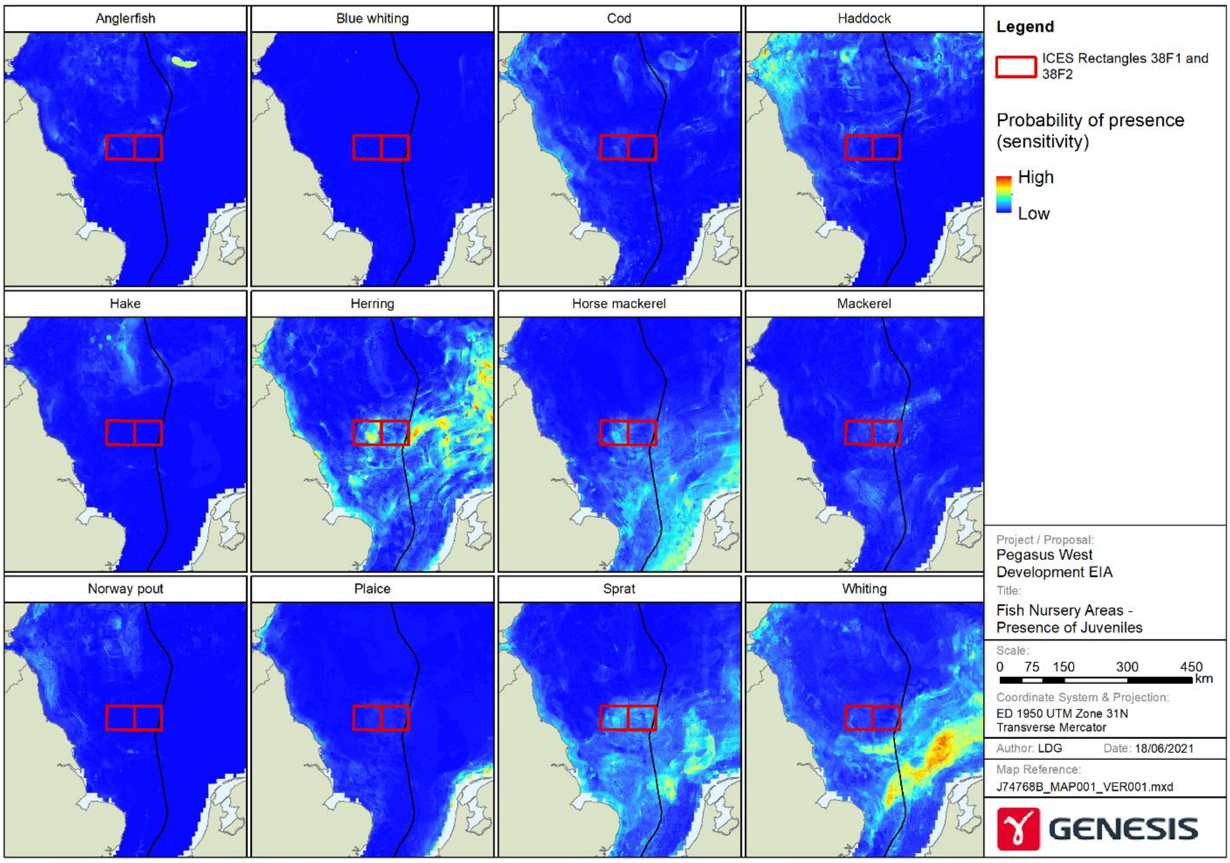


Figure 3-13 Probability of juvenile fish presence within ICES rectangles 38F1 and 38F2

3.3.3.2 Herring

Herring (*Clupea harengus*) is one of the most important commercially exploited marine species in UK waters. Spawning herring deposit their eggs on the seabed (demersal spawners), which later hatch with larval and post-larval stages dispersed in the water column (pelagic). The dependency of herring on specific substrates during spawning makes the species susceptible to impacts resulting from oil and gas exploration and production (Rogers & Stocks, 2001). Although herring are reported to deposit their sticky demersal eggs on a variety of substrates, gravel is widely considered to be the preferred spawning substrate (Rogers and Stocks, 2001; Drapeau, 1973). In the Dogger Bank area, herring spawn between August and October (Coull *et al*., 1998) some historic spawning grounds on the Dogger Bank currently have no, or very little, spawning activity (Ellis *et al*., 2012).

Determination of herring spawning potential for a specific area of seabed has been based on guidelines provided in Reach *et al*., (2013) as summarised in Table 3-7, and a variety of measured and inferred sediment and hydrodynamic characteristics including those originally adopted by CEFAS (2001). In order to be classified as ‘Prime’ or ‘Sub-Prime’ for herring spawning, the sediment must be composed of >50% gravel (>2 mm) or >25% gravel, respectively with little (<5%) mud (<63 µm, silt and clay). As such, the area must fall into one of 3 sediment types based on the modified Folk (1954) classification, gravel, sandy gravel or part gravelly sand. Consideration should also be given to other environmental (physical, chemical and abiotic) parameters such as oxygenation, siltation, and micro-scale morphological features (e.g. ripples and ridges). The area must be exposed to the main flow of water and the sediments well sorted in order to ensure maximum oxygenation of the sediment, and hence the lower layers of herring eggs, and the area should be elevated with respect to the surrounding seabed.

Criteria From	Habitat Sediment Class	Unsuitable	Marginal	Preferred	
	Habitat Sediment Preference	Unsuitable	Suitable	Sub-prime	Prime
Sediment Classes (Reach *et al*., 2013)	% Particle Contribution Preference	>5% muds, <10% gravel	<5% muds, >10% gravel	<5% muds, >25% gravel	<5% muds, >50% gravel
	Modified Folk Classification	Everything excluding gravel, sandy gravel and part gravelly sand	Part gravelly sand	Part sandy gravel and part gravelly sand	Gravel and part sandy gravel
Further Sediment Description Parameters (including those from CEFAS (2001))	% coarse sand to gravel	≤20%	20% to <40%	40% to <60%	≥60%
	Sorting coefficient and description (Folk & Ward)	≥1.00, poor to extremely poor	0.71 to <1.00, moderate	0.5 to <0.71. moderately well	≤0.5, well
	Wentworth Classification (mode grain size)	Silts and clays	Very fine to medium sand	Coarse to very coarse sand	Granule to pebble
Exposure (CEFAS, 2001; Reach *et al*., 2013)	Interpretation From MBES and SSS data	Flat seabed			Elevated (such as raised gravel banks) relative to surrounding seabed

Table 3-7 Herring spawning ground potential criteria (Gardline, 2018b; adapted from CEFAS (2001) and Reach *et al*., (2013))

The depths and currents along the Pegasus pipeline route are within the range suitable for herring spawning (Gardline, 2018b).

Overall, it was considered that stations ENV1, ENV2, ENV11, ENV14 and ENV15 presented the greatest herring spawning potential as these met both the ‘Prime’ habitat sediment preference and ‘Preferred’ sediment classification, and were also situated in areas of furrows and ripples at the western end of the route, or on top of the main sandbank, and exposed to the dominant tidal current direction. Stations ENV5, ENV6 and ENV20 were considered to be ‘Sub-prime’ sediment and exposed to the prevailing current. Station ENV10, with a gravel proportion of 10.8% was considered to offer ‘Marginal’ suitability for herring spawning and the remaining stations were overall considered to be ‘Unsuitable’ (Gardline, 2018b) (Table 3-8).

The EBS was conducted in April and May 2018, outside of the main herring spawning season, and no evidence of herring or their eggs was observed. The nearest survey stations to the Pegasus West well (ENV1 and ENV2) were assessed as having ‘Prime’ herring spawning potential (Gardline, 2018b). Herring spawning grounds were confirmed in the Pegasus West well area by a rig site survey completed between November 2011 and February 2012, that found herring eggs in sediment samples (Fugro, 2012).

Criteria		Dominant Grain Size			Habitat Sediment Preference (Reach *et al.*, 2013)[2]	Habitat Sediment Classification (Reach *et al.*, 2013)[3]	Exposure
Station	Designation[1]	Sorting Description (and Coefficient)	Wentworth Classification (Mode)	% Coarse Sand to Gravel	% Gravel, Fines	Modified Folk Classification	Evidence from MBES and SSS and Seabed Imagery Interpretation
ENV1	76m S KP0.255	Poor (1.7)	Granule	87.5	62.5, 1.7	Sandy gravel	Furrow, ripples
ENV2	103m N KP1.893	Very Poor (2.1)	Granule	83.7	69.8, 1.0	Sandy gravel	Furrow
ENV3	122m N KP3.975	Moderately Well (0.5)	Fine Sand	0.4	0.2, 0.0	Sand	Furrow, ripples
ENV4	101m S KP4.823	Very Poor (3.1)	Fine Sand	6.7	4.2, 47.7	Slightly gravelly muddy sand	Ripples, cobble, epifauna
ENV5	135m S KP5.487	Very Poor (2.9)	Pebble	55.0	38.7, 0.5	Sandy gravel	Ripples, cobbles, epifauna
ENV6	141m N KP6.349	Very Poor (2.1)	Medium Sand	56.0	26.8, 3.8	Gravelly sand	Ripples, epifauna
ENV7	101m S KP7.830	Very Poor (3.3)	Pebble	56.6	45.6, 6.4	Muddy sandy gravel	Ripples, cobble, clay, epifauna
ENV8	99m N KP10.753	Moderately Well (0.5)	Fine Sand	0.2	0.1, 0.0	Sand	Ripples
ENV9	153m S KP13.079	Moderately Well (0.5)	Medium Sand	8.1	0.0, 0.0	Sand	Ripples
ENV10	100m N KP15.219	Poor (1.2)	Coarse Sand	68.9	10.8, 0.1	Gravelly sand	Ripples, ridge on sandbank edge
ENV11	73m S KP16.806	Poor (1.5)	Granule	88.3	62.7, 0.6	Sandy gravel	Furrow on sandbank
ENV12	107m N KP20.753	Moderately Well (0.6)	Fine Sand	0.9	0.7, 0.0	Sand	Sandbank
ENV13	80m S KP24.743	Moderately Well (0.5)	Fine Sand	1.1	0.7, 0.0	Sand	Sandbank
ENV14	130m N KP28.285	Very Poor (2.4)	Pebble	80.8	57.7, 0.6	Sandy gravel	Furrows, ripples, cobbles on sandbank
ENV15	102m N KP30.141	Very Poor (2.1)	Pebble	89.7	75, 0.0	Sandy gravel	Furrows, ripples on sandbank
ENV16	74m S KP34.758	Moderately Well (0.6)	Fine Sand	2.2	1.7, 3.7	Slightly gravelly sand	Ripples, sandbank
ENV17	110m N KP38.751	Moderately Well (0.6)	Fine Sand	1.1	1.0, 0	Sand	Ripples, sandbank
ENV18	99m S KP42.985	Poor (1.1)	Medium Sand	38.7	6.6, 0.5	Gravelly sand	Ripples, sandbank
ENV19	107m N KP46.749	Moderately Well (0.6)	Fine Sand	1.2	1.0, 0.0	Slightly gravelly sand	Ripples, sandbank
ENV20	122m S KP50.746	Poor (1.1)	V. Coarse Sand	91.9	41.7, 0.4	Sandy gravel	Undulating seabed on sandbank
ENV21	100m N KP54.751	Moderate (0.8)	Fine Sand	5.1	3.9, 0.0	Slightly gravelly sand	Ripples, sandbank

1 Station designation is the distance and direction from the proposed Pegasus pipeline route. Classification criteria are detailed in Section 2.5.

2 Habitat Sediment Preference - Colours indicate where Prime, Sub-Prime, Suitable or Unsuitable spawning potential criteria were met ((Reach *et al.*, 2013).

3 Habitat Sediment Classification - Colours indicate where Preferred, Marginal or Unsuitable spawning potential criteria were met (Reach *et al.*, 2013).

Table 3-8 Summary of pipeline route herring spawning potential (Gardline, 2018b)

3.3.3.3 Sandeel

Sandeels are small eel-like fish which swim in large shoals. They are a significant prey resource for various predators including other commercial fish species, seabirds (such as fulmar and kittiwake) and cetaceans, in particular the harbour porpoise (CEFAS, 2007). Of the five species of sandeels inhabiting the North Sea, *Ammodytes marinus* is the most abundant. The distribution of sandeels within the North Sea is highly localised and they are abundant in the Dogger Bank region, with the population on the Dogger Bank concentrated along the edges in water depths of around 20-30 m. Their distribution is linked to local hydrography and higher levels of food resource at these locations with increased plankton abundance where fronts meet (Cefas, 2007).

A. marinus has specific habitat preferences and is found in coarse and medium sand seabed areas into which it burrows (Holland *et al.*, 2005). Sandeels are demersal spawners, depositing their eggs on the seabed between November and February (Coull *et al.,* 1998), their eggs attaching themselves to grains of sand (Hassel *et al.,* 2002). The larvae hatch after several weeks, usually in February-March, and drift in the currents for one to three months, after which they settle on sandy seabed areas (Marine Scotland, 2017). Like herring, dependency of sandeels on specific substrates during spawning makes the species susceptible to seabed disturbance.

Sandeel nursery areas are even more geographically localised than general sandeel distributions, being restricted to apparently 'higher quality' nursery habitat, such as the North West Riff area to the west of the Dogger Bank where the Pegasus West well and western half of the proposed pipeline route will be located (Figure 3-14). This is regarded as crucial as a sandeel nursery to the wider area (CEFAS, 2007). Importantly, this high degree of site attachment exhibited by sandeels indicates low re-colonisation potential of areas denuded by fishing.

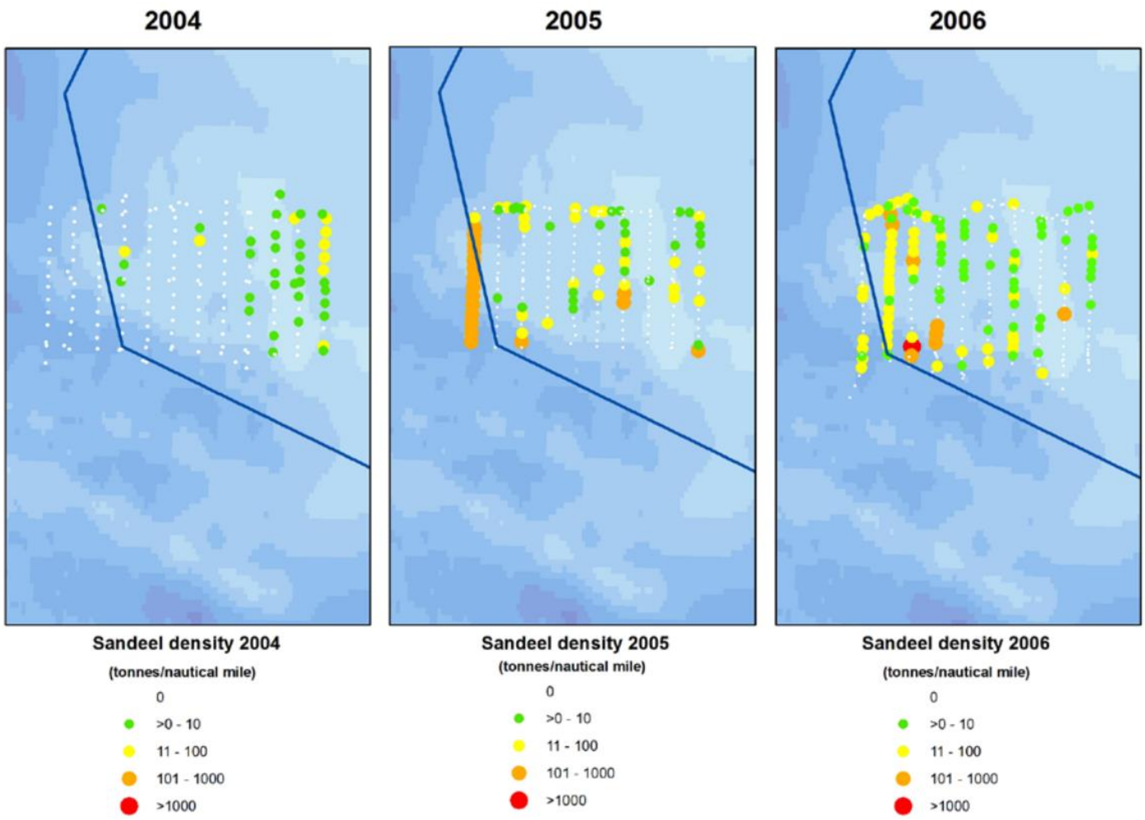


Figure 3-14 Sandeel density in the south-western section of the Dogger Bank from 2004-2006 (CEFAS, 2007)

Determination of sandeel spawning potential for a specific area of seabed has been based on guidelines provided in Latto *et al*., (2013), as summarised in Table 3-9. In order to be classified as 'Prime' or 'Sub-Prime' for sandeel spawning, the sediment must be composed of >85% sand or >70% sand, respectively with little mud (<1% or <4%, respectively). Although these criteria do not easily translate to the modified Folk (1954) classification, sandeel spawning habitat corresponds with sand, slightly gravelly sand or gravelly sand.

Criteria From	Habitat Sediment Class	Unsuitable	Marginal	Preferred	
	Habitat Sediment Preference	Unsuitable	Suitable	Sub-prime	Prime
Sediment Classes (Latto *et al*., 2013)	% Particle Contribution Preference	>10% muds, <50% sand	<10% muds, >50% sand	<4% muds, >70% sand	<1% muds, >85% sand
	Folk Classification based on % particle contribution preferences above	All others (including part mS, part (g)mS, part gmS, part msG and part sG)	Part S, part (g)S, part gS, part sG, part mS, part (g)mS, part gmS and part msG.	Part S, part (g)S, and part gS	Part S, part (g)S, and part gS
	Folk Classification generalised	All others	Sandy gravel	Sand, slightly gravelly sand and gravelly sand	

Table 3-9 Sandeel spawning ground potential criteria (Gardline, 2018b; adapted from Latto *et al*., (2013))

Based on these criteria, it was considered that stations ENV3, ENV8 to ENV10, ENV12, ENV13, ENV17 to ENV19 and ENV21 met the ‘Prime’ habitat sediment preference for sandeel spawning, and station ENV16 met the ‘Sub-prime’ habitat sediment preference (Figure 3-15). Each of these stations met the ‘Preferred’ habitat sediment classification for sandeel spawning according to their modified Folk classifications of sand, slightly gravelly sand and gravelly sand. Stations ENV5, ENV6 and ENV20 were considered ‘Suitable’ or ‘Marginal’ while the remaining stations were considered ‘Unsuitable’ against at least one sediment criteria (Gardline, 2018b). The sandeel spawning potential at each station are summarised in Table 3-10.

Station	Designation[1]	Habitat Sediment Preference (Latto *et al.*, 2013)[2]		Habitat Sediment Classification (Latto *et al.*, 2013)[3]	
		% fines	% sand	Modified Folk Classification with preference based on sand and fines criteria	Modified Folk Classification with preference based on generalised criteria
ENV1	76m S KP0.255	1.70	35.82	Sandy gravel	Sandy gravel
ENV2	103m N KP1.893	0.98	29.27	Sandy gravel	Sandy gravel
ENV3	122m N KP3.975	0.00	99.77	Sand	Sand
ENV4	101m S KP4.823	47.67	48.11	Slightly gravelly muddy sand	Slightly gravelly muddy sand
ENV5	135m S KP5.487	0.52	60.80	Sandy gravel	Sandy gravel
ENV6	141m N KP6.349	3.84	69.31	Gravelly sand	Gravelly sand
ENV7	101m S KP7.830	6.43	47.96	Muddy sandy gravel	Muddy sandy gravel
ENV8	99m N KP10.753	0.00	99.95	Sand	Sand
ENV9	153m S KP13.079	0.00	99.97	Sand	Sand
ENV10	100m N KP15.219	0.07	89.08	Gravelly sand	Gravelly sand
ENV11	73m S KP16.806	0.65	36.67	Sandy gravel	Sandy gravel
ENV12	107m N KP20.753	0.00	99.29	Sand	Sand
ENV13	80m S KP24.743	0.00	99.29	Sand	Sand
ENV14	130m N KP28.285	0.63	41.63	Sandy gravel	Sandy gravel
ENV15	102m N KP30.141	0.00	24.98	Sandy gravel	Sandy gravel
ENV16	74m S KP34.758	3.71	94.58	Slightly gravelly sand	Slightly gravelly sand
ENV17	110m N KP38.751	0.00	99.01	Sand	Sand
ENV18	99m S KP42.985	0.46	92.98	Gravelly sand	Gravelly sand
ENV19	107m N KP46.749	0.00	98.99	Slightly gravelly sand	Slightly gravelly sand
ENV20	122m S KP50.746	0.43	57.87	Sandy gravel	Sandy gravel
ENV21	100m N KP54.751	0.00	96.06	Slightly gravelly sand	Slightly gravelly sand

1 Station designation is the distance and direction from the proposed Pegasus pipeline route. Classification criteria are detailed in Section 2.6.

2 Habitat Sediment Preference - Colours indicate where Prime, Sub-Prime, Suitable or Unsuitable spawning potential criteria were met (Latto *et al.*, 2013).

3 Habitat Sediment Classification - Colours indicate where Preferred, Marginal or Unsuitable spawning potential criteria were met (Latto *et al.*, 2013) based on either the sand and fines criteria or the generalised criteria.

Table 3-10 Summary of sandeel spawning potential

The survey took place after the sandeel spawning season and there was no evidence of sandeels or their eggs observed along the proposed pipeline route.

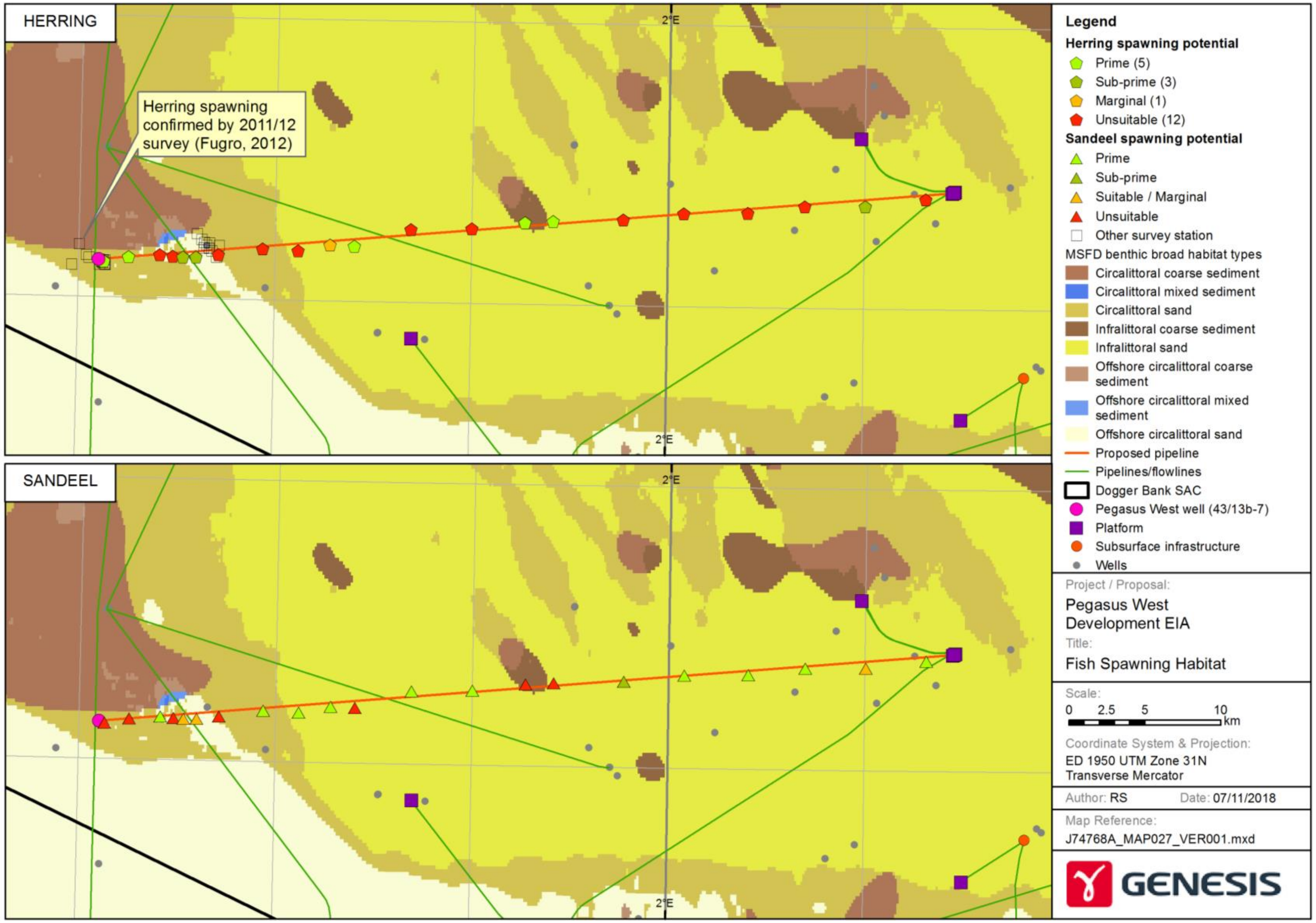


Figure 3-15 Herring and sandeel spawning habitat (Gardline, 2018b; Fugro, 2012)

3.3.3.4 Sharks, skates and rays

Due to their slow growth rates and hence delayed maturity and relatively low reproductive rates, sharks, rays and skates (all members of the subclass Elasmobranchii) tend to be vulnerable to anthropogenic activities. Historically, elasmobranch species have been targeted by commercial fisheries, specifically common skate (*Dipturus batis*), long-nose skate (*Dipturus oxyrinchus*) and angel shark (*Squatina squatina*). Overfishing has significantly depleted their numbers in the UK waters and they are still taken as bycatch to such an extent that the stocks are still being depleted in UK waters.

The distribution of elasmobranchs in the UKCS is not extensively documented. There are thought to be 27 species of skate within the north-east Atlantic (Ellis *et al*., 2015) of which many are present in UK waters. Among the most widespread is the thornback ray (*Raja clavata*) and the cuckoo ray (*Raja naevus*). The starry ray (*Amblyraja radiata*), the blonde ray (*Raja brachyuran*), the small-eyed ray (*Raja microocellata*), the undulate ray (*Raja undulata*) and the spotted ray (*Raja montagui*) are regionally abundant. The common skate (*Leucoraja batis*), listed as “critically endangered” on the International Union for Conservation of Nature (IUCN) Red List, is also present, but rare. The most abundant sharks found in UK waters are the lesser and greater spotted dogfish (*Scyliorhinus canicula* and *Scyliorhinus stellaris*), the spurdog (*Squalus acanthias*) and tope (*Galeorhinus galeus*) (BEIS, 2016).

The Shark, Skate, and Ray Conservation Plan sets out clear policy objectives with the overarching goal of managing elasmobranch stocks sustainably (Defra, 2013). The angel shark (*Squatina squatina*), white skate (*Rostroraja alba*) and basking shark (*Cetorhinus maximus*) are protected in UK waters under the Wildlife and Countryside Act (1981).

No elasmobranchs were observed by the EBS (Gardline 2018a).

3.3.3.5 Registered Concerns within the Area

The OGA has published guidance which includes advice from government departments and external agencies on seasonal environmental concerns related to the potential impacts of offshore seismic surveys and drilling (OGA, 2018a). A summary of the periods of concern for the licence blocks in which project activities will take place is provided in Table 3-11.

BLOCK	PERIOD OF CONCERN FOR SEISMIC SURVEYS	PERIOD OF CONCERN FOR DRILLING*	HERRING SPAWNING GROUNDS**
43/13	January – March May - August November – December	May to July and December	Yes
43/14	January – February May - August November – December	January, July, November, December	Yes
43/15	January – March May - August November – December	January, July, November, December	No
44/11	January – March May - December	January, July, November, December	Yes
44/12	January – March May - December	January, November, December	Yes

* Periods of concern for drilling operations identified using SOSI data in line with JNCC guidance: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/814936/Seabird_Oil_Sensitivity_Index__SOSI__Data_and_tables.xlsx

**Seabed surveys may be required before any drilling activity, to confirm whether there are any herring spawning sites within a 3nm radius of the proposed drilling location.

Table 3-11 Registered concerns for activities

The registered periods of concern relate to herring spawning between August and October, and high seabird sensitivity to oil pollution from January to April and September to October.

3.3.4 Seabirds

The UK and its surrounding seas are very important for seabirds. The extensive network of cliffs, sheltered bays, coastal wetlands and estuarine areas, provide breeding and wintering grounds for national and internationally important bird species and assemblages (BEIS, 2016). Approximately 26 species of seabird regularly breed in the UK and Ireland as do a number of other waterbird and wader species (BEIS, 2016).

Predicted maximum monthly abundance of seabirds in the Pegasus West Development area is based on an analysis of the European Seabirds at Sea (ESAS) data collected over 30 years (Kober *et al.,* 2010). Continuous seabird density surface maps were generated using the spatial interpolation technique ‘Poisson kriging’ and 57 seabird density surface maps were created to show particular species distribution in specific areas. Data from the relevant maps has been summarised for the Pegasus West Development area in Table 3-12.

Distribution and abundance of these bird species vary seasonally and annually. Seabirds such as Atlantic puffin use the project area in the breeding season (April – July), whereas other species such as the common guillemot and little auk are present in higher densities in the winter season (October - April).

Recent seabird distribution maps produced by Waggit *et al.* (2019) indicate the presence of black-legged kittiwake, common guillemot and herring gull at a medium density of *c*. 0.93 – 1.24 animals/ km^2, and lesser black backed gull, northern fulmar, northern gannet and razorbill at a low to medium density of *c.* 0.31– 0.93 animals/ km^2 around the Pegasus West Development area (Waggit *et al.* 2019).

SPECIES	SEASON	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
NORTHERN GANNET	Breeding												
	Winter												
GREAT SKUA	Breeding												
	Winter												
FULMAR	Breeding												
	Winter												
LITTLE AUK	Winter												
LESSER BLACK-BACKED GULL	Breeding												
	Winter												
BLACK-LEGGED KITTIWAKE	Breeding												
	Winter												
BLACK-HEADED GULL	Breeding												
COMMON GULL	Breeding												
GREAT BLACK-BACKED GULL	Breeding												
	Winter												
RAZORBILL	Breeding												
	Winter												
HERRING GULL	Winter												
COMMON GUILLEMOT	Breeding												
	Additional												
	Winter												
ATLANTIC PUFFIN	Breeding												
	Winter												
ALL SPECIES COMBINED	**Breeding**												
	Summer												
	Winter												

KEY	Not recorded	≤ 1.0	1.0 – 5.0	5.0 – 10.0	10.0 - 15.0	15.0 - >20.0

Table 3-12 Predicted seabird surface density (maximum number of individuals/km^2 (Kober *et al.*, 2010)

Seabirds are generally not impacted by routine offshore oil and gas production operations. However, they may be vulnerable to pollution from less regular offshore activities such as well testing and flaring, when hydrocarbon dropout to the sea surface can occasionally occur, or from unplanned events such as accidental oil or diesel spills.

The vulnerability of seabirds in the blocks and surrounding areas has been assessed according to the JNCC Seabird Oil Sensitivity Index (SOSI). Oil and Gas UK commissioned HiDef (a digital aerial video and image specialist consultancy) to develop the SOSI tool and the results are available on the JNCC website (JNCC, 2017a). The purpose of this index is to identify areas where seabirds are likely to be most sensitive to oil pollution by considering factors that make a species more or less sensitive to oil-related impacts.

The SOSI combines the seabird survey data with individual seabird species sensitivity index values. These values are based on a number of factors which are considered to contribute towards the sensitivity of seabirds to oil pollution, and include:

- Habitat flexibility (the ability of a species to locate to alternative feeding grounds),
- Adult survival rate,
- Potential annual productivity, and
- The proportion of the biogeographical population in the UK (classified following the methods developed by Certain *et al.,* (2015).

The combined seabird data and species sensitivity index values were then subsequently summed at each location to create a single measure of seabird sensitivity to oil pollution. The mean sensitivity SOSI data for the area is shown in Table 3-13. For blocks with ‘no data’, an indirect assessment has been made (where possible) using JNCC guidance (JNCC, 2017a). The sensitivity of birds to surface oil pollution is shown in Figure 3-16. The sensitivity of birds to surface oil pollution ranges from ‘low’ to ‘extremely high’ sensitivity within Blocks 43/13, 43/14, 43/15, 44/11 and 44/12, with ‘extremely high’ seabird sensitivity in the months of July and December (JNCC, 2017a).

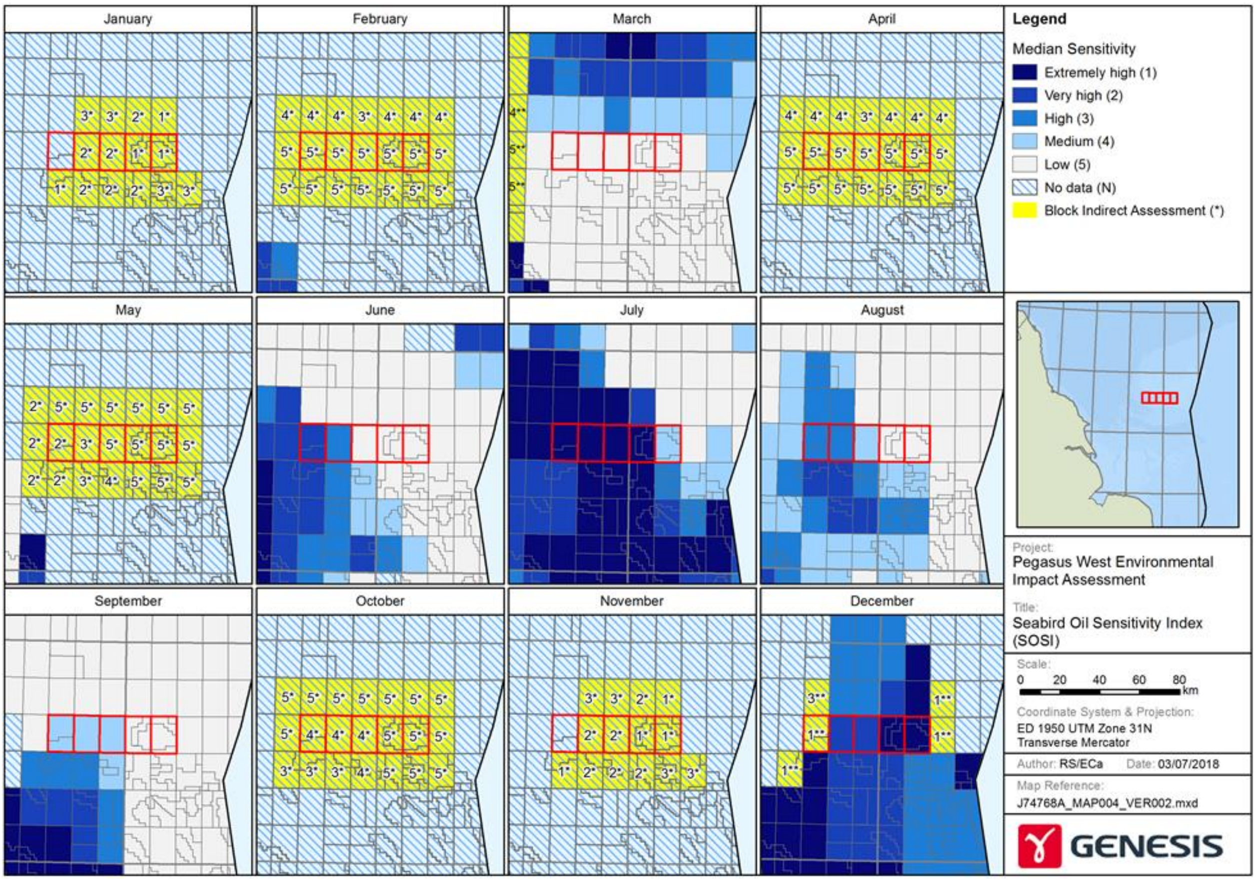


Figure 3-16 SOSI and indirect assessment for Blocks 43/13, 43/14, 43/15, 44/11 and 44/12 (incl. adjacent blocks) (JNCC, 2017a)

BLOCK	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
43/7	N	4*	4	4*	2*	3	1	4	5	5*	N	N
43/8	N	4*	4	4*	5*	5	1	3	5	5*	N	3**
43/9	3*	4*	4	4*	5*	5	1	3	5	5*	3*	3
43/10	3*	3*	3	3*	5*	5	1	5	5	5*	3*	3
44/6	2*	4*	4	4*	5*	5	2	5	5	5*	2*	2
44/7	1*	4*	4	4*	5*	5	5	5	5	5*	1*	1
44/8	N	4*	4	4*	5*	5	5	5	5	5*	N	1**
43/12	N	5*	5	5*	2*	2	1	4	5	5*	N	N
43/13	N	5*	5	5*	2*	2	1	3	4	4*	N	1**
43/14	2*	5*	5	5*	3*	3	1	3	4	4*	2*	2
43/15	2*	5*	5	5*	5*	5	1	4	4	4*	2*	2
44/11	1*	5*	5	5*	5*	5	1	5	5	5*	1*	1
44/12	1*	5*	5	5*	5*	5	4	5	5	5*	1*	1
44/13	N	5*	5	5*	5*	5	5	5	5	5*	N	1**
43/17	N	5*	5	5*	2*	2	2	3	3	3*	N	1**
43/18	1*	5*	5	5*	2*	2	2	2	3	3*	1*	1
43/18	2*	5*	5	5*	3*	3	1	2	3	3*	2*	2
43/20	2*	5*	5	5*	4*	4	1	3	4	4*	2*	2
44/16	2*	5*	5	5*	5*	5	1	4	5	5*	2*	2
44/17	3*	5*	5	5*	5*	5	3	4	5	5*	3*	3
44/18	3*	5*	5	5*	5*	5	4	5	5	5*	3*	3
KEY	1 Extremely High	2 Very High	3 High	4 Medium	5 Low	N = No Data						
	Indirect Assessment – data gaps have been populated following guidance provided by the JNCC (JNCC, 2017a). ** Data gap filled gap filled using data from the same block in adjacent months.* *** Data gap filled using data from the adjacent blocks within the same month.*											

Table 3-13 SOSI and indirect assessment for Blocks 43/13, 43/14, 43/15, 44/11 and 44/12 (including adjacent blocks (JNCC, 2017a)

3.3.5 Marine mammals

Marine mammals include pinnipeds (seals), cetaceans (whales, dolphins and porpoises) and mustelids (otters). Marine mammals are vulnerable to the direct effects of oil and gas activities such as underwater sound, contaminants and oil spills. Given the distance of the proposed Pegasus West Development from land, mustelids are unlikely to be impacted and are not considered further.

3.3.5.1 Pinnipeds

Two species of pinnipeds (seals) are resident in British waters: the grey seal (*Halichoerus grypus*) and the harbour seal (*Phoca vitulina*). Although both species are Annex II species of the EU

Habitats Directive, they are not listed on Annex IV and as such are not classified as EPS. Seals are protected in the UK under the Conservation of Seals Act 1970.

Grey seal pup between October and January, during which time mating also occurs (gestation period is 11.5 months). Harbour seals pup during June, which is followed by a moulting period of around a month. During breeding, pupping and moulting periods, both species tend to be more concentrated close to shore.

Distribution maps (see Figure 3-17) indicate that grey seals are likely to occur in the vicinity of the proposed Pegasus West Development at low densities. The maximum estimated density of grey seals is 5-10 individuals per in a 5 km × 5 km square (SMRU, 2017). Grey seals in the area most likely originate from the Humber Estuary SAC, for which grey seal is a qualifying species. Grey seals are also highly concentrated around Donna Nook NNR and during the pupping season, up to 2,000 pups are born at Donna Nook, with around 2,000 adult seals present at the peak period (Lincolnshire Wildlife Trust, 2021).

Harbour seals, with highest densities around The Wash SAC, are unlikely to forage far enough from shore to be present in the project area. Monitoring during the pipeline route geophysical survey, between 23rd April and 15th May-2018 supported this assessment. Three grey seals and two unidentified seals were recorded from 118 hours and 45 minutes of monitoring effort by a Marine Mammal Observer (Gardline, 2018d).

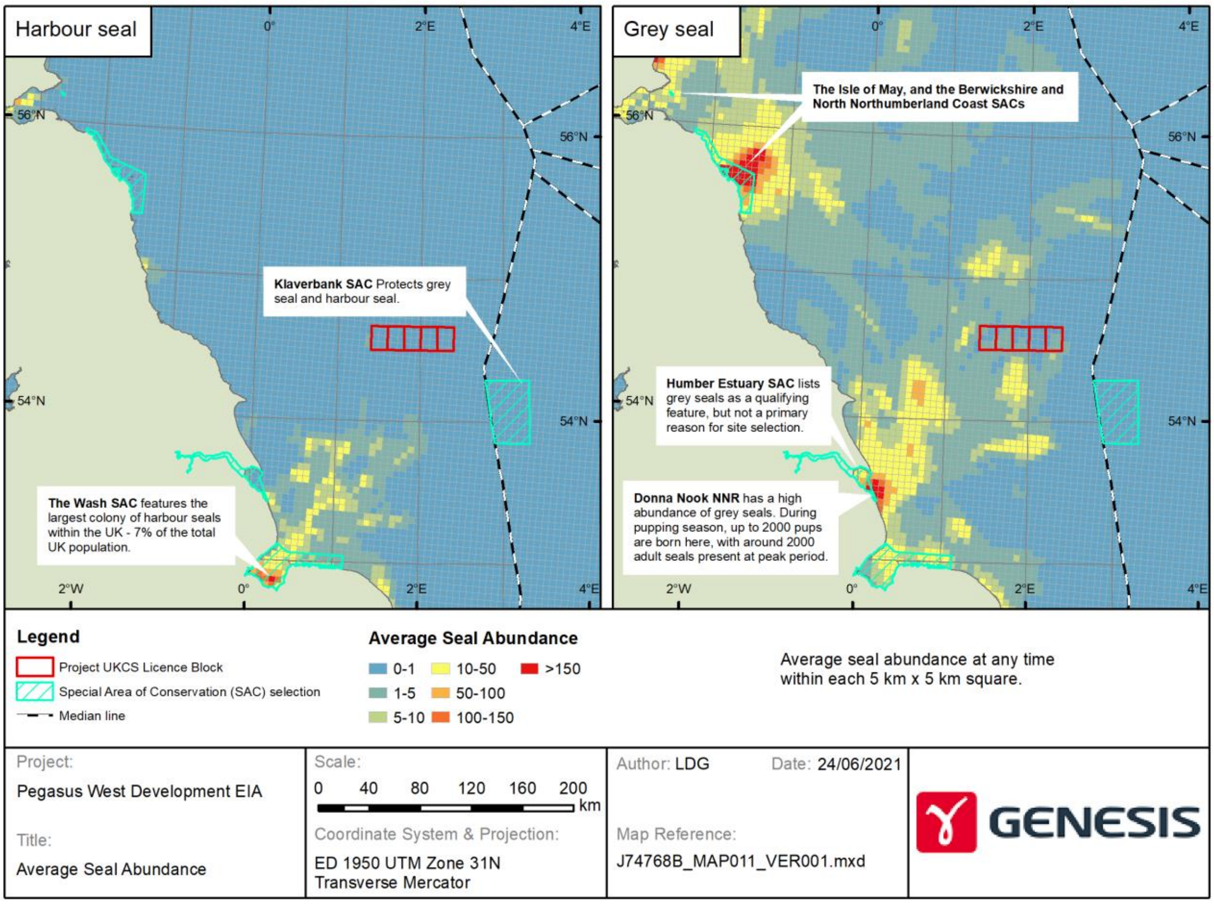


Figure 3-17 Harbour and grey seal distribution in the North Sea (SMRU, 2017)

3.3.5.2 Cetaceans

Many activities associated with the offshore oil and gas industry have the potential to impact on cetaceans by causing physical injury, disturbance or changes in behaviour. Activities with the potential to cause disturbance or behavioural effects include: drilling, seismic surveys, vessel movements, construction work and decommissioning (JNCC, 2008). All cetacean species occurring in UK waters are afforded EPS status (see Section 3.4.4).

Compared to the central North Sea and NNS, the SNS generally has a relatively low density of marine mammals, with the likely exception of harbour porpoise (BEIS, 2016). While over ten species of cetacean have been recorded in the SNS, only harbour porpoise (*Phocoena phocoena*) and white-beaked dolphin (*Lagenorhynchus albirostris*) can be considered as regularly occurring throughout most of the year, with minke whale (*Balaenoptera acutorostrata*) as a frequent seasonal visitor. Bottlenose dolphin (*Tursiops truncates*) and Atlantic white-sided dolphin (*Lagenorhynchus acutus*) can be considered uncommon visitors (BEIS, 2016).

Two minke whales were recorded by the Marine Mammal Observer during the 2018 pipeline route geophysical survey, on the 4th and 7th of May (Gardline, 2018d).

The JNCC has compiled an Atlas of Cetacean Distribution in Northwest European Waters (Reid *et al.,* 2003) which gives an indication of the annual distribution and abundance of cetacean species in the North Sea and wider UKCS. Figure 3-18 illustrates the distribution and abundance of the cetacean species most frequently recorded in the proposed Pegasus West Development area.

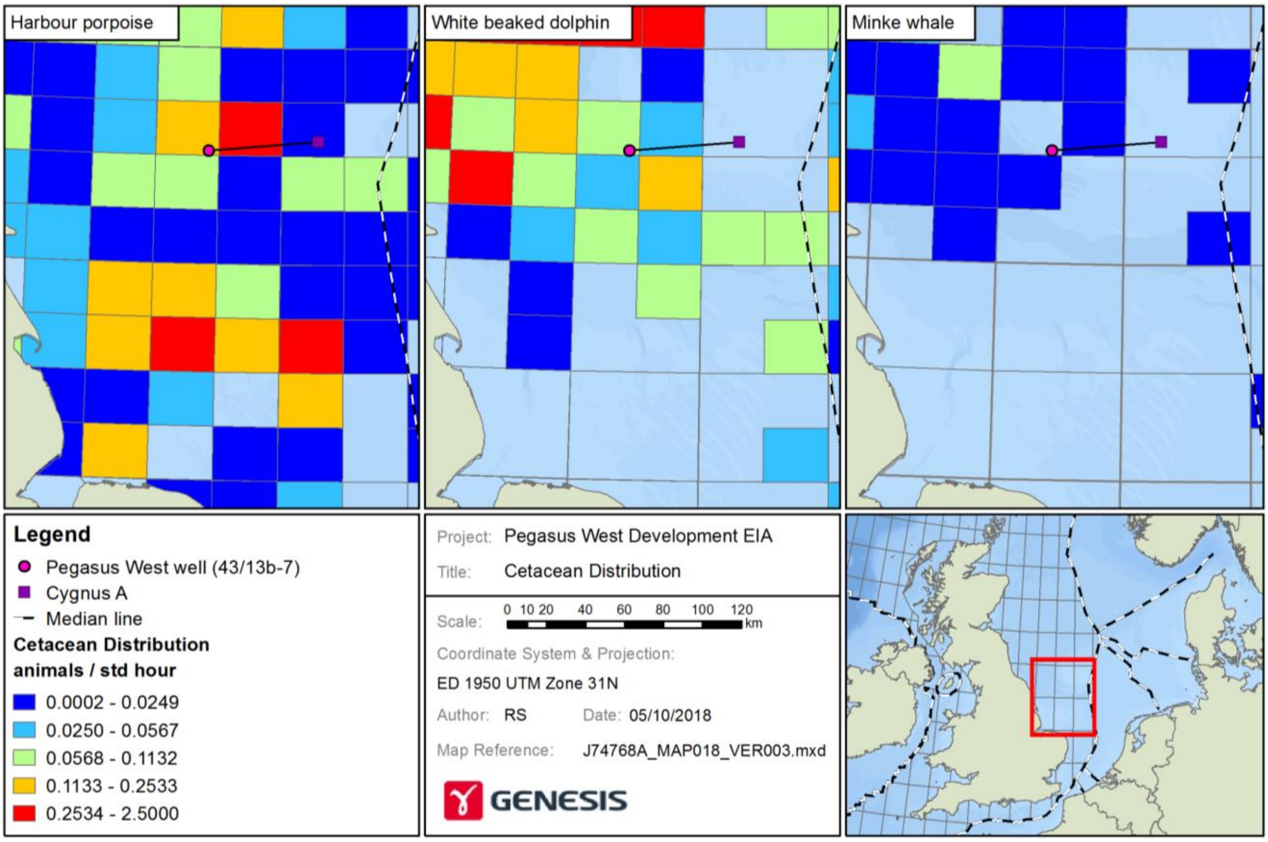


Figure 3-18 Distribution of cetacean species in the SNS (Reid *et al.,* 2003)

A series of Small Cetacean Abundance in the North Sea (SCANS) surveys have been conducted to obtain an estimate of cetacean abundance in North Sea and adjacent waters, the most recent results are SCANS-III are presented in Hammond *et al.,* (2017). Aerial and shipboard surveys were carried out during the summer of 2016 to collect data on the abundance of harbour porpoise, bottlenose dolphin, Risso's dolphin, white-beaked dolphin, white-sided dolphin, common dolphin, striped dolphin, pilot whale, all beaked whale species combined, sperm whale, minke whale and fin whale.

The proposed Pegasus West Development is located within SCANS-III survey area 'O'. Aerial survey estimates of animal abundance and densities (animals per km^2) within this area are provided in Table 3-14.

SCANS-III SURVEY BLOCK	SPECIES	ANIMAL ABUNDANCE	DENSITY (ANIMALS/KM^2)
O	Harbour porpoise	53,485	0.888
	White-beaked dolphin	143	0.002
	Minke whale	603	0.010

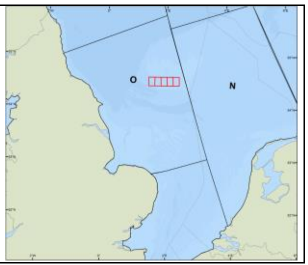


Table 3-14 Cetacean abundance and density in SCANS-III Survey Block 'O' (Hammond *et al.*, 2017)

The JNCC have published the 'regional' population estimates for the seven most common species of cetacean occurring in UK waters (Inter-Agency Marine Mammal Working Group IAMMWG, 2015). Divided into Management Units (MUs), the estimated abundance of animals in these MUs are currently considered the reference populations for cetacean species in the North and Celtic Seas. Phase III of the Joint Cetacean Protocol (JCP) provides abundance estimates (adjusted average summer density surfaces from 2007-2010) which can be used to scale the MU populations to provide a reference population estimate for any given area (Paxton *et al.,* 2016). These abundance estimates provide an indication of the spatial scale and the relevant populations at which impacts should be assessed. The relevant populations are presented in Table 3-15.

SPECIES	MU POPULATION	DOGGER BANK		SOUTH DOGGER BANK	
		% AREA OF RELEVANT MU	SCALED ABUNDANCE TO RELEVANT AREA	% AREA OF RELEVANT MU	SCALED ABUNDANCE TO RELEVANT AREA
Harbour porpoise	227,298	3	6,819	2.4	5,455
White-beaked dolphin	15,895	1.6	254	1.3	207
Minke whale	23,528	1.6	376	1.3	306

Table 3-15: MU cetacean abundance scaled to relevant area (IAMMWG, 2015; Paxton *et al.*, 2016)

Recent cetacean distribution maps produced by Waggit *et al.* (2019) indicate the presence of harbour porpoise at a high density of *c*. 0.565 – 0.791 animals/ km^2, and white-beaked dolphin at a low density < 0.226 animals/ km^2 around the Pegasus West Development (Waggit *et al*. 2019). These values differ slightly from the densities noted by Hammond *et al.,* (2017) across the SCANS III survey area (Block O) within which the blocks occur (Table 3-14).

3.3.5.2.1 Harbour porpoise

Tagging studies undertaken in Denmark indicate that harbour porpoises range widely in the North Sea, with individuals tagged in the Skagerrak occurring off the east coasts of Scotland and England (Sveegaard *et al*., 2011). Harbour porpoise densities vary seasonally and across the Southern

North Sea SAC. In the central and northern area of the SAC, the highest densities occur during the summer period, with modelled harbour porpoise densities greater than 3.0 per km^2 occurring widely across the SNS, including the project area (Figure 3-19). During the winter period the distribution of harbour porpoise in the SNS changes, with reduced densities over the central and northern area but an increase in densities in nearshore waters and the southern part of the Southern North Sea SAC (Figure 3-19) (Heinänen and Skov, 2015).

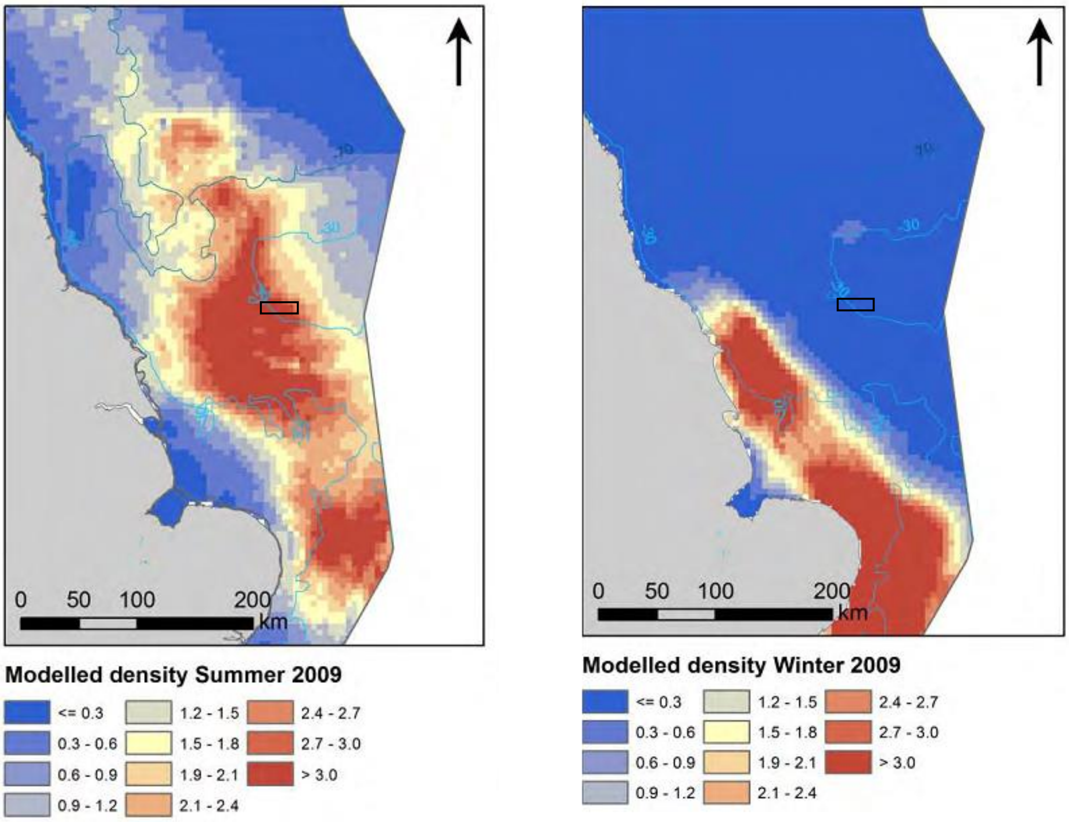


Figure 3-19 Estimated densities (no/km^2) of harbour porpoise in the SNS in relation to the project location (Heinänen & Skov 2015)

Harbour porpoise show a preference for coarser seabed sediment areas such as sand and gravel rather than fine sediments (e.g. mud). These sediments are also associated with sandeels, one of their preferred prey species. Harbour porpoise feed on a wide variety of fish and generally focus on the most abundant local species. The predominant prey type appears to be bottom-dwelling fish, although shoaling fish such as mackerel and herring are also taken (JNCC, 2017d).

3.4 Habitats and Species of Conservation Concern

The EU Habitats Directive (92/43/EEC) and the EU Birds Directive (79/409/EEC) are the main driving forces for safeguarding biodiversity in Europe. Through the establishment of a network of protected sites these directives provide for the protection of animal and plant species of European importance and the habitats that support them. The Habitats Directive and the Birds Directive have been enacted in the UKCS by UK legislation as described in Section 1.5.

The Habitats Directive lists those habitats and species (Annex I and II respectively) whose conservation requires the designation of special areas of interest. These habitats and species are to be protected by the creation of a series of SACs, and by various other safeguard measures such as Sites of Community Importance (SCIs) for particular species. SACs are sites that have been adopted by the European Commission (EC) and formally designated by the government of the country where the site lies and SCIs are sites that have been adopted by the EC but not yet formally designated by the government of the relevant country.

The Birds Directive requires member states to nominate sites as Special Protection Areas (SPAs). Together with adopted SACs, the SPA network form the ‘Natura 2000’ network of protected areas in the European Union. Figure 3-20 shows the location of the proposed Pegasus West Development in relation to protected areas.

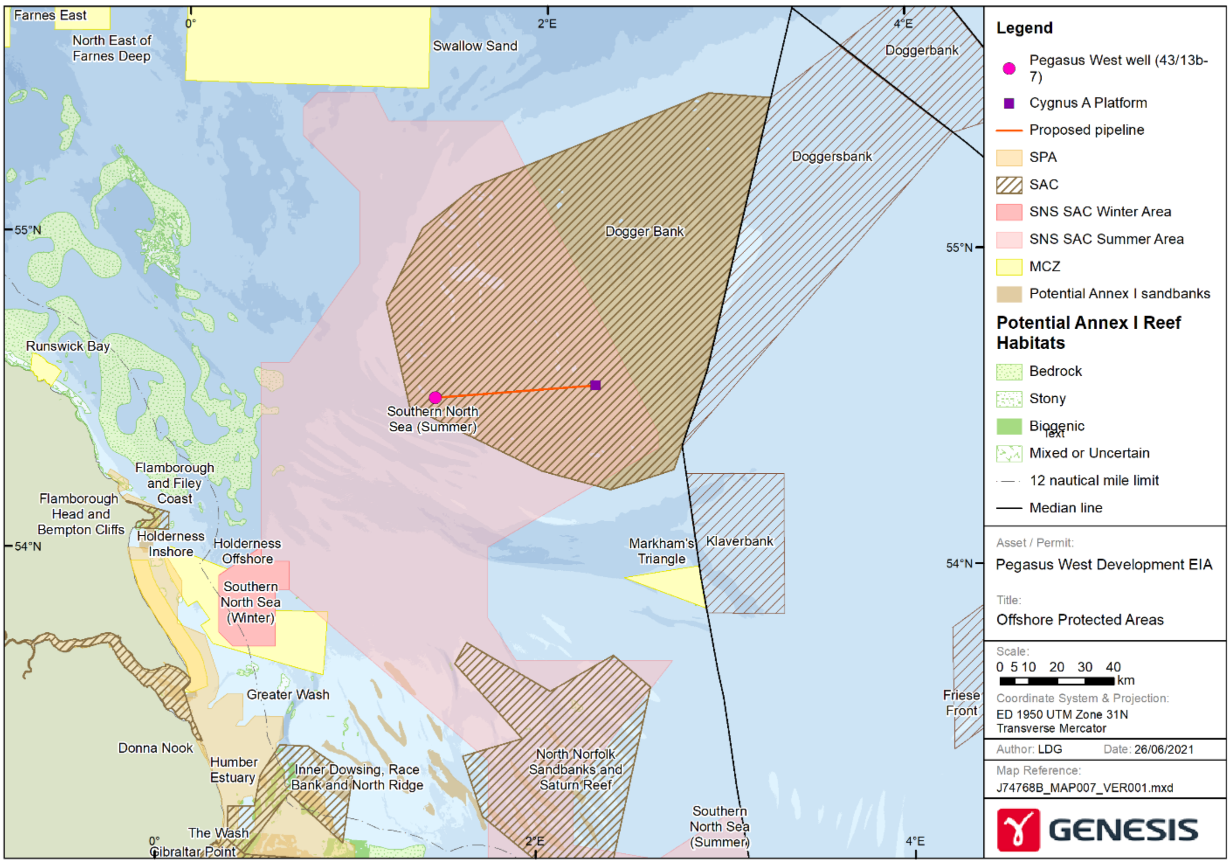


Figure 3-20 Protected areas and potential Annex I habitats in the region

3.4.1 Special areas of conservation/sites of community importance

There are currently 116 SACs with marine components, covering approximately 14% of the UK's marine area.

Of the Annex I habitat types listed as requiring protection in the Habitats Directive, three potentially occur in the UK offshore waters (EC, 2013):

- Sandbanks which are slightly covered by seawater at all times;
- Reefs:
    - Bedrock reefs – made from continuous outcroppings of bedrock which may be of various topographical shapes (e.g. pinnacles and offshore banks);
    - Stony reefs- aggregations of boulders and cobbles which may have some finer sediments in interstitial spaces;
    - Biogenic reefs – formed by e.g. cold water corals (e.g. *Lophelia pertusa*), polychaete worm *Sabellaria spinulosa*, horse mussel *Modiolus modiolus*;

- Submarine structures made by leaking gases.

The proposed Pegasus West Development is located within two SACs, the Dogger Bank SAC and the Southern North Sea SAC. Beyond these, the nearest SAC/SCI is Klaverbank in the Dutch sector of the North Sea, approximately 44 km to the south-east of Cygnus (Figure 3-20).

The pipeline EBS identified areas that fall within the definition of 'Sandbanks which are slightly covered by seawater at all times' (Gardline, 2018b). No other Annex I habitats have been identified in the vicinity of the proposed project activities (Gardline, 2018b; Fugro, 2012; Gardline, 2010).

3.4.1.1 Dogger Bank SAC

The Dogger Bank has been selected under the EU Habitats Directive as an SAC based on the following features:

- Sandbanks which are slightly covered by sea water all the time (qualifying);
- Harbour porpoise (*Phocoena phocoena*) (non-qualifying);
- Grey seal (*Halichoerus grypus*) (non-qualifying); and
- Common seal (*Phoca vitulina*) (non-qualifying);

The SAC boundary encompasses 12,331 km^2 of seabed, and includes the largest single continuous expanse of shallow sandbank in UK waters. In strict geological terms, the Dogger Bank is not a sandbank at all, but is a large shallow plateau which was formed by glacial processes before being submerged by sea level rise. A large part of the southern area of the bank is covered by water seldom deeper than 20 m, the reason for its qualification as an Annex I habitat. It is also of international importance, extending into German and Dutch waters where it is designated as the German Dogger Bank SAC and Dutch Dogger Bank SCI respectively.

The Conservation Objectives for the Dogger Bank SAC are:

For the (qualifying) feature to be in favourable condition thus ensuring site integrity in the long term and contribution to Favourable Conservation Status of Annex I Sandbanks which are slightly covered by seawater all the time. This contribution would be achieved by maintaining or restoring, subject to natural change:

- *The extent and distribution of the qualifying habitat in the site;*
- *The structure and function of the qualifying habitat in the site; and*
- *The supporting processes on which the qualifying habitat relies (JNCC, 2018).*

3.4.1.2 Southern North Sea SAC

The proposed Pegasus West Development is located within the Southern North Sea SAC, identified as an area of importance for harbour porpoise. The SAC is a single feature site, designated solely for the purpose of contributing to the Favourable Conservation Status (FCS) of harbour porpoise populations at the national, bio-geographical and European level. The Conservation Objectives for the site are:

To avoid deterioration of the habitats of the harbour porpoise or significant disturbance to the harbour porpoise, thus ensuring that the integrity of the site is maintained and the site makes an appropriate contribution to maintaining FCS for the UK harbour porpoise.

The aim is to achieve this by ensuring that:

- *The species is a viable component of the site (e.g. they are able to survive and live successfully within the site);*

- *There is no significant disturbance of the species; and*
- *The supporting habitats and processes relevant to harbour porpoises and their prey are maintained (JNCC, 2016a).*

As harbour porpoise are highly mobile species, the SAC covers a large area. The Southern North Sea SAC covers 36,958 km^2, extending down the North Sea from the River Tyne south to the Thames. The SAC ranges in depth from Mean Low Water down to 75 m, with the majority of the site is shallower than 40 m and characterised by sandy, coarse sediments. These physical characteristics are thought to be preferred by harbour porpoise, likely due to availability of prey.

3.4.2 Special Protection Areas

The Birds Directive requires member states to identify and nominate sites as SPAs for the protection of birds listed in Annex I of the Directive or sites that hold significant populations of regularly occurring migratory species. SPAs are designated in two stages, firstly as potential (p)SPAs for sites approved by Government prior to confirmation of classification at an EU level. SPAs are also designated as Sites of Special Scientific Interest (SSSI).

The closest SPA to the proposed Pegasus West Development is the Flamborough Head and Bempton Cliffs SPA, designated for an internationally important seabird assemblage. It is approximately 104 km from the Pegasus West well location and, given this distance, is unlikely to be directly impacted by the proposed project activities.

3.4.3 Marine Conservation Zones

The Marine and Coastal Access Act 2009 allows for the creation of Marine Conservation Zones (MCZs) in the territorial waters adjacent to England and Wales and UK offshore waters. The purpose of these new conservation measures is to halt the deterioration of the state of the UK's marine biodiversity and promote recovery where appropriate, support healthy ecosystem functioning and provide the legal mechanism to deliver the UK's European and international marine conservation commitments, such as those laid out under the Marine Strategy Framework Directive, OSPAR Convention and Convention on Biological Diversity. MCZs protect a range of nationally important marine wildlife, habitats, geology and geomorphology.

The nearest MCZ to the proposed Pegasus West Development is the Markham's Triangle MCZ (Figure 3-20) which is approximately 68 km south of Cygnus and designated for broad scale habitat features such as subtidal sand and subtidal coarse sediments.

3.4.4 Species of conservation concern

3.4.4.1 Marine mammals

Four marine mammal species listed under Annex II of the Habitats Directive occur in relatively large numbers in UK offshore waters:

- Grey seal (*Halichorerus grypus*);
- Harbour seal (*Phoca vitulina*);
- Bottlenose dolphin (*Tursiops truncatus*); and
- Harbour porpoise (*Phocoena phocoena*).

As discussed in Section 0, the grey seal and harbour porpoise are the most likely to occur in the project area.

All the cetacean species found in UK waters are listed under Annex IV of the Habitats Directive and therefore have EPS status, meaning it is an offence to injure or disturb them. Developers must therefore consider the requirement to apply for the necessary licences if there is a risk of causing injury or disturbance to EPS.

3.4.4.2 Other species

The designation of species requiring special protection in UK waters is receiving increasing attention with particular consideration being paid to large slow growing species such as sharks and rays. A number of international laws, conventions and regulations as well as national legislative Acts have been implemented which provide for the protection of these species. They include:

- The UK Biodiversity Action Plan (BAP) priority fish species (JNCC, 2016b);
- The OSPAR List of Threatened and/or Declining Species & Habitats (OSPAR, 2018);
- The IUCN (International Union for Conservation of Nature) Red List of Threatened Species (IUCN, 2021);
- The Wildlife and Countryside Act 1981 (which consolidates and amends existing national legislation to implement the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention) and the Birds Directive in Great Britain) (JNCC, 2016c). The Wildlife and Countryside Act makes it an offence to intentionally kill, injure, possess or trade any animal listed in Schedule 5 and to interfere with places used by such animals for shelter or protection; and
- The EC Habitats Directive (transposed into UK law through the Conservation of Habitats and Species Regulations 2010 in England and Wales and also the 1994 Regulations in Scotland).

The species of fish listed under these measures, that could potentially occur in the vicinity of the Pegasus West Development, are listed in Table 3-16.

SPECIES	UK BAP	OSPAR	IUCN	BERN CONVENTION	HABITATS REGULATIONS
Allis shad *(A. alosa*)	✓	✓	Least Concern	✓	×
Twaite shad (*A. fallax*)	✓	×	Least Concern	✓	×
Angel shark *(S. squatina*)	✓	✓	Critically Endangered	✓[1]	×
Atlantic salmon (*S. salar*)	✓	✓	Least Concern	✓[2]	×
Atlantic cod *(G. morhua)*	✓	✓	Vulnerable	×	×
Common skate (*D. batis*)	✓	✓	Critically Endangered	×	×
Herring (*C. harengus*)	✓	×	Least Concern	×	×
Lesser sandeel (*A. marinus*)	✓	×	Least Concern	×	×
Whiting (*Merlangius merlangus*)	✓	×	Least Concern	×	×
Basking shark (*C. maximus*)	✓	×	Endangered	✓	×
Porbeagle shark (*L. nasus*)	✓	✓	Vulnerable	✓	×

[1] Applies in the Mediterranean only.
[2] Does not apply in sea waters.

Table 3-16 Designation of fish species occurring in the vicinity of the proposed development

3.4.4.3 Arctica islandica

As discussed in Section 3.3.2.4, *A. islandica* is listed on the OSPAR list of threatened and/or declining species and habitats (OSPAR, 2008).

3.5 Socio-Economic Baseline

Socio-economic impact assessment is a requirement of the 2020 Offshore EIA Regulations. All new projects must consider both their positive and negative socio-economic impacts in terms of benefits to the local communities and the country, along with the potential interface with existing industries and communities.

Negative socio-economic impacts associated with the proposed Pegasus West Development are unlikely given that the offshore oil and gas industry is an established part of the UK's economy and society. The project will have positive impacts by creating and maintaining skilled employment in the construction, energy and service industries. Pegasus production will reduce the UK's dependence on imported natural gas and provide revenue to the Exchequer.

The project does have the potential to have localised impacts on offshore industries and users of the project area, which are described in this section.

3.5.1 Commercial fishing

The physical presence of offshore structures has the potential to interfere with fishing activities by obstructing access to fishing grounds. Knowledge of fishing activities and the location of the major fishing grounds is, therefore, an important consideration when evaluating any potential socio-economic impacts from offshore developments.

The International Council for the Exploration of the Sea (ICES) divides the North-east Atlantic into rectangles measuring 30 nm by 30 nm. Each ICES rectangle covers approximately one half of one oil and gas quadrant i.e. 15 license blocks. ICES rectangles are used to collect statistics describing the distribution of fishing effort and landings across sea areas. The proposed Pegasus West Development is located within ICES rectangles 38F1 and 38F2.

3.5.1.1 Fishing effort

The importance of an area to the fishing industry can be assessed in terms of fishing effort, measured by the number of days fished in each ICES rectangle. Based on annual fishing effort by UK vessels >10m in length, the importance of ICES rectangles 38F1 and 38F2 can be considered low when compared to other areas of the UKCS. Fishing effort is greater in 38F2 than in 38F1. For both rectangles combined, total effort was 355.79 days in 2019, which constitutes 0.28% of the total UK fishing effort[1] (Scottish Government, 2021). A more detailed breakdown of fishing effort within ICES rectangles 38F1 and 38F2 is provided in Table 3-17 and Figure 3-21.

YEAR	UK TOTAL EFFORT (DAYS)	EFFORT (DAYS) IN 38F1	EFFORT (DAYS) IN 38F2	% OF UK TOTAL (38F1 & 38F2 combined)
2015	124822.39	92.50	248.06	0.27
2016	131589.72	34.78	236.61	0.21
2017	125824.01	50.24	196.80	0.20
2018	124843.04	22.46	126.56	0.12
2019	126235.62	278.87	76.92	0.28
Average	**126662.96**	**95.77**	**176.99**	**0.22**

Table 3-17 Annual fishing effort in the ICES rectangles 38F1 and 38F2 (Scottish Government, 2021)

[1] Note this value is based on landing values reported for ICES rectangles within which more than five UK vessels measuring 10m were active. In those ICES rectangles where < 5 vessels were active the information is considered disclosive and is therefore not available.

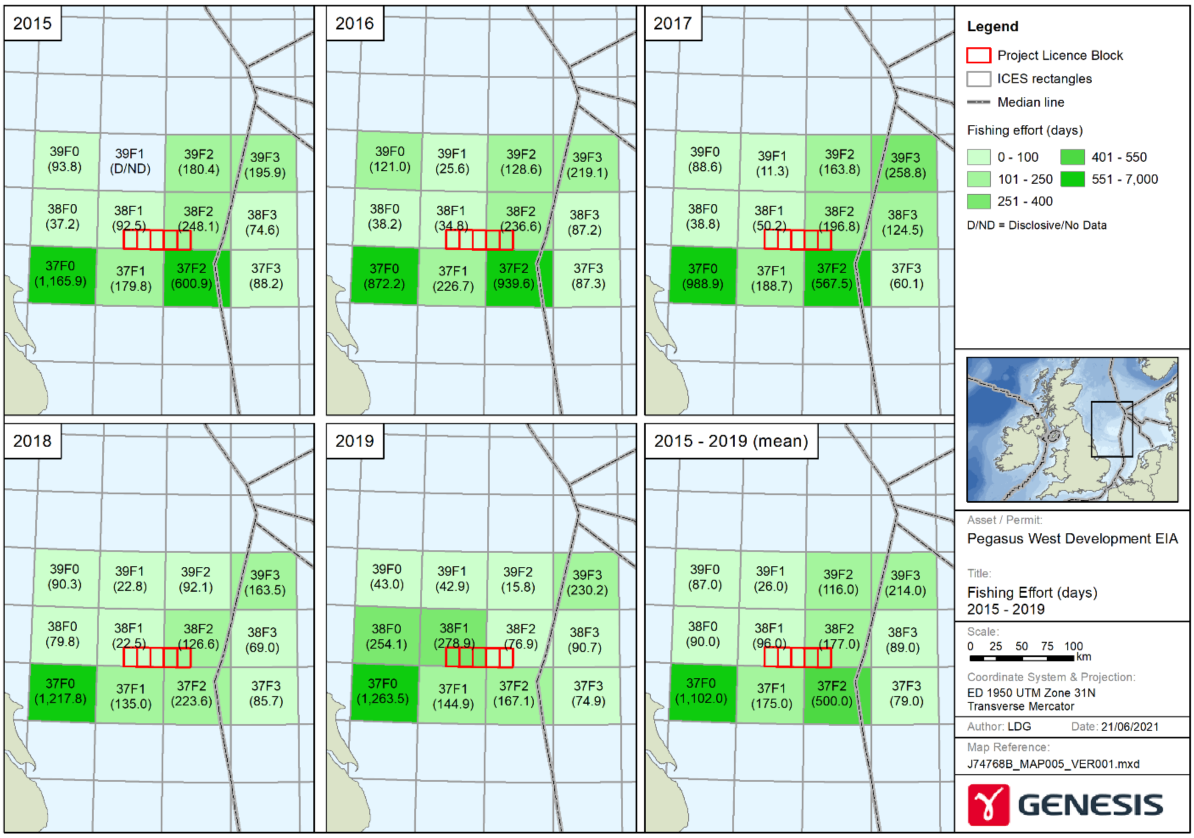


Figure 3-21 Fishing effort over five years (2015 – 2019) in the vicinity of the proposed project (Scottish Government, 2021)

It should be noted that fishing activity is not uniformly distributed within ICES rectangles. Figure 3-22 illustrates this, showing relatively low levels of fishing effort around the pipeline route, and an area of high fishing effort approximately 47 km south of Cygnus where *Nephrops* are targeted.

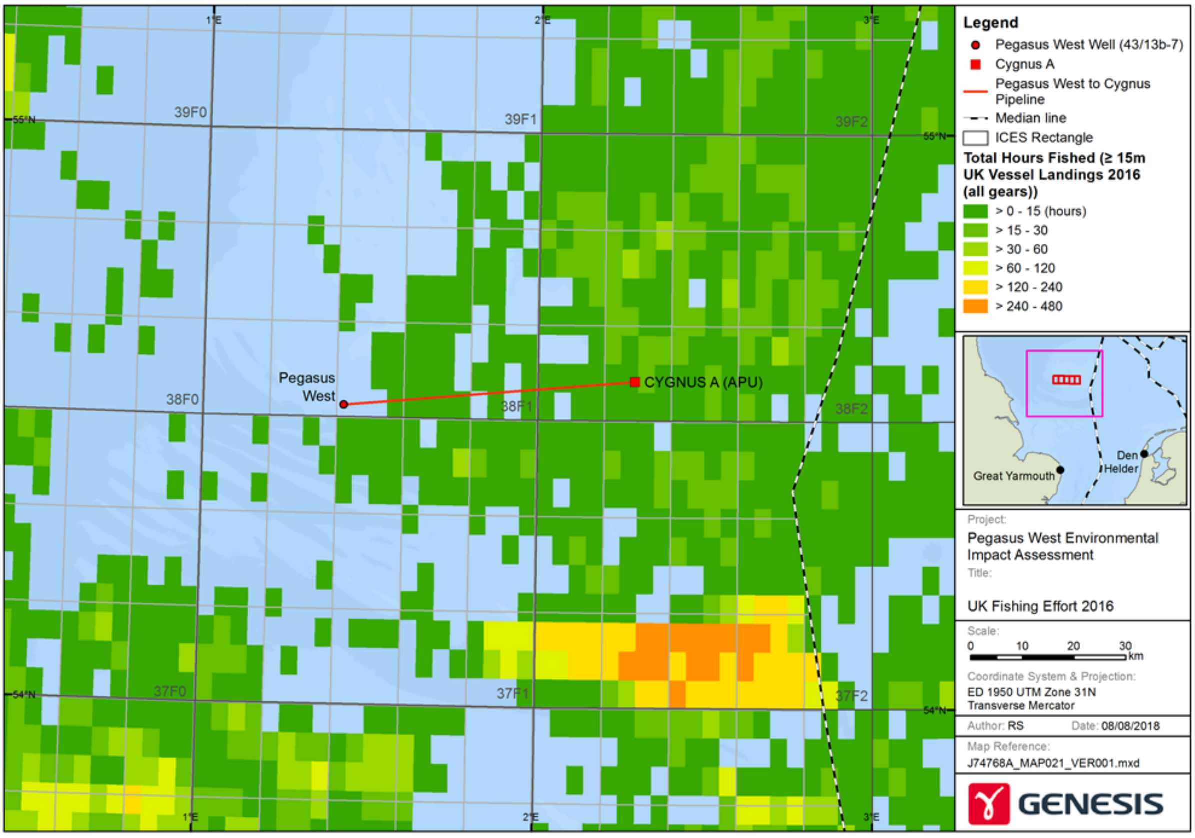


Figure 3-22 Fishing effort in the project area in 2016 (MMO, 2018a)

3.5.1.2 Fishing gear

Data from 2015 to 2019 shows that trawls are used primarily in ICES rectangles 38F1 and 38F2, with 38F2 showing higher levels of effort than 38F1 (Table 3-18). Data for fishing using seine nets and traps is classified as disclosive (i.e. less than five vessels (>10 m) recorded).

Gear Type	2015		2016		2017		2018		2019	
	38F1	38F2	38F1	38F2	38F1	38F2	38F1	38F2	38F1	38F2
Seine nets	D	D	-	-	-	-	-	-	-	D
Trawls	59	219	33	237	50	197	22	127	26	76
Traps	D	-	D	-	-	-	-	-	252	-

Table 3-18 Gear types used within ICES 38F1 and 38F2 (2015-19) (Scottish Government, 2021)

3.5.1.3 Fishing landings

Figure 3-23 and Table 3-19 show the annual landings between 2015 – 2019 of demersal, pelagic and shellfish species in ICES rectangles 38F1 and 38F2[2].

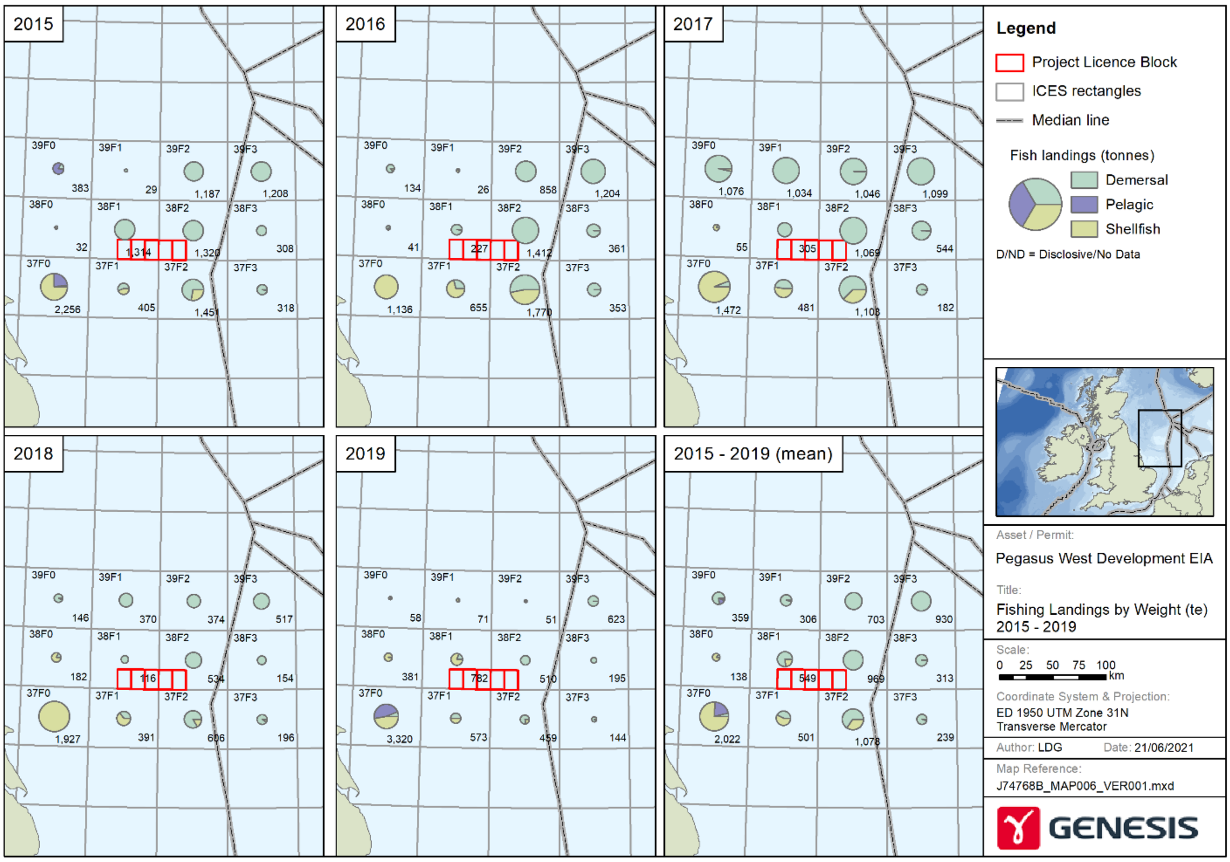


Figure 3-23 UK reported landings by quantity (te) within the proposed Pegasus West Development (2015 – 2019) (Scottish Government, 2021)

Landings were largely dominated by demersal fish species from 2015 to 2018, however, in 2019 demersal species comprise only 33.4 % of the total value and 50.7 % of the total live weight of landings from 38F1 and 38F2 combined. Shellfish were also a key contributor to landings in 2019, comprising 66.6 % of the total value and 49.2 % of total live weight of landings from 38F1 and 38F2 combined. However, the contribution of 38F1 and 38F2 to total UK landings is relatively low, totalling with only 0.27 % of the total UK value and 0.26 % of the total landed weight in 2019.

[2] As for fishing effort data, reporting landing data provided refers to landings data by UK vessels over 10 m into UK ports where > 5 m vessels have been active.

ICES	SPECIES TYPE	2015		2016		2017		2018		2019	
		Value (£)	Live weight (Te)	Value (£)	Live weight (Te)	Value (£)	Live weight (Te)	Value (£)	Live weight (Te)	Value (£)	Live weight (Te)
38F1	Demersal	677,009	1,311	306,224	221	401,668	303	275,226	115	105,458	149
	Pelagic	26	0	381	0	253	0	107	0	26	0
	Shellfish	6,340	3	8,139	6	2,492	2	542	1	1,367,043	632
	Total	**683,375**	**1,314**	**314,745**	**227**	**404,414**	**305**	**275,875**	**116.16**	**1,472,528**	**782**
38F2	Demersal	1,864,323	1,311	2,036,993	1,404	1,457,677	1,063	1,115,222	531	583,071	506
	Pelagic	25	0	162	0	442	0	52	0	146	0
	Shellfish	9,694	9	8,529	8	4,936	5	1,895	3	4,098	4
	Total	**1,874,042**	**1,320**	**2,045,684**	**1,412**	**1,463,054**	**1,069**	**1,117,169**	**534.29**	**587,315**	**510**
Total (38F1 & 38F2)		2,557,417	2,634	2,360,429	1,639	1,867,468	1,374	1,393,044	650.45	2,059,843	1,292

Table 3-19 Live weight and value of fish landings by species type in 38F1 and 38F2 (2015 – 2019) (Scottish Government, 2021)

3.5.2 Aquaculture and shellfish water protection sites

The worldwide decline of ocean fisheries stocks has provided impetus for the rapid growth of aquaculture. For example, between 1987 and 1997 global production of farmed fish and shellfish more than doubled in weight and value (Naylor *et al.,* 2000). The aquaculture industry is important to the UK's economy, with the production of farmed Atlantic salmon (*Salmo salar*) concentrated in Scottish coastal waters. The mariculture industry in English, Northern Irish and Welsh coastal waters places greater emphasis on shellfish production.

The nearest mariculture sites to the proposed Pegasus West Development are shellfish farms on the north Norfolk coast, and there are designated shellfish waters in the Wash. These mariculture sites and shellfish waters are approximately 176 km south-west of the Pegasus west well. Shellfish waters were introduced by the Shellfish Waters Directive (79/923/EEC) and enabling UK legislation, and are designated to protect and manage water quality in areas where shellfish live and are harvested.

Shellfish waters and shellfish aquaculture sites can be impacted by pollution from various sources, such as run-off from agricultural land or discharges from sewage treatment works. Given their distance from the proposed Pegasus West Development, these sites are not expected to be impacted by the routine operations, however they may be at risk in the event of a large hydrocarbon release to sea, e.g. from a well blowout (considered further in Section 11).

3.5.3 Shipping

The North Sea contains some of the busiest shipping routes in the world, with significant traffic generated by vessels trading between ports at either side of the North Sea and the Baltic. The OGA categorises levels of shipping activity in UKCS licence blocks in terms of vessel density. Shipping density increases along the length of the proposed pipeline route from 'low' at the Pegasus West well end (Blocks 43/13 and 43/14), increasing to 'moderate' where the pipeline traverses Blocks 43/15 and 44/11, then to 'high' around Cygnus (Block 44/12) (OGA, 2016) (Figure 3-24).

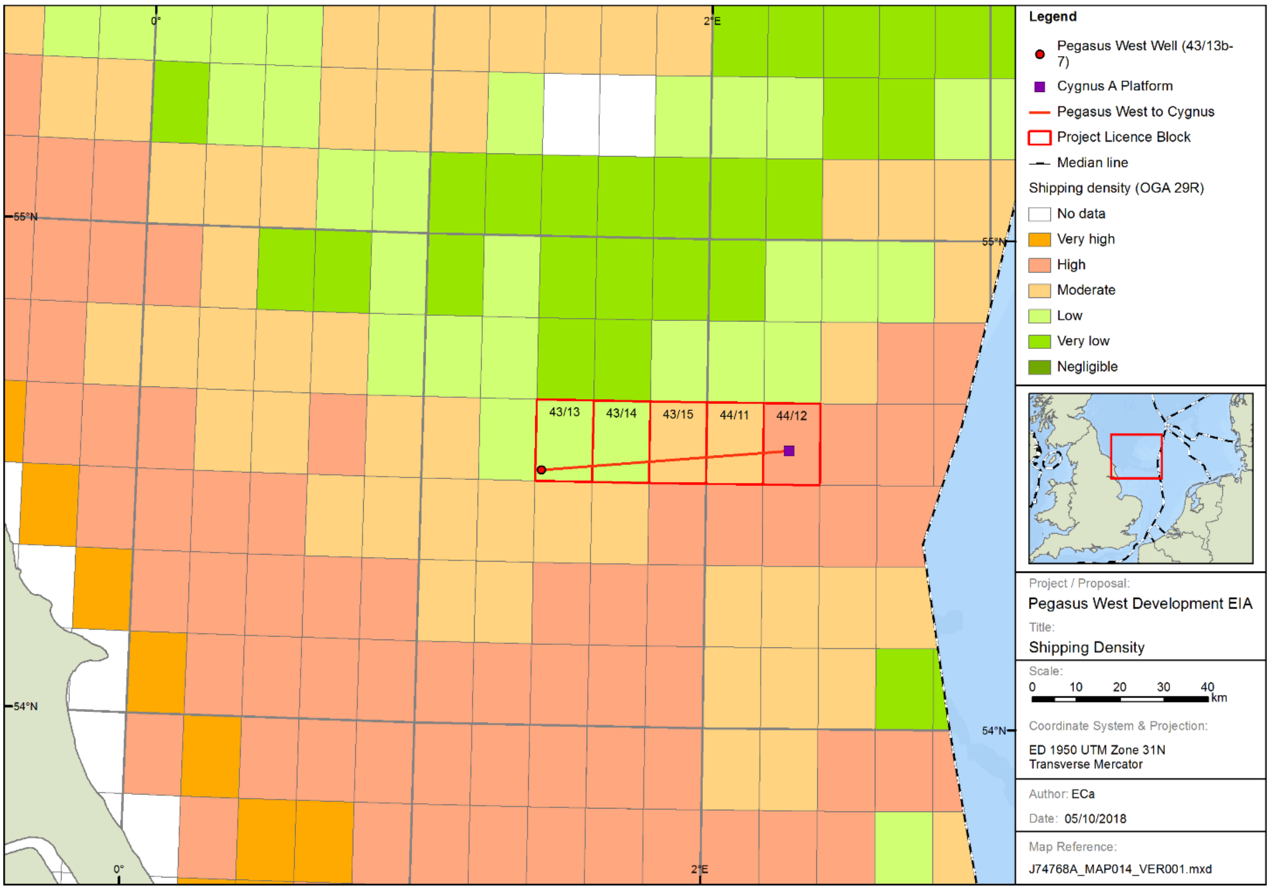


Figure 3-24 Shipping density as categorised by OGA (OGA, 2016)

Where shipping density is low around Pegasus West, this translates to an estimated 1,509 ships per year, or an average of 4 to 5 vessels per day, passing within 10 nm of the Pegasus West well location. The closest identified shipping lane to the Pegasus West well is approximately 0.4 nm away and is used by approximately 84 ships per year (Anatec, 2014). Where shipping density is higher around Cygnus, an estimated 2,027 vessels per year, average of 5 to 6 vessels per day, has been estimated passing within 10 nm of Cygnus (Anatec, 2011).

3.5.4 Renewable energy

Marine renewable energy technologies are developing to exploit wind, wave and tidal resources. Offshore wind is the most developed renewable energy the North Sea, and there are several offshore wind farms in the SNS (note that these include wind farms at the pre-planning stages and the Round 4 preferred sites, as well as operational windfarms). Four offshore wind site agreements are located to the north of the proposed Pegasus West Development (Figure 3-25). They are Dogger Bank A, B, and C, and Sofia wind farms. The closest site is Dogger Bank A, approximately 11 km north of the proposed pipeline route at its nearest point. The Hornsea One Wind Farm is located in excess of 60 km to the south. There is a Round 4 preferred prospects site within the Pegasus West Development area. There are no proposed wave and tidal power developments in the area at this time.

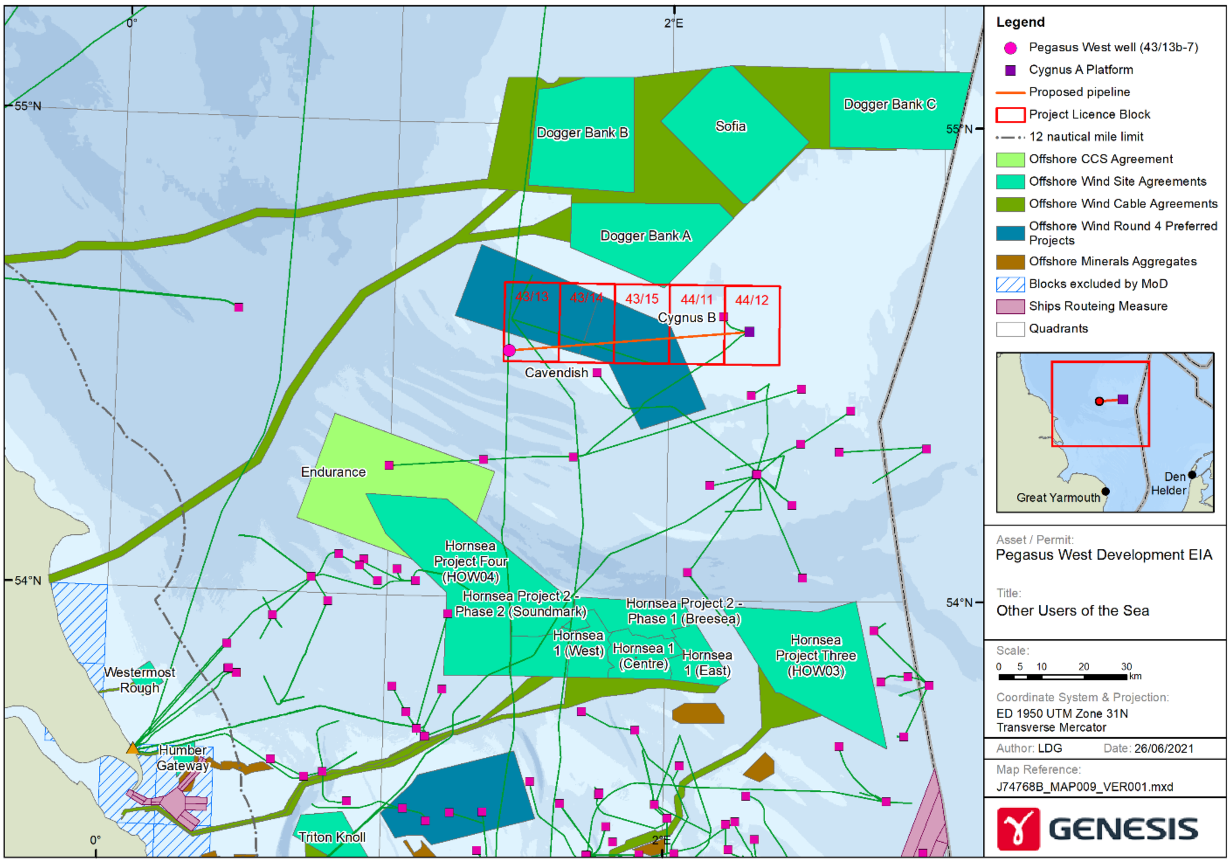


Figure 3-25 Other sea users in the vicinity of the development

3.5.5 Oil and gas activities

The proposed Pegasus West Development is located on the northern edge of a well-established oil and gas production area. The closest surface installation to the project location, excluding the Cygnus host facility, is the Cygnus B platform. Cavendish is situated approximately 6.5 km south of the proposed pipeline route at its closest point (Figure 3-25).

As described in Section 2.5.3.3, the proposed pipeline route will cross three oil and gas pipelines, the:

- Esmond to Bacton pipeline;
- Esmond to Gordon pipeline; and
- Cygnus A to Cygnus B infield pipeline and umbilical.

The Shell-operated Shearwater to Bacton (SEAL) 34" gas line (PL1570) is approximately 355 m west of the start of the proposed Pegasus pipeline route (Gardline, 2018c).

3.5.6 Other offshore activity

3.5.6.1 Military

There are no military exercise areas in proximity the proposed development.

3.5.6.2 Telecommunications cables

There is one active telecommunications cable, 'TAMPNET', in the vicinity of the proposed project which connects the Cygnus A Hub to the UK mainland, making landfall at Lowestoft. The cable does not spatially coincide with the project footprint (KIS-ORCA, 2018).

3.5.6.3 Carbon and gas storage

The Endurance carbon capture and storage agreement is located approximately 27 km south west of the proposed Pegasus West Development.

3.5.6.4 Marine aggregates

There are no marine aggregate extraction areas in proximity the proposed development. There is an aggregate licence application area, the Humber 5 (Area 483), approximately 79 km south of the proposed Pegasus West Development.

3.5.6.5 Meteorological equipment

The Dogger Bank West Meteorological Met Mast is located approximately 22 km north of the proposed Pegasus West Development.

3.5.6.6 Cultural heritage

There are no protected wreck sites or site protected by the Military Remains Act (1986) in the vicinity of the proposed Pegasus West Development (MMO, 2018b).

As can be seen in Figure 3-26, the nearest potential wreck to the location of the proposed activities (Greynight) is *c*. 4 km from the proposed pipeline. At this distance, the proposed activities will not impact on the wreck such that the presence of wrecks is not considered further.

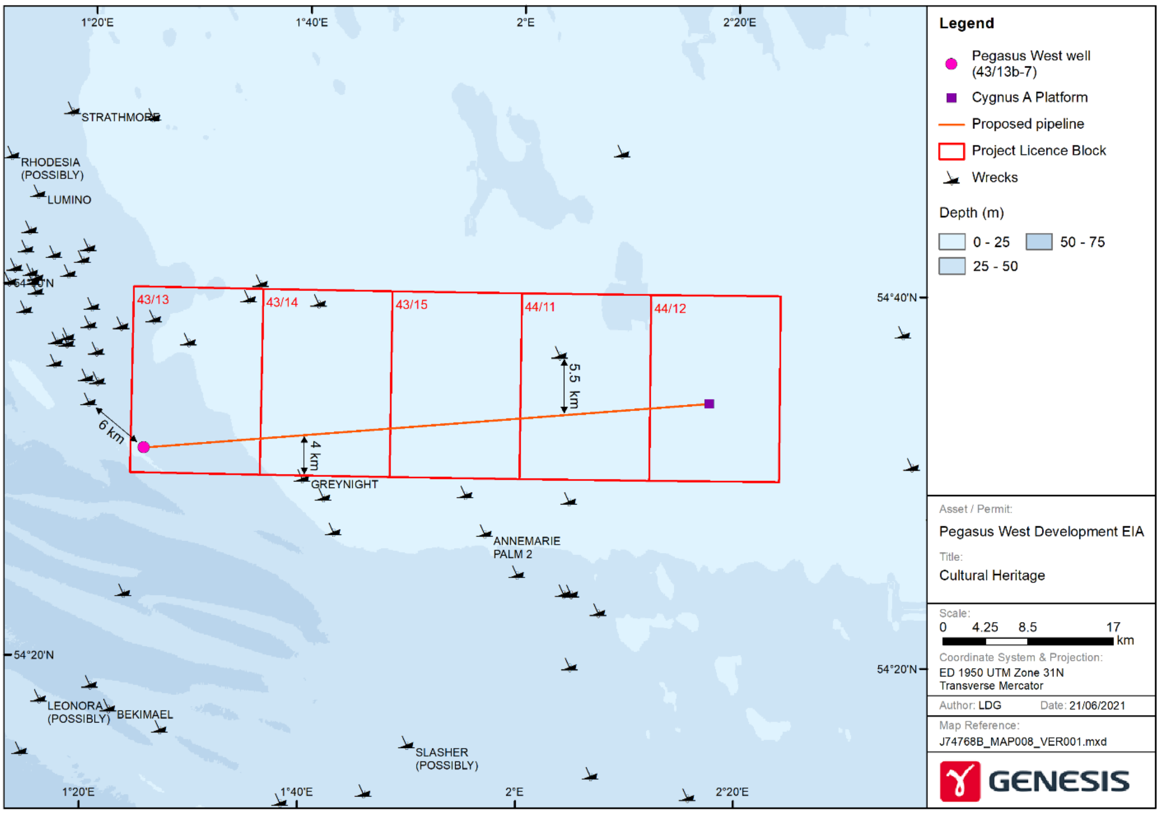


Figure 3-26 Wrecks in the vicinity of the Pegasus West Development

4. ENVIRONMENTAL IMPACT ASSESSMENT METHOD

This section describes the method used by Spirit Energy to assess the significance of environmental and social impacts and risks associated with the proposed Pegasus West Development project.

4.1 Overview

The EIA process reviews project activities to identify planned and unplanned interactions with the environment (aspects). Using baseline environmental information to identify receptors, the potential environmental and socio-economic impact of the project from both planned and unplanned activities is assessed using the method described in Spirit Energy's Guidance for Environmental Management in Capital Projects. The Spirit Energy EIA process aims to preferentially avoid, then minimise, then restore and finally offset adverse impacts using control and mitigation measures. The significance of impacts is evaluated (on a scale of 'low' to 'high' significance) given the application of inherent control and mitigation measures. Where necessary additional and supplementary control and mitigation measures are identified and applied in order to reduce any adverse impacts to a level that is 'as low as reasonably practicable' in line with the philosophy of the Spirit Energy Environmental Policy.

The methods used to assess the impacts of planned and unplanned activities differ slightly, and are described in detail in the following sections.

4.2 Definitions

The most important consideration in any assessment is whether the impacts have been identified, are understood, and that suitable controls and mitigation measures have been documented and will be implemented such that the impacts will be managed to as low as reasonably practicable in line with the philosophy of the Spirit Energy HSES Policy (Figure 1-2).

Definitions of the key terms used in the EIA method are shown in Table 4-1.

Aspect (ISO 14001:2004)	Element of an organisations activities, products or services that can interact with the environment.
Impact (ISO 14001:2004)	Any change to the environment wholly or partially resulting from an organisations environmental aspects.
Inherent Control and Mitigation Measures	• Standard controls for the activity within the region; • Administrative or procedural controls; and • Engineering or physical controls.
Additional or supplementary Control and Mitigation Measures	• Project specific; and • Spirit Energy best practice.
In-combination effect	Effects on the environment which are caused by the combined results of past, current and future activities.

Table 4-1 Definition of key terms

4.3 Significance of Planned Activity Impacts

The Spirit Energy Environmental Assessment Table is used to assess the significance of impacts from planned activities as a function of their extent, and duration (recovery time) for relevant environmental and socio-economic receptor types (Table 4-2).

							Benefit	**Duration of harmful effect/recovery** (c. 80% of damage rectified)				
Land (soil or sediment) and air								within 1 month	within 1 year	≤3 years	>3 years or >2 growing seasons	>20 years
Surface water (any harm of drinking water source or ground water would be cat 4 or above)								Immediate	< 1 month	≤1 years	>1 year	>10 years
Reinstatement of Built Environment - Can be repaired								immediately	in <1 year	in <3 years	in >3 years	Cannot be rebuilt
Recovery for Societal - Decrease in the availability or quality of a resource								Access immediately	Short term decrease	Medium term decrease	Medium to long term decrease	Long term decrease
Habitats / Species	**Air**	**Soil or sediment**	**Water**	**Built Environment**	**Societal**		+1	1	2	3	4	5
Large area of habitat and/or large number or proportion of population or species impacted.	Large increase in contaminants in the air exceeding quality limits	Large area with contamination resulting in hazardous soil to humans (e.g. skin contact) or the living environment, remediation available (but difficult).	Drinking water standards breached for a large number of properties. Large groundwater body effected. Large water body exceeds a water quality guideline or objective.	Complete destruction of an area of built importance	Large population with high dependence on the impacted resource or large loss for other users.	5	-	6 Minor	10 Moderate	15 Significant	20 Major	25 Catastrophic
Moderate area of habitat and/or moderate number or proportion of population or species impacted.	Moderate increase in contaminants in the air exceeding quality limits.	Moderate area with contamination sufficient to be environmental damage[1] or in alignment with contaminated land legislation.	Drinking water standards breached for a moderate number of properties. Moderate groundwater body effected. Moderate water body exceed a water quality guideline or objective.	Loss of integrity to an area of built importance or nationally registered building leading to de-registering / categorisation with a need for remedial / restorative work.	Moderate population with moderate dependence on the impacted resource or moderate loss for other users.	4	-	4 Negligible	8 Minor	12 Moderate	16 Significant	20 Major
Small area of habitat impacted and/or small number or proportion of population or species impacted.	Small Increase in contaminants in the air exceeding quality limits	Contamination not leading to environmental damage	Drinking water standards breached for a small number of properties. Small groundwater body effected. Small water body exceed a water quality guideline or objective.	Loss of integrity to an area of built importance or nationally registered building with a need for remedial / restorative work.	Small population with small dependence on the impacted resource or small loss for other users.	3	-	3 Negligible	6 Minor	9 Minor	12 Moderate	15 Significant
Change is within scope of existing variability (or acceptable mixing zone) but potentially detectable or all within the site boundary / 500m zone (78.5 hectares).				Loss of integrity to an area of built importance or nationally registered building need for remedial / restorative work.	A small population with some dependence on the impacted resource. Negligible loss to other users.	2	-	2 Negligible	4 Negligible	6 Minor	8 Minor	10 Moderate
Effects are unlikely to be noticed or detectable.						1	-	1 Negligible	2 Negligible	3 Negligible	4 Negligible	5 Negligible

Low	Impact broadly acceptable and considered 'as low as reasonably practicable'	High	Impact intolerable without control and mitigation measures required to be reduce impacts to 'as low as reasonably practicable'
Medium	Impact is tolerable but to be managed to 'as low as reasonably practicable'	P	Positive – Positive or beneficial impact

Table 4-2 Environmental Assessment Table

[1] Damage is defined as per the EU Environmental Liability Directive or equivalent

It is considered that a receptor has recovered when approximately 80% of the damage has been rectified. When these extent and duration variables are combined on the assessment table, the position on the matrix ranks the impacts numerically, and on a scale of 'low', 'medium', or 'high' significance.

All reasonably practicable mitigation and control measures should be applied to drive the level of significance to the bottom left corner. The level of significance which is acceptable should be decided on an impact by impact basis, dependent on project factors such as alternatives, receiving environment and in combination effects, nevertheless all potential impacts should be "as low as reasonably practicable".

4.4 Risk of Impacts from Unplanned Events

The Spirit Energy Risk Assessment Matrix is used for assessing the significance of environmental risks from unplanned events. This is based on the Spirit Energy E&P HSES Risk Assessment Matrix (Table 4-4), and incorporates the likelihood of an event occurring, as well as the severity of the potential impacts, to determine the risk.

The significance of the potential impact is assessed using the Spirit Energy Environmental Assessment Table as described in Section 4.3, and translates across onto the consequences scale on the Risk Assessment Matrix is as shown below in Table 4-3.

IMPACT ASSESSMENT TABLE		Equivalent to	RISK ASSESSMENT MATRIX[2]	
SCALE of IMPACT	Severity ranking		Consequence Scale	ENVIRONMENTAL DESCRIPTION (N/A to built environment or societal)
Catastrophic (25)	H	→	6	**Catastrophic** environmental impact which is widespread or affects a highly sensitive valuable environment requiring long term remediation.
Major (20)	H	→	5	**Major** environmental impact to regional or high value environment requiring protracted remediation.
Significant (15-16)	H	→	4	**Significant** environmental impact on local area. Long term natural recovery or moderate remediation intervention.
Moderate (10-12)	M	→	3	**Moderate** environmental impact in neighbouring area. Longer term natural recovery or minor remediation intervention.
Minor (6-9)	M	→	2	**Minor** environmental impact on site or to lower value environment with short term natural recovery.
Negligible (1-5)	L	→	1	**Negligible** environmental impact.

Table 4-3 Impact to risk conversion

[2] Spirit Energy Risk Assessment Matrix CEU-HSEQ-GEN-GUI-0051

		Frequency (per year) and Likelihood					
		≤1x10^{-5}	>1x10^{-5} to 1x10^{-4}	>1x10^{-4} to 1x10^{-3}	>1x10^{-3} to 1x10^{-2}	>1x10^{-2} to 1x10^{-1}	> 1x10^{-1}
		Highly Unlikely	Very Unlikely	Unlikely	Possible	Moderately Likely	Likely
Consequences – Environment (E)		1	2	3	4	5	6
Catastrophic environmental impact which is widespread or affects a highly sensitive/valuable environment requiring long term remediation.	6	6	12	18	24	20	36
Major environmental impact to regional or high value environment requiring protracted remediation.	5	5	10	15	20	25	30
Significant environmental impact on local area. Long term natural recovery or moderate remediation intervention.	4	4	8	12	16	20	24
Moderate environmental impact in neighbouring area. Longer term natural recovery or minor remediation intervention.	3	3	6	9	12	15	18
Minor environmental impact on site or to lower value environment with short term natural recovery.	2	2	4	6	8	10	12
Negligible environmental impact.	1	1	2	3	4	5	6

KEY

Low	Risk broadly acceptable and considered 'as low as reasonably practicable'
Medium	Risk is tolerable but to be managed to 'as low as reasonably practicable'
High	Risk unacceptable

Table 4-4 Risk Assessment Matrix

4.5 Assessing Project Impacts and Risks

An Environmental Assessment and Management Workshop was held during which project planned activities and potential unplanned events were reviewed, environmental aspects were identified, and the associated environmental impacts and risks were assessed using the method described in Sections 4.3 and 4.4.

The workshop assessed the following project phases:

- Vessel use;
- Well completion;
- Subsea installation activities ;
- Cygnus topsides modifications; and
- Commissioning, start-up and production.

Environmental aspects considered were:

- Physical presence;
- Energy use and atmospheric emissions;
- Underwater sound;
- Seabed disturbance;
- Discharges and releases to sea;
- Large releases to sea; and
- Waste.

The outcome of this initial assessment is presented in Appendix B. Table 4-5 identifies those activities and aspects evaluated as having a 'medium' or 'high' significance impact or risk after the application of control and mitigation measures.

ASPECT	ACTIVITY	SIGNIFICANCE
Seabed disturbance (temporary)	Positioning (and jack up) of JUDR.	6 Medium
Large release to sea	Unplanned event. Well blowout (uncontrolled hydrocarbon release in the event of loss of well control).	6 Medium
Seabed disturbance (temporary)	Installation of subsea infrastructure (e.g. Xmas tree and WPS, pipeline, umbilical, tie-in spools, connection tee or manifold, SSIV, stabilisation features).	12 Medium
Seabed disturbance (permanent)		9 Medium
Physical presence	Physical presence of subsea infrastructure including Pegasus 500m exclusion zone and pipeline spot rock protection.	8 Medium

Table 4-5 Activities identified as having an environmental impact or risk greater than 'low'

The assessment showed that, with the application of inherent control and mitigation measures, the majority of the planned activities are anticipated to have environmental and socio-economic impacts of low significance. The significance of impacts associated with activities that disturb the seabed has been assessed as medium, as has the impact from the physical presence of subsea infrastructure, primarily associated with the new Pegasus West 500 m safety zone. No impacts of high significance are considered to be associated with planned project activities.

As with the planned activities, the significance of environmental risks associated with identified unplanned events were found to be low following the application of inherent control and mitigation measures which reduced the likelihood of the events occurring. One unplanned event, a large release to sea as a result of a well blowout, was assessed to be of medium significance (Table 4-5).

Sections 5 to 10 further assess the impacts of the activities and aspects that:

- Are subject to regulatory control;
- Were found to have a medium impact or medium risk significance to the environment;
- Were raised during the consultation phase; or
- Were identified as areas of public concern.

Section 11 presents the results of modelling carried out to determine the impact of a large hydrocarbon release.

5. PHYSICAL PRESENCE

This section identifies and assesses the impact and risk of impacts associated with the physical presence of project activities and installed subsea infrastructure.

Following the adoption of appropriate control and mitigation measures, residual impacts (and risk of impacts) are assessed in the context of the sensitivity of the receiving environment and the abundance of known receptors.

Note that the impact of sound generated by project vessels is assessed in Section 7, and that the impacts to the seabed and on local benthic communities are assessed in Section 8.

5.1 Sources

The principal planned project activities, including their location and estimated duration, are described in Section 2. Of these, the general use of vessels, including the JUDR, and installed subsea infrastructure have been identified as warranting further assessment in terms of the impact, and potential impact, of their physical presence.

5.1.1 Vessels

A range of vessels will be temporarily present in the project area during well completion, subsea infrastructure installation and Cygnus topsides modifications during which their physical presence may result in navigational restriction and hazard to shipping, prevention of commercial fishing, and behavioural disturbance to marine mammals and seabirds.

5.1.2 Installed subsea infrastructure

The permanent physical presence of installed subsea infrastructure, including the Pegasus West well Xmas tree and associated WPS, surface laid mid-line sections of the production pipeline and EHC umbilical, the production pipeline tie-in spools, surface laid ends of the production pipeline and EHC umbilical, the SSIV at Cygnus, and associated protection and stabilisation features, have the potential to impact commercial fishing, marine mammals and fish. The temporary physical presence of the production pipeline and EHC umbilical on the seabed prior to burial, estimated at up to one week, also have the potential to impact these receptors.

5.2 Impacts and Receptors

5.2.1 Vessels

5.2.1.1 Shipping

The physical presence of project vessels may oblige shipping vessels to alter their course. When compared to shipping levels throughout the UKCS, shipping density in the area of the Pegasus Field Development varies from ‘low’ at the Pegasus West well end (Blocks 43/13 and 43/14), increasing to ‘moderate’ where the pipeline traverses Blocks 43/15 and 44/11, then to ‘high’ around Cygnus (Block 44/12) (Section 3.5.3). Where background levels of shipping are lower around Pegasus West, this translates to an average of 4 to 5 vessels per day passing within 10nm of the well (Anatec, 2014). Around Cygnus, an estimated 2,027 vessels per year, averaging of 5 to 6 vessels per day, has been calculated (Anatec, 2011).

The development is located in an area containing a number of existing gas fields and infrastructure, with associated industry-related shipping. Vessels required for Cygnus topsides modifications will be located primarily within the Cygnus 500m safety zone where they should not have an additional impact on shipping. Along most of the proposed pipeline route, and at Pegasus West, background shipping activity is lower that around Cygnus, and the risk to shipping from project vessels is correspondingly lower. At Cygnus, collision risk is lower, at 1.0 x 10^{-4} collisions per year, or a collision every 9,900 years on average (Anatec, 2011). The annual ship collision frequency for a JUDR at Pegasus West has been calculated as 4.7 x 10^{-4} collisions per year, corresponding to a collision every 2,130 years, higher than for Cygnus, but below the historical average on the UKCS (Anatec, 2014).

To minimise navigation hazards, all vessels engaged in the project operations will have markings and lighting as per the International Regulations for the Prevention of Collisions at Sea (COLREGS) (International Maritime Organisation (IMO), 1972) and vessel use will be optimised.

The JUDR will be equipped with marine navigational aids and an aviation obstruction lights system, as per the Standard Marking Schedule for Offshore Installations (Health and Safety Executive (HSE), 2009), to warn ships and aircraft of its position. The systems comprise:

- Marine navigation lights;
- Fog-lights;
- Aviation obstruction lights;
- Helideck beacons (helideck status light system);
- Fog-horns;
- Fog detector;
- Helideck lighting; and
- Radar beacons.

As required by HSE Operations Notice 6 (HSE, 2014), a warning communication will be issued at least 48 hours before any rig movement. Notice of the mobilisation and demobilisation of the JUDR and its support vessels will be sent to the Lighthouse Board of Trinity House. The route for the JUDR will be selected in consultation with other users of the sea, with the aim of minimising interference to other vessels and the risk of collision. Prior to commencement of offshore activities, Spirit Energy will apply for a 500 m safety zone at the Pegasus West well location to mitigate any collision risk, and an ERRV will patrol the Pegasus West area for the duration of well completion activities. Any vessel use required for Cygnus topsides modifications will be located within the Cygnus 500 m safety zone. In addition, a CtL application will be submitted to OPRED for the location of the JUDR and CtL requirements complied with.

Given the above, the generally low to moderate levels of shipping in the vicinity of the proposed development, and the temporary and localised nature of vessel activities, the significance of the impacts associated with the physical presence of project vessels on shipping has been assessed as **low**.

5.2.1.2 Commercial fishing

The physical presence of project vessels has the potential to temporarily prevent commercial fishing in their vicinity. Fishing vessels will be excluded from the 500 m safety zone that will be established around the Pegasus West well from when the JUDR arrives on location, through to when subsea infrastructure installation and commissioning is complete.

The area in which fishing will be prevented will however be very small relative to that available in the SNS. Furthermore, the development is located within ICES rectangles 38F1 and 38F2. The information presented in Section 3.5.1 suggests that fishing effort within these rectangles, and specifically around the well location and pipeline route, is relatively low when compared to other areas of the UKCS.

Spirit Energy will consult with the NFFO throughout the project. The fishing industry will be informed of relevant vessel activities and locations using Kingfisher Information Services.

Given the above, the relatively low levels of fishing activity in the vicinity of the proposed development, and the temporary and localised nature of vessel activities, the significance of the impacts associated with the physical presence of project vessels on commercial fishing has been assessed as **low**.

5.2.1.3 Marine mammals

The physical presence of project vessels has the potential to disturb marine mammals in their vicinity. Furthermore, there is a risk of direct injury to marine mammals through vessel strikes.

The marine mammal species most likely to be in the project area are harbour porpoise, white-beaked dolphin and grey seal (Section 3.3.5). Available sightings data indicate that densities of marine mammals are low, with the exception of harbour porpoise for which modelling indicates densities greater than three individuals per square kilometre may be present in the summer months (Heinänen & Skov 2015).

Around Pegasus West well in particular, there will be a short term, localised increase in vessel activity above low background levels, with the relative project-related increase in vessel activity becoming less significant towards the Cygnus end of the development where levels of background shipping are higher. However, given that the project is within an area of existing oil and gas activity, it is likely that marine mammals have become generally habituated to vessel traffic.

The evidence for lethal injury from ship collisions with marine mammals suggests that collisions are very rare (CSIP, 2011). Out of 478 post-mortem examinations of harbour porpoise in the UK carried out between 2005 and 2010, only four (0.8 %) were attributed to ship collisions. It is likely that marine mammals will move away from the immediate vicinity of vessels, possibly in response to vessel-generated underwater sound (Section 7), and therefore collisions with vessels are unlikely.

Given the above, and that marine mammals are anticipated to quickly adapt to the temporary presence of vessels, which will occupy in any case a very small proportion of their overall available habitat, the significance of the impact of the physical presence of project vessels to marine mammals has been assessed as **low**.

5.2.1.4 Seabirds

A number of species of seabird are found in the project area. Many of these birds will travel to the area from the SPAs located along the coasts of eastern England and Scotland. Seabirds such as Atlantic puffin use the area in the breeding season (April – July), whereas other species such as the common guillemot and little auk are present in higher densities in the winter season (October - April) (Section 3.3.4).

The presence of project vessels has the potential to cause displacement of seabirds from foraging habitat and may cause migrating birds to deviate from their flight routes. For example, auk species (e.g. guillemot, little auk) are believed to avoid vessels by up to 200 to 300 m, but gull species (e.g. kittiwake, herring gull and great black-backed gull) are attracted to vessels (Furness and Wade, 2012). Seabird densities in the North Sea are reported to be seven times greater within 500 m of an oil platform. Lights are known to attract seabirds, however increased food availability at oil and gas installations and the availability of roost sites may also be a factor (Weise *et al*. 2001). However, given the background presence of shipping and oil and gas installations in the area, the additional lighting associated with vessels is unlikely to have a significant impact.

Though evidence indicates that the presence of project vessels could cause some bird species to be displaced from their foraging area, the very small proportion of their overall available foraging habitat that will be occupied by project vessels suggests that any impacts would be negligible.

Given the above, existing vessel activity in the area, and the relatively close proximity of other offshore infrastructure, the significance of the impact of the physical presence of project vessels on seabirds has been assessed as **low**.

5.2.2 Installed subsea infrastructure

5.2.2.1 Commercial fishing

Installed infrastructure on the seabed has the potential to prevent commercial fishing from its vicinity (by the use of safety exclusion zones), and/or to present a snagging hazard to fishing vessels using demersal gears.

The fishing effort in the project area is relatively low when compared to other areas of the UKCS (Section 3.5.1). The fishing activity that does take place however is dominated by demersal trawling, where fishing gear is towed across the seabed such that it may come in to contact with structures on the seabed. This can result in damage to seabed infrastructure, fishing gear and fishing vessels.

The implementation of a new 500 m safety zone at Pegasus West will exclude fishing from an area of seabed of approximately 0.785 km^2 which is considered small relative to that available for exploitation in the wider SNS. However, fishing will be excluded from this area for a relatively long period of time (likely to be several years throughout the production phase and until decommissioning is complete), and therefore the significance of the impact of prevention of commercial fishing operations associated with the physical presence of subsea infrastructure has been assessed as **medium**.

As discussed previously (see Section 2.2.2), the majority of the production pipeline and EHC umbilical will be trenched and buried. However, out with the 500 m safety exclusion zones a 4.033 km section will be surface laid (between KP4.35 and KP8.38) protected with a single rock berm. The rock berm will be over trawlable and any spot rock deposits that may be required along the line length will also be over trawlable. As the majority of the production pipeline and EHC umbilical will be trenched and buried and any deposited rock will be over trawlable, the presence of the lines are not considered to present a significant snagging risk to fishing gear.

At the pipeline crossings and within the 500 m zones at each end of the lines, the production pipeline and EHC umbilical will transition out of their trench(es) and a combination of rock and concrete mattresses will be used to protected these surface laid sections, including that of the production pipeline’s tie-in spools, protection.

All pipeline crossings and areas of required rock cover will be designed and installed or deposited in accordance with industry best practice. For the period when the production pipeline and EHC umbilical are on the seabed prior to jetting, estimated at up to one week, guard vessels will be in deployed for the safety of other sea users.

Installed subsea infrastructure above seabed level, other than the production pipeline and EHC EHC umbilical and its pipeline crossings, will either be located inside the existing Cygnus 500 m safety zone, or within the new Pegasus West 500 m safety zone, from which areas, fishing vessels will be excluded. Furthermore, the Xmas tree and WPS at Pegasus West is designed to be ‘fishing friendly’ such that in the unlikely event of an interaction with a demersal trawl, the fishing gear would be able to be recovered by reversing or ‘backing-up’.

Trawling will routinely take place along or across the pipelines out with the 500 m safety zones. A recent study by Rouse *et al*. (2017) which analysed fishing activity in proximity to oil and gas pipelines using data for vessels > 15m in length indicates however that fishing with demersal and dredge gear at pipelines in the Dogger Bank SAC is of relatively low intensity compared to other parts of the UKCS (Scottish Government, 2017).

Given the above, the significance of the snagging risk presented to commercial fishing associated with the physical presence of installed subsea infrastructure has been assessed as **low**.

5.2.2.2 Marine mammals and fish

Marine mammals and fish in the area are anticipated to adapt to the presence of installed subsea infrastructure, which will occupy a very small proportion of their overall available habitat in the SNS. Impacts on seabed habitats used by fish and marine mammals are described in Section 8 (Seabed Disturbance).

Therefore, the significance of the impacts associated with the physical presence of installed subsea infrastructure on marine mammals and fish has been assessed as **low**.

5.2.3 Decommissioning phase

At CoP the Pegasus West infrastructure will be decommissioned in line with legislation and practices in force at that time. During decommissioning activities, vessel activity in the area will increase relative to the number of vessels that will have been typically present during the production. All decommissioning activities will be assessed and managed such that they will not significantly impact shipping and fishing activities in the area at the time.

It is expected that the Xmas tree and WPS, production pipeline tie-in spools, surface laid ends of the production pipeline and EHC umbilical, the SSIV at Cygnus, and exposed mattresses and grout bags will be recovered at the end of field life. In line with current BEIS decommissioning guidance (BEIS, 2018b) a comparative assessment will be carried out to determine the optimal approach. It is likely that the trenched and buried sections of the production pipeline and EHC umbilical, pipeline crossings, and rock cover will be decommissioned *in situ*.

Following decommissioning, over-trawl trials or surveys (e.g. side-scan sonar) will be carried out along the pipeline route and within the Pegasus West 500 m safety zone to ensure a clear seabed. Subject to legislation and guidance in force at that time, the Pegasus West 500 m safety zone will also be surrendered.

5.2.4 Transboundary and cumulative impacts

The project is located approximately 35 km from the UK/NL jurisdictional median line at its closest point, Cygnus. Given this distance and the localised nature of the impacts resulting from the physical presence of project vessels and installed subsea infrastructure, no transboundary impacts are anticipated.

Similarly, given that the increase in vessel activity will be temporary and localised, and that installed subsea infrastructure will cover a small area, cumulative impacts on shipping, commercial fisheries, fish, marine mammals and seabirds associated with the physical presence of the proposed development are not expected to be significant.

5.3 Control and Mitigation Measures

The following measures will be adopted to ensure that the impacts associated with physical presence are minimised to ‘as low as reasonably practicable’:

- Consultation with the NFFO;
- The fishing industry will be informed of relevant vessel activities and locations using Kingfisher Information Services;
- A Notice to Mariners will be circulated prior to JUDR mobilisation;
- Notice will be sent to Trinity House of any movements associated with the mobilisation and demobilisation of the JUDR;

- All vessels will adhere to COLREGS and will be equipped with navigational aids, including radar, lighting and AIS (Automatic Identification System) etc.;
- Vessel use will be optimised by minimising the number required, and their length of time on site;
- The JUDR will abide by CtL conditions;
- The JUDR will be equipped with navigational aids and aviation obstruction lights system, as per the Standard Marking Schedule for Offshore Installations;
- An ERRV will patrol the Pegasus West area for the duration of well completion activities;
- The production pipeline and EHC umbilical will be trenched and buried (jetting) for the majority of their length to minimise interactions with fishing gear;
- Guard vessels will be in deployed for the period when the production pipeline and EHC umbilical are on the seabed prior to burial or covering with rock;
- All permanently unburied subsea infrastructure will be located within the existing Cygnus 500 m safety zone, or that which will be established at the Pegasus West well, and will be designed to be ‘fishing friendly’ or over-trawlable;
- All subsea infrastructure installed out with 500 m safety zones will either be buried or designed to be over-trawlable (e.g. at third party pipeline crossings and surface laid line section); and
- The requirement for pipeline protection and stabilisation features will be minimised through project design and they will be installed in accordance with industry best practice.

5.4 Conclusion

The principal sources of impacts associated with physical presence concern the use of Pegasus West Development project vessels and the presence of subsea infrastructure on the seabed. These have the potential to cause temporary navigational hazards and nuisance to shipping, a temporary restriction of fishing operations, and disturbance to marine mammals and seabirds.

Standard measures to ensure that the impacts associated with the physical presence of vessels are minimised include notifying other sea users of the timing and location of vessel activities, use of legally required navigation aids, and minimising the number of vessels required and their length of time on site. Measures to mitigate the impacts of seabed infrastructure include the use of statutory 500 m safety zones and the design of infrastructure to minimise the risk of interactions with fishing gear.

In summary, due to the localised and relatively short duration of vessel activities, and due to the limited unburied infrastructure on the seabed, and with the identified control and mitigation measures in place, the overall significance of physical presence is considered to be **medium**.

6. ENERGY USE AND ATMOSPHERIC EMISSIONS

This section identifies the various sources of atmospheric emissions associated with project activities and subsequent hydrocarbon production operations. The quantity of atmospheric emissions is estimated, and their impact assessed.

Following the adoption of appropriate control and mitigation measures, residual effects and impacts are assessed in the context of the sensitivity of, and the dispersive capacity of, the receiving environment.

For emissions during production, quantities of emitted gases have been calculated on the basis of the high case production profile presented in Section 2 as these provide a realistic worst case for impacts. Equivalent values for the mid case production profile are given in places for comparison.

The window for first gas is estimated to be between January 1st 2024 and September 31st 2024. The production profiles presented in Section 2 assume a mid-point within this window of May 2024 for first gas. To determine whether the start date has a material impact on the emissions calculations, a sensitivity case has been considered with start up on 1st January 2024 (Section 6.6).

6.1 Sources

The principal planned activities, including their location and estimated duration, are described in Section 2. Of these, the general use of vessels (including the JUDR), well completion, commissioning and the production of hydrocarbons have been identified as warranting further assessment in terms of the impact of their atmospheric emissions.

6.1.1 Vessels

Energy in the form of liquid fuel (e.g. marine diesel, and combustion of which will result in atmospheric emissions) is required by vessels to provide propulsion, dynamic positioning and ancillary services (e.g. electrical power).

While contracts securing the services of named vessels have not yet been established, the performance characteristics (including the fuel consumption) of the required generic vessel types are well understood. This has allowed, in conjunction with a consideration of the planned vessels' work programme, estimates of atmospheric emissions to be made (Table 6-1).

SOURCE	FUEL USE (Te)[1]	ENERGY USE (GJ)[1]	EMISSIONS FROM FUEL USE (Te)[1]						
			CO_2	NO_x	N_2O	SO_2	CO	CH_4	VOC
Well completion vessels	1,293	55,750	4,139	77	0	5	20	0	3
Subsea infrastructure installation	2,673	115,185	8,552	159	1	11	42	0	5
Cygnus topside modification	350	15,085	1,120	21	0	1	5	0	1
Total vessels	**4,316**	**186,019**	**13,811**	**256**	**1**	**17**	**68**	**1**	**9**
UK shipping emissions 2019 (CCC, 2020)			13,680,000						
Total vessel emissions as % of 2019 UK shipping emissions			0.1						
[1] Institute of Petroleum (2000)									

Table 6-1 Fuel and energy use and emissions associated with vessel use

6.1.2 Well completion

Well clean-up is an activity necessary to ensure that a well no longer contains any drilling and completion - related debris (mud, brine, cuttings) which could damage the topside process when commissioning and production begins. Following completion activities, the well will be flowed to displace remaining completion brine.

Atmospheric emissions resulting from clean-up and testing have been calculated using emissions factors from the EEMS Atmospheric Calculations Issue 1.810a (Austin, 2008) and are presented in Table 6-2.

SOURCE	TOTAL FLARED (Te)	EMISSIONS (Te)						
		CO_2	NO_x	N_2O	SO_2	CO	CH_4	VOC
Gas flared	6,767	18,948	8	1	0	45	305	34
Condensate flared	307	981	1	0	0	6	8	8
Total		**19,928**	**9**	**1**	**0**	**51**	**313**	**42**

Table 6-2 Summary of emissions from well clean-up operations

6.1.3 Commissioning

Following completions and displacement of residual brines in the well bore, the well will start to be produced. During an initial period to balance pressures in pipelines and reception equipment, produced fluids will be directed to the Cygnus flare. Based on previous well start-up experience at Cygnus an estimated 40 Te of hydrocarbon will be flared. The resultant emissions from well start up are presented in Table 6-3.

SOURCE	TOTAL FLARED (Te)	EMISSIONS (Te)						
		CO_2	NO_x	N_2O	SO_2	CO	CH_4	VOC
Gas flared	40	112	0.048	0.003	0.0005	0.27	1.8	0.2

Table 6-3 Emissions during well start-up

6.1.4 Production of hydrocarbons

The principal atmospheric emissions that will arise during production are associated with power generation, export compression and flaring at the Cygnus host.

No physical modifications to the current power generation, compression and flaring systems at Cygnus will be required to process Pegasus West gas. These existing systems have been assessed as being sufficient to meet the operational requirements for the processing of Pegasus West production over field life.

Emissions increases due to the production of Pegasus West are discussed and estimated in Section 6.2.

6.2 Emissions Increases Due to Pegasus West Production

6.2.1 Power generation

Power on Cygnus is provided by two dual fuel gas turbine generators (GTG) operating one on one off. The main load is taken for MEG and TEG reboilers and dehydration. Although able to run on either fuel gas or diesel, the use of the latter is reserved for certain start-up conditions only, with fuel gas accounting for almost all power generation.

Based on annual figures for 2019, 600 te diesel was used and 6,279 Te fuel gas. Power requirements are fixed and not linked directly to the production throughput. Note the data for 2019 is used as it's the most representative of a regular year (with minimal unplanned shutdowns).

The introduction of Pegasus West will not substantially alter the power requirements on Cygnus. However, some increase is anticipated for example for additional condensate export pumping. For the purposes of assessing the realistic worst case impact of emissions it has been assumed that an additional 15% of fuel gas (942 Te/yr) will be utilised for power generation in future years over Pegasus West field life.

Annual emissions of atmospheric emission gases due to combustion of diesel and fuel gas for power generation at Cygnus platform are presented in Table 6-4. Estimates are presented for Cygnus without the introduction of Pegasus West, for Cygnus with the introduction of Pegasus West and, by difference, the incremental additional emissions resulting from the development of Pegasus West. Emissions are based on the EEMS emission factors for GTGs, except for CO_2 which is based on gas composition analyses at Cygnus for 2019 – 2021.

SOURCE	FUEL USE (Te/yr)	EMISSIONS (Te/yr)						
		CO_2	NO_x	N_2O	SO_2	CO	CH_4	VOC
Cygnus Alone	6,879	17,269	46	1.51	1.28	38	5.8	0.40
Cygnus with Pegasus West	7,821	19,571	52	1.72	1.29	44	6.7	0.44
Difference	**942**	**2,302**	**5.7**	**0.21**	**0.01**	**5.7**	**0.9**	**0.03**

Table 6-4 Emissions from power generation at Cygnus during Pegasus peak production

6.2.2 Compression

Introduction of Pegasus West fluids will have an impact on gas export compression and consequently on fuel gas consumption in the compressors, and associated emissions.

Gas is currently exported from Cygnus without the requirement for compression. Gas export from Cygnus is predicted to peak in 2022 whether or not the Pegasus West Development proceeds. As wellhead pressures decline, compression will be required to maintain export rates from the platform. Compression is designed for operation in medium pressure (MP) mode and low pressure (LP) mode.

Initially in MP mode, the compressors will be operating at maximum capacity on full load. Compressor fuel gas usage will be proportional to the gas export rates and therefore as export rates decline the compressor fuel gas usage will also decline. As wellhead pressures and export gas rates continue to fall it will reach a threshold (*c.* 160 mmscf per day) whereby LP compression is required.

The Cygnus compression system is designed such that the same power turbine is used to drive the MP and LP compressors. In MP mode the LP compressor is not installed and therefore 100% of the power is used to drive the MP compressor. In LP mode the turbine power is split between the LP and MP compressors, which also corresponds to a reduction in gas capacity. Therefore when Cygnus initially moves into LP mode the compressor power turbine will be at full load, at maximum export rates and therefore will result in an increase in fuel gas usage. As export rates decline in LP mode the fuel usage will again begin to decline.

Without the introduction of Pegasus West, declining production from the Cygnus wells means that LP mode is projected to be required from 2025. The introduction of Pegasus West will delay this transition to 2026 in the base case (P50) production profile, and to 2027 in the High (P10) profile case. In all cases, the peak year for compressor fuel use corresponds to the onset of LP compression mode. Table 6-5 presents the peak annual emissions due to compression with and without the introduction of Pegasus West. The data shows that peak annual emissions from compression will be a small amount higher without Pegasus West than it will be with Pegasus West production. This is because the gas production in the first year of LP compression mode is lower for the Cygnus + Pegasus profile (123 mmscf per day in 2027) than it would be in the first year of LP compression mode for the Cygnus Alone profile (141 mmscf per day in 2025).

SOURCE	GAS USE (Te)	EMISSIONS (Te)						
		CO_2	NO_x	N_2O	SO_2	CO	CH_4	VOC
Cygnus Alone	26,987	65,969	165	5.94	0.35	162	24.8	0.97
Cygnus with Pegasus West	24,354	59,533	149	5.36	0.31	146	22.4	0.88
Difference	**-2,633**	**-6,436**	**-16**	**-0.58**	**-0.03**	**-16**	**-2.4**	**-0.09**

Table 6-5 Maximum annual emissions at Cygnus from compressors during Pegasus field life

6.2.3 Flaring

There are both LP and HP flare systems at Cygnus, both utilising the same flare stack. The LP flare combusts a small stream of gas from seals and blanketing from the process systems. This will not be increased due to introduction of Pegasus West fluids. The HP flare combusts small quantities from pressure relief on HP process and is used for blowdown for planned shutdown, start-up of new wells and unplanned trips. Again, this is not expected to be influenced by the introduction of Pegasus West fluids into the Cygnus topside other than when the well is first brought on stream in 2024.

Flare records for 2019 provide a baseline for what would be expected for standard operations, with occasional spikes in flare volume superimposed on a consistent baseline. Spikes occur during preparation for a planned shut-down (*c*. 8 Te), during start-up of a new well (*c*. 40 Te), and smaller increments related to occasional process upset conditions. The combined LP and HP flare figures for 2019 therefore represents the normal, expected annual flaring and resultant emissions at Cygnus, and these figures are anticipated to be the same for each year of Pegasus West field life. Emissions based on 2019 flare quantities are presented in Table 6-6.

SOURCE	GAS USE (Te/yr)	EMISSIONS (Te/yr)						
		CO_2	NO_x	N_2O	SO_2	CO	CH_4	VOC
Combined HP & LP Flaring	2,294	5,607	2.8	0.19	0.03	15.4	41.3	4.6

Table 6-6 Emissions from flaring at Cygnus (2019)

6.3 Aggregated Emissions

Of interest to the impact assessment are:

- The maximum emission levels for substances that reduce air quality; and
- The aggregated emissions of GHGs over the field life.

Both metrics are linked to the production profile, over which a degree of uncertainty will remain until the reservoir behaviour can be monitored following commencement of production. The uncertainty is expressed by profiles showing the most likely (P50) case together with High (P10) and Low (P90) sensitivity cases.

To consider the impacts from a worst realistic case, emissions are presented for the High profile case during production field life along with estimates for emissions during the installation and start-up stages scheduled to occur in 2024.

6.3.1 Emission gases impacting air quality

Total emissions prior to production are presented in Table 6-7, based on data in Section 6.1.

	USE (Te)	EMISSIONS (Te)						
		CO_2	NO_x	N_2O	SO_2	CO	CH_4	VOC
Installation, Completions & Start-up	11,430	33,852	266	1.5	17	119	316	51

Table 6-7 Total emissions prior to production

The peak year for emissions at Cygnus following the introduction of Pegasus West has been identified as 2027 and Table 6-8 presents the quantities aggregated from Section 6.2.1, 6.2.2 and 6.2.3 for that year.

PEAK YEAR FOR CYGNUS WITH PEGASUS WEST	FUEL USE (Te/yr)	EMISSIONS (Te/yr)						
		CO_2	NO_x	N_2O	SO_2	CO	CH_4	VOC
Power Generation	7,821	19,571	52	1.72	1.29	44	6.7	0.44
Compression	24,354	59,533	149	5.36	0.31	146	22.4	0.88
Flare	2,294	5,607	2.8	0.19	0.03	15.4	41.3	4.6
Total	**34,469**	**84,711**	**203**	**7.3**	**1.6**	**205**	**70**	**5.9**
Total without Pegasus	**36,160**	**88,845**	**214**	**7.6**	**1.7**	**216**	**72**	**6.0**

Table 6-8 Maximum total annual production emissions at Cygnus during Pegasus field life and without Pegasus

Note, the emissions presented in Table 6-8 are projected worst case emissions for the full operation of Cygnus, not those specifically resulting from the introduction of Pegasus West. Were Pegasus West not developed, then the peak year of emissions at Cygnus would be 2025, and quantities of emissions for that scenario are also presented in Table 6-8 for comparison.

For context, the emissions for the UK as a whole, and for the UKCS offshore oil and gas industry are presented in Table 6-9 in units of thousand tonnes per year. By way of example the NO_x emissions from the installation, completions and start of up Pegasus West would be *c.* 0.4% of the annual emissions from the UKCS offshore industry in 2018, and the peak year NO_x emissions from production would be *c.* 0.3%.

SOURCE	EMISSIONS (Thousand Te/yr)						
	CO_2	NO_x	N_2O	SO_2	CO	CH_4	VOC
UK Emissions (2018)[1]	380,800	834	64	163	1,560	2,080	806
UKCS Emissions (2018)[2]	13,200	59	1	3	30	44	50

[1] UK Greenhouse Gas Inventory, 1990 to 2018 from the Annual Report for submission under the Framework Convention on Climate Change (UK NIR, 2020).

[2] UKCS EEMS emissions data (EEMS, 2021).

Table 6-9 Emissions from the UK, and from the UKCS, in 2018.

6.3.2 GHG emissions

GHG emissions are presented in Table 6-10 for pre-production stages and annually over the Pegasus West field life as CO_2 equivalents (CO_2e). The values for CO_2e are derived using GWP values for CO_2, methane and nitrous oxide from the IPCC 4th Assessment Report (IPCC, 2007).

For Cygnus, in the absence of Pegasus West, both the power generation and flare emissions are taken to be constant for each year. To accommodate the introduction of Pegasus West, an incremental increase of 15% in power generation has been assumed and no increase in flaring. In both cases (Cygnus alone or with Pegasus West), emissions from compression are determined annually according to projected throughput.

YEAR	EMISSIONS (Te CO_2e)		
	CYGNUS ALONE	CYGNUS WITH PEGASUS WEST	PEGASUS WEST INCREMENTAL
2024	78,059	85,460	7,401
2025	92,918	83,633	-9,285
2026	81,247	78,631	-2,616
2027	72,911	88,635	15,724
2028	73,043	75,429	2,386
2029	72,911	75,296	2,386
2030	72,911	75,296	2,386
2031	72,911	75,296	2,386
2032	73,043	75,429	2,386
2033	72,911	75,296	2,386
2034	72,911	75,296	2,386
TOTAL OPERATIONS	835,774	863,698	27,924
Installation, Completions & Start-up (2024)	0	42,196	42,196
TOTAL DEVELOPMENT	835,774	905,894	70,120

Table 6-10 Total installation and operation GHG emissions by year

6.4 Air Quality Impacts and Receptors

Increased concentrations of NO_x, SO_2 and VOCs in the atmosphere can result in the formation of photochemical pollution in the presence of sunlight, comprising mainly low level ozone, but by-products may include nitric acid, sulphuric acid and nitrate-based particulate. The formation of acid and particulates contributes to acid rainfall and the dry deposition of particulates. If such deposition occurs at sea, it is possible that the substances will dissolve in seawater. The ultimate fate of emitted pollutants can often be difficult to predict owing to the dependence on metocean conditions (especially wind), which may be highly variable and lead to wide variations in pollutant fate over short timescales.

6.4.1 Installation and commissioning phase

Vessel emissions, summarised in Table 6-1, and well clean-up flaring emissions summarised in Table 6-2, will be of localised extent, of relatively short duration, and take place a substantial distance (*c*. 107 km) from the nearest coastline. They are expected to disperse rapidly and dilute to background concentrations, resulting in localised and short term impacts only to air quality.

Given the above, the significance of the impact of energy use and atmospheric emissions from vessels and from well clean-up has been assessed as **low**.

6.4.2 Production phase

Production of Pegasus West will require only small increases in quantities hydrocarbons combusted at Cygnus in some (later) years, and a reduction in other (earlier) years. Crucially, there will be a reduction in combustion requirements for those years when peak emissions are anticipated. This is a consequence of the deferment of compression mode change from MP to LP that the introduction of Pegasus production will cause. As a result, the maximum emission of gases that impact on air quality will be the same (within the bounds of uncertainty) with or without Pegasus West, as can be seen in Table 6-8. The impact on air quality from producing the Pegasus West well has therefore been assessed as **low**.

6.4.3 Decommissioning phase

A range of specialist and support vessel types will be required at various times, and for various durations, to undertake the decommissioning activities at the EoFL. This will lead to an increase in vessel activity relative to that associated with production.

A JUDR will be brought to Pegasus West to plug and permanently abandon the well. In addition, vessels will be required to remove and recover seabed infrastructure, and to complete pre-decommissioning, execute phase and post-decommissioning legacy surveys.

Vessel emissions associated with decommissioning activities are likely to be similar to those associated with subsea infrastructure installation. The extent, magnitude and duration of impact on air quality from offshore decommissioning activities are consequently anticipated to be less than those for the installation and commissioning phase and has therefore been assessed as **low**. This will be confirmed during the preparation work of decommissioning and included in the Environmental Appraisal report submitted with the Decommissioning Programme.

6.4.4 Transboundary and cumulative impacts

The proposed Pegasus West Development is located *c*. 35 km from the UK/NL jurisdictional median line at its closest point, Cygnus. Given this distance and the localised nature of air quality impacts expected, no transboundary impacts are anticipated.

6.5 Impact on Climate Change

In isolation the GHG emissions from the Pegasus West development would not cause a change to the global climate, however it is their contribution to the cumulative impact of total global emissions that is of relevance in assessing the impact of the development. As such, the Pegasus West GHG emissions are considered in the context of the UK emissions and the UK commitments to emissions reductions.

6.5.1 Pegasus West GHG emissions in the present national and sector-wide context

The total GHG emissions for 2018 across the UK were reported in the UK National Inventory Report (UKNIR, 2020) as 465.9 MTeCO_2e. The UK offshore oil and gas sector accounted for 14.54 MTeCO_2e, *c*. 3% of the UK total (EEMS, 2019).

The incremental additional GHG emissions resulting from production of Pegasus West over Cygnus peak in 2027 at 0.0157 MTeCO_2e, which is 0.0034 % of the UK total in 2018 and 0.11 % of the UKCS oil and gas total in 2018.

This peak year represent the worst case for GHG emissions over Pegasus West field life, coinciding with the change to LP compression mode. For all other years the incremental increase in GHG emissions due to Pegasus West are substantially lower.

GHG SOURCE	EMISSIONS (MTe CO_2e)	% UK TOTAL	% UKCS
UK Total (2018)	465.9		
UKCS Total (2018)	14.54		
Pegasus West (2027) High Case	0.0157	0.0034	0.11

Table 6-11 Pegasus incremental GHG emissions in the context of total UK and UKCS

6.5.2 Pegasus West GHG emissions in the future national context

The Climate Change Act 2008, which committed the UK government by law to reducing greenhouse gas emissions by at least 80% of 1990 levels by 2050, was amended in 2019 to commit to achieving 100% reduction (net zero) by 2050. The Climate Change (Scotland) Act (2019) establishes an accelerated target for achieving net zero emissions by 2045 in Scotland.

The Climate Change Act requires the government to set legally-binding ‘carbon budgets’ to act as stepping stones towards the 2050 target. A carbon budget is a cap on the amount of greenhouse gases emitted in the UK over a five-year period.

Table 6-12 shows the UK Carbon Budgets allocation set under the UK Climate Change Act alongside the projected additional emissions from Cygnus arising from the development of Pegasus West.

Under the High production profile case, the Pegasus West development spans the 4th, 5th and 6th Carbon Budget periods, with installation, start-up and the first four years of operation occurring in the 4th budget period, the subsequent 5 years of operation occurring in the 5th budget period, and the final two years production occurring in the 6th budget period. The total future GHG emissions from the Pegasus West development within each budget period are presented within Table 6-12 as million tonnes of CO_2 equivalent and as a percentage of the UK budget allocations. Under the Mid case production profile, production would cease within the 5th budget period.

CARBON BUDGET	BUDGET PERIOD	UK BUDGET ALLOCATION ($MTeCO_2e$)	PEGASUS WEST INCREMENTAL	
			($MTeCO_2e$)	% OF BUDGET ALLOCATION
1	2008 - 2012	3,018	-	-
2	2013 - 2017	2,782	-	-
3	2018 - 2022	2,544	-	-
4	2023 - 2027	1,950	0.053	0.0027
5	2028 - 2032	1,725	0.012	0.0007
6	2033 - 2037	965	0.005	0.0005

Table 6-12 Pegasus West GHG emissions in the context of UK Carbon Budgets

6.5.3 Pegasus West GHG Emissions in the future oil & gas sector context

In October 2017 the UK Government published its Clean Growth Strategy (UK Government, 2017) setting out policies and proposals for meeting future carbon budgets, together with pathways to the 2050 target (then of 80% reduction). In keeping with the Net Zero pathway the UK Government and offshore oil and gas industry established a North Sea Transition Deal (NSTD) in 2021 which, among other actions, agreed targets for staged reductions in GHG emissions from the UKCS as presented in the first two columns of Table 6-13. Based on the recorded UKCS GHG emissions for 2018, the third column of the table shows the target emissions for subsequent years stipulated in the NSTD. The final two columns of the table present the proportion of the NSTD budget that incremental GHG emissions from Pegasus West would account for under High and Mid case production profiles. Note, the values for 2025 are negative because the total emissions at Cygnus in 2025 without the introduction of Pegasus West would be higher than with Pegasus West.

YEAR	NORTH SEA TRANSITION DEAL		PEGASUS WEST INCREMENTAL	
	% OF 2018	$MTeCO_2e$	HIGH CASE (%)	MID CASE (%)
2018	100	14.54	-	-
2025	90	13.09	- 0.07	- 0.07
2027	75	10.90	0.14	0.11
2030	50	7.27	0.03	0.03
2050	0	0	-	-

Table 6-13 Pegasus West GHG emissions in the context of the North Sea Transition Deal

The GHG emissions from Pegasus West represent a small proportion of the UKCS and UK annual totals and make up a small proportion of the 4th, 5th and 6th Carbon Budget allocations and of the total UKCS emissions targets established for 2025, 2027 and 2030 under the NSTD.

6.5.4 Pegasus West GHG emissions relative to production

In 2018, oil and gas production in the UKCS averaged 1.7 mmboe (56 MTe oil equivalent), or 620 mmboe (20 billion tonnes oil equivalent) for the full year (BEIS, 2019). The sector resulted in emissions totalling 14.54 MTe CO_2e, giving on average 23.4 kgCO_2e per boe.

Pegasus West is forecast to deliver 20 million barrels of oil equivalent (mmboe) over its eleven year field life based on the High case production profile for which emissions have been presented in this ES. Production is forecast to peak in 2025 at 4.6 mmboe before declining to a minimum of around 0.2 mmboe in 2034. Pegasus West is estimated to give rise to a total of 0.070 MTe CO_2e over the full field life and including installation, commissioning and start-up. This equates to 3.5 $kgCO_2e$/boe which is significantly lower than the 2018 average of 23.4 $kgCO_2e$/boe for the UKCS. Equivalent calculations based on the Mid case production profile indicate emissions would be 5.2 $kgCO_2e$/boe.

This is relative to 2018 as a base case. Further consideration has been given to whether Pegasus West would still provide GHG value in the context of reductions required under the NSTD. Whereas emissions reductions have been set within the NSTD, there are no equivalent forecasts for hydrocarbon production in the basin beyond 2024. Were the 2018 level of UKCS production maintained over the Pegasus West field life, Pegasus West production would make up 0.74% of the UKCS total at its peak in 2025, dropping off to 0.03% by 2034. High and Mid case production from Pegasus West for the target years of the NSTD are shown in Table 6-14 as total quantities and as a proportion of total UKCS production in 2018. Comparison of these % production figures with the % GHG emissions presented in Table 6-13 indicates that production at Pegasus West gives rise to GHG emissions per boe that are considerably lower than is required to meet the targets set in the NSTD.

YEAR	PEGASUS WEST PRODUCTION (MMBOE PER YEAR)		PEGASUS WEST PRODUCTION AS % UKCS TOTAL FOR 2018	
	HIGH CASE	MID CASE	HIGH CASE (%)	MID CASE (%)
2018	0	0	-	-
2025	4.60	4.15	0.74	0.67
2027	2.93	2.17	0.47	0.35
2030	0.74	0.43	0.12	0.07
2050	0	0	-	-

Table 6-14 Pegasus production in the context of the UKCS

The demand in the UK for oil and gas is predicted to decline significantly over the next 30 years to 2050, although the UK Government forecasts show that oil and gas will remain an important part of the UK energy mix for the foreseeable future, including under net zero (OGA, 2021).

Any decline in the total UKCS production during the Pegasus West field life would increase the proportion of UKCS production provided by Pegasus West, and result in a consequential increase in the ratio of Pegasus production as a proportion of the UKCS total versus Pegasus emissions as a proportion of the UKCS total.

For further context, imported gas to the UK from Norway has a GHG intensity of *c*. 9 $kgCO_2e$/boe.

6.5.5 Climate change impact conclusion

Impacts from GHG emissions are difficult to assess in isolation because they derive from all cumulative emissions, rather than from any one activity. Nevertheless, GHG emissions from Pegasus West are low in the context of current UK and UKCS emissions and in the context of projected targets for future emissions reductions. Furthermore, Pegasus West production represents significantly lower than average emissions per barrel of oil equivalent produced for the UKCS, even when accounting for the emission reductions for the UKCS established by the NSTD.

6.6 Sensitivity of Impact Results to First Gas Date

All calculations undertaken in this section to determine impacts from emissions were repeated based on a first gas date of 1st January 2024. This demonstrated that the earlier start date gave rise to less than 0.2% difference in peak emissions of atmospheric contaminants (as presented, for example, in Table 6-5). Total life of field GHG emissions remained unchanged, although values for some individual years changed as would be expected, with those for 2024 higher, and subsequent years lower. This was most notable for the mid case production profile.

It is concluded that the present uncertainty in the date by which first gas can be achieved has no material impact on atmospheric emissions, and has no effect on the impact assessment or its conclusions.

6.7 Control and Mitigation Measures

The following measures will be adopted to ensure that the impacts associated with energy use and atmospheric emissions during the installation and commissioning stage are minimised to 'as low as reasonably practicable':

- The JUDR and other project vessels will be subject to audits ensuring compliance with UK legislation and the Spirit Energy Marine Operations and Vessel Assurance Standard (SPT-MAL-GEN-STA-0010);
- Vessel use will be optimised where possible by minimising the number of vessels required, and their length of time on site; and
- Vessels will be operated where possible in modes that allow for economical fuel use.

During the operation stage, emissions associated with Pegasus West production will be from existing equipment on Cygnus and will be controlled through the efficient operation of Cygnus processing and export conditions. The majority of emissions derive from compression of gas for export. Production of Pegasus West will replace declining ullage from Cygnus wells and will prolong the, more efficient, MP compression operating mode. In accordance with the revised OGA strategy and associated Stewardship Expectation 11 as well as the industry commitments within the North Sea Transition Deal, all incorporating the 'Net Zero 2050' requirement, Neptune will incorporate the impact of the Pegasus West production within developing controls including:

- Asset GHG Emission Reduction Action Plans;
- Flaring and venting reviews to identify/action zero routine flaring by 2030;
- Active flare reduction strategy;
- Active vent reduction strategy;
- Emission key performance indicators and targets;
- Industry level benchmarking of flaring and venting; and
- Asset Methane Action Plan.

These will ensure that opportunities for efficiency and reduction of atmospheric emissions, where not in conflict with safe operations, are identified, actioned as appropriate and reviewed.

6.8 Conclusion

The impact of installation, completions and start-up activities on air quality will be localised, short term and will mainly occur more than 100 km from the nearest shoreline. The significance of impact to the local ecological receptors will be **low**.

Peak emissions of exhaust gases that impact on air quality at Cygnus will be no higher following the introduction of Pegasus West than would occur without this development. The impact on air quality over the life of field for Pegasus West has therefore been assessed as **low**.

The development of Pegasus West will result in a small increase in GHG emissions at Cygnus (between 8% and 10%), while significantly increasing gas production (between 37% and 47%). In the context of UKCS oil and gas production, Pegasus West offers very low GHG emissions per barrel of oil equivalent produced.

In summary, the overall significance of the impact of energy use and atmospheric emissions is considered to be **low**.

7. UNDERWATER SOUND

This section identifies and assesses the impact of underwater sound generated by project activities.

Following the adoption of appropriate control and mitigation measures, residual impacts are assessed with regard to the sensitivity and abundance of known receptors.

7.1 Sources

The principal planned project activities, including their location and estimated duration, are described in Section 2. Of these, the general use of vessels (including the JUDR) and the positioning of vessels has been identified as the only activities warranting further assessment in terms of the potential impact of generated underwater sound.

Vessel traffic can be considered the largest contributor to anthropogenic ocean sound, the primary sources being propellers, propulsion and other machinery (Ross, 1976; Wales and Heitmeyer, 2002; Richardson, 1995). The characteristics of the sound produced, in terms of strength or intensity, and range of frequencies, vary with the type of activity and vessel type.

Acoustic broadband source levels typically increase with increasing vessel size, with smaller vessels (< 50 m) having a source root mean square (rms) sound pressure level (SPL) of 160-175dB re 1µPa at 1m, medium size vessels (50-100m) 165-180dB re 1µPa at 1m and large vessels (> 100m) 180-190dB re 1µPa at 1m (Richardson *et al*., 1995). However, sound levels depend on the operating status of the vessel. Some of the vessels used for the proposed activities will use dynamic positioning (DP) systems to maintain and adjust their position when working. Sound levels can be louder during use of DP, which requires the operation of thrusters to control a vessel's location.

Vessel acoustic energy is strongest in the frequency range 10Hz to 1kHz (Wales and Heitmeyer, 2002). Sound levels in the marine environment diminish with distance from the source.

Drilling rig sound propagates from any rotating machinery such as generators, pumps, the drilling unit and risers (McCauley, 1998). However, there will be no actual drilling activity required for well completion, and therefore it is considered that the underwater sound generated by the JUDR will be similar to that generated by other vessels.

The project will not use explosives, install foundation piles or undertake surveying that requires the use of a seismic source.

7.2 Impacts and Receptors

Sound levels in the marine environment diminish with distance from the source. The potential impact of underwater sound depends on the intensity, frequency and duration of sound received by the receptors, and the sensitivity and response of receptors to that sound. Certain fish species and marine mammals are considered sensitive to underwater sound (NMFS, 2018; Southall *et al*., 2019; Popper *et al*., 2014).

7.2.1 Fish

Fish species differ in their hearing capabilities depending on the presence of a swimbladder, which acts as a pressure receiver, and whether the swimbladder is connected to the otolith hearing system, which further increases hearing sensitivity (McCauley, 1994; Popper *et al*., 2014). Most fish can hear within the range 100Hz to 1kHz, but species with a connection between the swimbladder and otolith system may detect frequencies up to 3 kHz. Within this range, the hearing threshold varies from *c*. 50 dB re 1 μPa for hearing specialists to 110 dB re 1 μPa for non-specialists. Elasmobranchs do not have a swim bladder and therefore have less sensitive hearing (Popper *et al*., 2006).

Many species of fish produce sounds for communication that are typically emitted at frequencies below 1 kHz (Montgomery *et al*., 2006). This information suggests that sound from vessels is likely to be within the frequency range of sound detection for most fish species.

Anthropogenic sound has the potential to interfere with acoustic communication, predator avoidance, prey detection, reproduction and navigation in fish. The effects of "excessive" sound on fish include avoidance reactions and changes in shoaling behaviour (Slabbekoorn *et al*., 2010). Prolonged avoidance of an area may interfere with feeding or reproduction or cause stress-induced reduction in growth and reproductive output. However, the peak sound levels and frequency spectra generated by the project sources of underwater sound are not deemed capable of causing any physical injury to fish.

Fish exhibit avoidance reactions to vessels and it is likely that radiated underwater sound is the cause. For example, noise from research vessels has the potential to bias fish abundance surveys by causing fish to move away (de Robertis and Handegard, 2013; Mitson and Knudsen, 2003). Reactions include diving, horizontal movement and changes in tilt angle (de Robertis and Handegard, 2013).

As described in Section 3.3.3.5, Blocks 43/13 and 43/14 have registered periods of concern for seismic and drilling activities between August and October, relating to potential herring spawning sensitivities. Surveys have confirmed the presence of herring spawning grounds in the Pegasus West well area (Fugro, 2012) and reported seabed of high herring spawning potential at stations ENV1 and ENV2 near the well, and ENV5, ENV6, ENV11, ENV14, ENV15 and ENV20 further east on the proposed pipeline route (Gardline, 2018a) (Figure 3-14). Underwater sound therefore has the potential to inhibit access to spawning grounds. Spawning of other species with a swim bladder including cod, whiting and sprat may also occur near project vessel activities, although very wide spawning distributions.

Sound generated by vessel thrusters when starting is likely to elicit a startle response in fish in the immediate vicinity, but fish tend only to avoid vessels at close range (Coull *et al*., 1998). Therefore, any temporary displacement from spawning grounds would be very localised and not significant in comparison to the area of available spawning habitat. Furthermore, fish behaviour would be expected to be habituated to general vessel sound in the area, particularly around the eastern area of the proposed pipeline route and around Cygnus where levels of shipping activity are relatively high.

Given the above, and the localised extent and short duration of the activities, the significance of the impact of sound generated by project vessels upon fish has been assessed as **low**.

7.2.2 Marine mammals

Sound is important for marine mammals for navigation, communication and prey detection (e.g. Southall *et al*., 2007; Richardson *et al*., 1995). The introduction of anthropogenic underwater sound therefore has the potential to impact on marine mammals if it interferes with the ability of an animal to use and receive sound (e.g. OSPAR, 2009b).

All the cetacean species found in UK waters have EPS status and it is an offence under the Conservation of Offshore Marine Habitats and Species Regulations 2017 to injure or disturb a EPS (Section 1.5.2). Here, injury is defined as a permanent threshold shift (PTS) i.e. a permanent shift in the hearing of an EPS.

The extent to which underwater sound might cause an adverse environmental impact is dependent on numerous factors. JNCC guidance on the protection of marine EPS from injury and disturbance (JNCC, 2010) recommends considering the following factors when assessing the impact of sound exposure:

a) Duration and frequency of the activity;
b) Intensity and frequency of sound and extent of the area where the disturbance and injury thresholds may be exceeded, taking into consideration species-specific sensitivities;
c) The interaction with other concurrent, preceding or subsequent activities in the area;
d) The most up to date thresholds for injury and behavioural responses; and
e) Whether the local abundance or distribution could significantly be affected.

The marine mammals most likely to be in the area are harbour porpoise, white-beaked dolphin and grey seal (Section 3.3.5).

The maximum anticipated underwater SPL from vessels (180-190dB re 1µPa at 1m) is below the thresholds for potential injury of marine mammals in terms of PTS (NMFS, 2018; Southall *et al*., 2019).

It is possible, however, that some sound induced disturbance to marine mammals may occur, potentially causing them to move away from the local area during periods of vessel use. Marine mammal species with the potential to be present in the project area are shown, grouped according to hearing range, in Table 7-1 with the project sound sources that are relevant to each hearing range group (NMFS, 2018; Southall *et al*., 2019).

FUNCTIONAL HEARING GROUP	GENERALISED HEARING RANGE	SPECIES KNOWN KNOWN TO OCCUR IN THE AREA	ACTIVITIES PRODUCING SOUND IN THIS BAND*
Low-frequency cetacean	7 Hz to 35 kHz	Minke whale	Vessel engine and propeller noise Drilling rig engine noise
Mid-frequency cetacean	150 Hz to 160 kHz	**White-beaked dolphin**, Atlantic white-sided dolphin, bottlenose dolphin	Vessel noise especially dynamic positioning Drilling rig machinery noise
High-frequency cetacean	275 Hz to 160 kHz	**Harbour porpoise** Other species when echolocating	No significant high-frequency sources present
Phocid pinnipeds	50 Hz to 86 kHz	**Grey seal**, Harbour seal	Vessel engine and propeller noise Drilling rig engine noise
* The frequency bands distinguish between very broad categories of sensitivity and sound sources			

Table 7-1 Hearing groups of marine mammals known to occur in the project area (NMFS, 2018)

Marine mammal behaviour would be expected to be habituated to general vessel sound, particularly around the eastern area of the proposed pipeline route and around Cygnus where levels of shipping activity are relatively high (Weir *et al*., 2001). This is supported, in the case of seals, by observations made during the pipeline route survey, where a grey seal was observed to surface next to, then swim alongside the survey vessel (Gardline, 2018d).

Given the above, and the localised extent and short duration or intermittent nature of the activities, the significance of the impact of sound generated by project vessels to marine mammals has been assessed as **low**.

7.2.2.1 Southern North Sea SAC for harbour porpoise

As described in Section 3, the project activities would take place within the Southern North Sea SAC for harbour porpoise (Figure 3-19). Project activities must minimise any impact which could threaten these objectives. There should be no significant disturbance to, and no deterioration of, the qualifying species (harbour porpoise) or the habitats upon which it relies (JNCC, 2020). The Draft Conservation Objectives and Advice on Activities document assessed the current level of impact risk (based on sensitivity and exposure to certain activities) and identifies anthropogenic underwater sound as having a medium level of risk meaning that there is some scope for harbour porpoise to be impacted by sound (JNCC, 2016a).

Although harbour porpoise might be expected to be habituated to general vessel sound, increased vessel activity has the potential to cause local disturbance, causing individuals to temporarily avoid the area where project vessels are working, or to reduce foraging effort. Harbour porpoise have been observed to show negligible responses to large, slow moving ships (Oakley *et al*., 2017) and it is anticipated that as a worst case, harbour porpoise would be displaced from or reduce foraging effort in areas in close proximity to vessels (Verboom and Kastelein, 2005) with some levels of displacement occurring out to 400 m from the vessel (Akkaya Bas *et al*. 2017, Polacheck 1990). However, the behavioural impacts are temporary with porpoises resuming activities relatively quickly once the vessel has passed (Hermannsen *et al*. 2014, Wisniewska *et al.* 2018a). As a high-frequency echolocator, harbour porpoise use signals well beyond the low frequencies predominantly produced by vessels, and thus, may be less sensitive to the effects of vessel noise than lower-frequency toothed whale species (Wisniewska *et al*., 2018b).

The total area of the SAC for harbour porpoise is 36,958 km^2 and the proportion of the SAC that could be impacted by sound associated with project vessels is very small, up to 0.5 km^2 for each vessel. Furthermore, advice on activities within the SAC states that, in relation to shipping-related underwater sound, additional management is unlikely to be required given current levels within the site (JNCC, 2016a). Therefore, project underwater sound will not impact the achievement of the Conservation Objectives of the Southern North Sea SAC.

Given the above, the significance of impacts from underwater sound generated by project vessels on the Southern North Sea SAC has been assessed as **low** with no detrimental impact to the conservation objectives of the site anticipated.

7.2.3 Decommissioning phase

A range of specialist and support vessel types will be required at various times, and for various durations, to undertake the decommissioning activities at the EoFL. This will lead to an increase in vessel activity relative to that associated with production.

A JUDR will be brought to Pegasus West to plug and permanently abandon the well. In addition, vessels will be required to remove and recover seabed infrastructure, and to complete pre-decommissioning, execute phase and post-decommissioning legacy surveys.

Underwater sound associated with decommissioning activities is likely to be similar to that associated with well completion and subsea infrastructure installation. The use of explosives or surveying that requires the use of a seismic source is not anticipated.

7.2.4 Transboundary and cumulative impacts

The proposed Pegasus West Development is located *c*. 35 km the UK/NL jurisdictional median line at its closest point, Cygnus. Given this distance and the localised nature of the impacts resulting from project sources of underwater sound, no transboundary impacts are anticipated.

The only potentially significant project sound sources are expected to be from localised, relatively short term increases in vessel activity. It is possible that this may cause marine mammals to move away from the local area during periods of vessel use, though they would be expected to return once the vessels have moved off location (Hermannsen *et a*l., 2014; Wisniewska *et al*., 2018a).

The primary source of background anthropogenic underwater sound in the area is from shipping, levels of which are 'low' around Pegasus West and the western area of the pipeline, increasing to 'moderate' around the middle and eastern parts of the pipeline route, then to 'high' around Cygnus. The proposed project is also located on the northern edge of a developed oil and gas production area in the SNS with associated sources of underwater sound. The localised, relatively short term increases in vessel activity will result in a small, local and short term increase in underwater sound relative to that produced by background shipping. Given that fish and marine mammal behaviour would be expected to be habituated to general vessel sound, any avoidance, displacement of fish from spawning grounds or reduced marine mammal foraging effort would be temporary and over a small area such that no significant cumulative impacts are anticipated.

There are a number of consented offshore wind farms to the north of the project area of which the closest

Dogger Bank A (also known as Creyke Beck A), is *c*. 11 km north of the proposed pipeline route at its nearest point (see Figure 3-25). Preconstruction UXO Survey clearance is planned to occur between May and December 2021 over a duration of *c*. 6 weeks, before offshore construction of Dogger Bank A and B commences in February (Q2) 2022. Within any 24-hour period a maximum of two UXO detonations will be allowed (MMO 2021). Expected operational first phase of Dogger Bank A and B is to be in 2023. Dogger Bank C is considered the third phase and will be developed on a later stage timescale (Dogger Bank 2020). The Hornsea One Wind Farm is the closest wind farm currently in construction, located in excess of 60 km to the south (Section 3.5.4). Pile-driving is usually required for offshore wind farm construction. This generates relatively high levels of underwater sound which is considered to pose a medium risk of impact to harbour porpoise (JNCC, 2016a) and may displace marine mammals from the area.

The Effective Deterrent Radius (EDR) has been proposed by the Statutory Nature Conservation Bodies (SNCBs) as a means to measure potential impacts on harbour porpoise (JNCC 2017e). The EDR is an empirically derived generic distance of 26 km within which deterrence, i.e. displacement, of harbour porpoise is predicted to occur from pile-driving. The EDR is based on published studies that have monitored the effects on harbour porpoise during pile-driving at offshore wind farms and reflects the overall loss of habitat if all animals vacate the area around a pile driver (Tougaard et al. 2014). Should piling at Creyke Beck A coincide with Pegasus West Development activities, harbour porpoise would be displaced from the Pegasus West project area because it would be almost entirely within the EDR. The Pegasus West well is just outside the EDR for piling at the Creyke Beck A site southern boundary, being located *c*. 28.2 km away. Therefore, sound generated by project vessels outside the EDR could displace harbour porpoise from, or cause behavioural disturbance within, a small additional area.

However, in comparison to sources of underwater sound associated with wind farm construction, the area of any additional harbour porpoise behavioural disturbance would be very small. For each pile-driving operation, harbour porpoise could be displaced from an area of up to 2,124 km^2, compared to up to 0.5 km^2 for each project vessel.

Given that any displacement as a result of project underwater sound will be very localised, no significant cumulative impacts or in combination effects associated with other sources of underwater sound are anticipated. The significance of cumulative impacts associated with underwater sound has therefore been assessed as **low**.

7.3 Control and Mitigation Measures

The following measures will be adopted to ensure that sound levels, and their effects upon potential receptors, are minimised to 'as low as reasonably practicable':

- Machinery, tools and equipment will be in good working order and well-maintained (as required under the contract with the subcontractor); and
- Vessel use will be optimised where possible by minimising the number of vessels required, and their length of time on site.

7.4 Conclusion

The principal sources of underwater sound arise from the use of vessels (including the JUDR) for subsea infrastructure installation and well completion activities. These have the potential to impact marine mammals and certain species of fish.

The project sources of underwater sound are not deemed capable of causing any physical injury to fish or marine mammals. As a worst case, fish and marine mammals may be temporarily displaced from, or reduce foraging effort in, areas in close proximity to vessels, but this would not be significant given the area of available habitat. Project underwater sound will not impact the achievement of the Conservation Objectives of the Southern North Sea SAC.

In summary, due to the localised and short duration, or intermittent nature of activities, and with the identified control and mitigation measures in place, the overall significance of the impact of underwater sound is considered to be **low**.

8. SEABED DISTURBANCE

This section identifies and assesses the impact of the various sources of planned seabed disturbance that will result from project activities and subsequent hydrocarbon production operations.

Following the adoption of appropriate control and mitigation measures, residual impacts are assessed in the context of the sensitivity, and the attenuating capacity, of the receiving environment.

For the purposes of this assessment, seabed disturbance is termed either 'temporary' or 'permanent'. Temporary seabed disturbance is used to describe the shorter-term impacts arising from activities connected with the users of vessels (including the JUDR) and the installation of seabed infrastructure; permanent seabed disturbance is used to describe the longer-term impacts arising from the physical presence of subsea infrastructure - following its installation - on the seabed.

Note that this section primarily assesses the impact of disturbance to the seabed and benthic communities. The impacts to commercial fishing, marine mammals and fish associated with the physical presence of installed subsea infrastructure are assessed in Section 5.

8.1 Sources

The principal planned project activities, including their location and estimated duration, are described in Section 2. Of these, the positioning of vessels (the JUDR) and the installation of subsea infrastructure have been identified as warranting further assessment in terms of their potential to disturb the seabed.

8.1.1 Temporary disturbance

Temporary disturbance can result in both direct impacts (e.g. crushing or physical abrasion, and burial of, benthos) and in indirect impacts (e.g. interference with the respiration or feeding mechanisms of benthos related to increased turbidity and/or smothering). The principal sources of temporary seabed disturbance, described in this section, are itemised in Table 8-1 with corresponding estimates of maximum area.

8.1.1.1 Positioning of vessels

Once at the Pegasus West well location the JUDR will be jacked down onto the seabed, raising (jacking up) the JUDR hull above the water and providing a stable platform for well completion activities. Excessive penetration by the legs into the seabed is minimised by large round feet at the bottom of the legs called 'spud cans'. On completion of well completion activities the legs will be raised (jacked down), possibly leaving scars and/or mounds in the seabed. Seabed disturbance caused by the penetration of these legs into the seabed will be influenced by:

- The nature of the seabed sediments; and
- The prevailing sediment transport system in the vicinity of the well location.

The depth of penetration of the legs will be dependent on the shear strength and load bearing capacity of the seabed sediments; a firm seabed will result in less depth of penetration than a soft seabed. Seabed sediments at the Pegasus West well location comprise gravelly sand, with areas of sand and sandy gravel (Section 3).

No anchors or dynamic positioning thrusters will be used by the JUDR, such that the only disturbance to the seabed will be caused by its spud cans directly below its hull.

8.1.1.2 Subsea infrastructure installation

This ES assesses the worst case seabed disturbance whereby the production pipeline and EHC umbilical are laid, and then trenched and buried in separate, parallel trenches by the jetting method (Section 2.5.3.2). Jet trenching of the production pipeline and EHC umbilical will be by far the largest contributor to temporary seabed disturbance.

Jet trenching does not leave spoil mounds on the seabed since majority of the disturbed sediments fall back into the trench naturally. No seabed material will therefore be removed from the project area.

The pipeline will be secured for installation by an initiation anchor either at Pegasus West or Cygnus.

To achieve the target depth of coverage for the pipeline and EHC umbilical their trenches will be excavated to depths of *c*. 1.8 m and 1.2 m respectively. This will result in a vertical redistribution of sediment, burying surface sediments and bringing deeper deposits to the surface. If the depth of superficial sediments is less that the trench depths, different sediments may be brought to the surface along the pipeline route (e.g. clay), changing the character of the seabed.

The Xmas tree and WPS will be lowered through the water column and installed on the seabed as a single unit by the JUDR. The production pipeline's tie-in spools and the SSIV at Cygnus will be installed on the seabed by a DSV in a controlled manner through the water column using the vessel's lifting apparatus.

Installed subsea infrastructure will require to be protected and/or stabilised with a range of features and materials. Concrete mattresses and grout bags will be installed by a DSV in a controlled manner. Rock will be deposited using a specialised subsea rock installation vessel using a fall pipe in combination with images that will be supplied in real time to the vessel from an ROV to aid accuracy of placement. Table 2-8 summarises the maximum quantities of rock cover, mattresses and grout bags to be installed.

Table 8-1 summarises the anticipated area of disturbance associated with the subsea infrastructure and the associated installation activities.

SOURCE OF SEABED DISTURBANCE	BASIS OF CALCULATIONS	AREA DISTURBED (km^2)	
		Temporary	Permanent
VESSELS			
Jack-up drilling rig	3 no. 18 m diameter spud cans. The area of temporary disturbance extends 1 m from the spud can edge.	0.01700	-
SUBSEA INFRASTRUCTURE			
Xmas tree and associated WPS and the SSIV	Dimensions of the Xmas tree and associated WPS and the SSIV are presented in Table 2-6. The area of temporary disturbance extends 1 m from the edge of the infrastructure footprint.	0.00009	0.00006
Trenched and buried section of production pipeline	Jet trenched section of the pipeline (*c.* 52.479 km – excludes 4.033 km surface laid section covered in rock berm). The area of temporary disturbance assumed to be over a corridor width of 10 m.	0.52479	-
Trenched and buried section of EHC umbilical	Jet trenched section of the EHC umbilical (*c.* 52.949 km – excludes 4.033 km surface laid section covered in rock berm) The area of temporary disturbance assumed to be over a corridor width of 10 m.	0.52949	-
PROTECTION AND STABILISATION FEATURES			
Deposited rock over surface-laid section of production pipeline and EHC umbilical	Section 2.5.3.1 details the length of production pipeline and EHC umbilical to be surface laid (4.033 km) and the width of the single rock berm (7.5 m) to be laid to protect the two lines. Area of temporary disturbance extends 5 m either side of the rock berm.	0.04033	0.03025
Deposited rock at Esmond to Bacton pipeline crossing	Section 2.5.3.3 details the Esmond to Bacton pipeline crossing which occurs within the surface laid sections of the production pipeline and EHC umbilical. An additional 300 m of rock will require to be laid due to the production pipeline and EHC umbilical diverging from the single rock berm for c. 150 m either side of the crossing. A rock berm width of 7.5 m is applied. Area of temporary disturbance extends 5 m either side of the rock berm.	0.00300	0.00225
Deposited rock at Esmond to Gordon pipeline crossing	Section 2.5.3.3 details the Esmond to Gordon pipeline crossing which occurs within the trenched and buried sections of the production pipeline and EHC umbilical. *C.* 100 m of production pipeline and EHC umbilical will require to be rock covered at this crossing. Separate rock berms will be used for each line. Area of temporary disturbance extends 5 m either side of each rock berm.	0.00200	0.00150
Deposited spot rock for pipeline free-span remediation and UHB mitigation	Table 2-8 includes an allowance of 10,000 te of spot rock cover The area of permanent disturbance associated with the deposition of spot rock assumes that each tonne has a footprint of 1 m^2. The area of temporary disturbance associated with spot rock cover is assumed to be twice the footprint of permanent disturbance.	0.02000	0.01000

<table>
<tr><th rowspan="2">SOURCE OF SEABED DISTURBANCE</th><th rowspan="2">BASIS OF CALCULATIONS</th><th colspan="2">AREA DISTURBED (km²)</th></tr>
<tr><th>Temporary</th><th>Permanent</th></tr>
<tr><td>Deposited rock on approach to Pegasus West</td><td>Within the Pegasus 500 m safety exclusion zone, c. 75 m of production pipeline/spools and c. 150 m of EHC umbilical will required to be protected with deposited rock (Section 2.5.3.4). Assessment of permanent impact assumes a rock berm of 7.5 m on these sections. Area of temporary disturbance extends 5 m either side of each rock berm.</td><td>0.00225</td><td>0.00169</td></tr>
<tr><td>Deposited rock on approach to Cygnus</td><td>Within the Cygnus 500 m safety exclusion zone, c. 60 m of production pipeline/spools and c. 230 m of EHC umbilical will required to be protected with deposited rock (Section 2.5.3.4). Assessment of permanent impact assumes a rock berm of 7.5 m on these sections. Area of temporary disturbance extends 5 m either side of each rock berm.</td><td>0.00290</td><td>0.00218</td></tr>
<tr><td>Concrete mattresses at approaches to Pegasus West and Cygnus</td><td>Table 2-8 details 86 mattresses (6 m (L) x 3 m (W)) out with any crossings (23 at Pegasus West and 63 at Cygnus). rea of temporary disturbance extends 1 m around each mattress.</td><td>0.00189</td><td>0.00155</td></tr>
<tr><td colspan="2">Total</td><td>1.14374</td><td>0.04948</td></tr>
<tr><td colspan="4">The disturbance associated with installing the surface-laid sections of production pipeline/tie-in spool, and EHC umbilical at the well and platform approaches (Table 2-6) is not considered separately as the impact is accounted for by the overlying protection and stabilisation features and materials.
The disturbance associated with installing concrete mattresses over historically deposited rock, over newly deposited rock (required for this project), or which are laid and subsequently covered by deposited rock required for this project, are not considered separately to avoid double-counting.
The grout bags identified in Table 2-8 have not been accounted for separately as their footprint will overlap with that of the rock cover and mattresses included above.
It is also assumed that the temporary placement of objects on the seabed will be within the footprint of other sources of disturbance accounted for above.</td></tr>
</table>

Table 8-1 Estimated area of seabed disturbance

8.1.2 Permanent disturbance

The installation of subsea infrastructure, including the Pegasus West well Xmas tree and WPS, the surface-laid ends of the production pipeline (including its tie-in spools) and EHC umbilical, the SSIV at Cygnus, and associated protection and stabilisation features, will result in permanent seabed disturbance. The degree of seabed disturbance caused will be directly related to the size (‘footprint’) of this infrastructure.

An estimate of the seabed area permanently disturbed is presented in Table 8-1. It shows that the worst case estimated total area impacted is 0.0495 km^2. To put this into context, a licence block is approximately 200 km^2 and the Dogger Bank SAC is 12,331 km^2.

8.2 Impacts and Receptors

The positioning of vessels, and the installation of subsea infrastructure has the potential to cause a range of direct and indirect impacts.

The seabed that would be disturbed by project activities is characterised by sand and shell fragments with areas of coarser sediment. These areas of coarser sediment comprise sandy gravel with shell fragments and cobbles and pebbles (Gardline, 2018a). The proportions of fine material (<63µm; silt and clay) were generally low at all stations.

The pipeline survey identified five biotopes on the proposed pipeline route, all of which fall under the definition of ‘sandbanks which are slightly covered by seawater all of the time’ Annex I habitat, particularly where they occur at less than 20 m LAT. No other Annex I habitats were identified in the project area. The survey recorded the presence of *A. islandica* at some stations. Furthermore, impacts on the habitats and prey species that support harbour porpoise could indirectly impact harbour porpoise and the Conservation Objectives of the Southern North Sea SAC.

The sensitivity of receptors to seabed disturbance, based on the Marine Evidence based Sensitivity Assessment (MarESA) approach (Tyler-Walters *et al*., 2018), is summarised in Table 8-2.

8.2.1 Temporary disturbance

8.2.1.1 Direct impacts

In total, it has been calculated that up to 1.144 km^2 of seabed will be directly disturbed by temporary project activities, primarily as a result of trenching and burial of the production pipeline and EHC umbilical.

The crushing of benthos under temporarily deposited items, and physical abrasion and burial by trenching, may result in mortality or in physical injury. The significance of impact will depend upon the number and type of species present, including their ability to move away from the area of operations. The impacts of temporary seabed disturbance should be assessed in the context of other sources of seabed disturbance in the project area including from natural disturbance by waves and currents, and anthropogenic disturbance such as from trawling. Trawling occurs widely across Dogger Bank, coinciding with the area of existing oil and gas developments and the proposed development, but at relatively low intensity (Section 3.5.1).

The seabed habitats that would be disturbed by project activities range from low to medium sensitivity to physical abrasion of the seabed, or burial. Where *A. islandica* is present, there may be mortality of, or damage to individuals that are directly impacted by the trenching plough or temporarily deposited items. However, *A. islandica* would not be impacted by burial (Table 8-2). Recolonization of impacted areas would occur through species recruitment from adjacent undisturbed areas.

BIOTOPE/RECEPTOR	PHYSICAL ABRASION OR PENETRATION OF THE SEABED	SMOTHERING/BURIAL	CHANGE OF SEABED TYPE
A5.143 *Protodorvillea kefersteini* and other polychaetes in impoverished circalittoral mixed gravelly sand	Characteristic species are likely to be relatively tolerant, being either robust, buried within sediments or adapted to frequent natural disturbance (e.g. storms). Polychaetes will be displaced and may be predated or injured and killed. However, most species will recover rapidly, within 2 years (Tillin, 2016a).	Characteristic species burrow in to the sediment and would be expected to be tolerant of burial. They are also exposed to natural sediment transport and light smothering, and are expected to be tolerant.	Characterising species live within the sediment and would not be able to survive if the substratum was changed to either a rock or hard artificial type. Consequently, the biotope would be lost altogether if such a change occurred (Tillin, 2016a).
A5.233 *Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand	The biotope is present in mobile sands, associated species are in low abundance and adapted to frequent disturbance suggesting resistance is high. The small size, infaunal position and mobility of characterising species means a large proportion of the population to escape injury (Tillin, 2016b).	A thick layer of sediment has a smothering effect and in most instances buried species will die, although some polychaetes can escape up to 90 cm of burial. *Bathyporeia* has been shown to migrate through up to 40 cm of sand overburden. Recovery could be expected within one year (Tillin, 2016b).	Characterising species live within the sediment and would not be able to survive if the substratum was changed to either a rock or hard artificial type. Consequently, the biotope would be lost altogether if such a change occurred (Tillin, 2016a).
A5.445 *Ophiothrix fragilis* and/or *Ophiocomina nigra* brittlestar beds on sublittoral mixed sediment	Likely to remove both the infauna and epifauna. Consequently, the biotope could be lost or severely damaged. However, the extent of this habitat is limited on the proposed pipeline route (only station ENV4). Recovery in 2–10 years (De Bastos, 2016).	Brittlestars are likely to be adversely affected by the smothering effect of heavy sediment deposition. Lighter smothering can affect the efficiency of filter feeding but an increase in suspended organic matter may provide increased food material. Dispersion of sediments by currents and wave action would reduce exposure (De Bastos, 2016).	If the mixed sediments were replaced with rock or other hard substrata, this would represent a fundamental change to the physical character of the biotope which would be lost (De Bastos, 2016).
A5.444 *Flustra foliacea* and *Hydrallmania falcata* on tide-swept circalittoral mixed sediment	Damage to individuals through abrasion, and by overturning surfaces could result in the smothering of fauna or reductions in respiration, feeding efficiency. However, the habitat is likely to be exposed natural movement of substrata (e.g. from storms) (Readman, 2016).	Smothering is likely to prevent feeding, respiration, growth and reproduction in bryozoans resulting in some mortality. It may also interfere with larval settlement. However, the biotope occurs in areas of sand scour and deposition, and recovery is considered high (<1 year) (Readman, 2016).	This biotope is characterized by the hard substratum provided by the pebbles and cobbles to which the key characterizing species can firmly attach (Readman, 2016). A change to a more stable hard substrate would change the habitat and species composition, although some characterising species may remain.
A5.134 *Hesionura elongata* and *Microphalmus similis* with other interstitial polychaetes in infralittoral mobile coarse sand	Some mortality is likely but characterising species have been shown to quickly recolonise areas disturbed by aggregate extraction and scouring. However, deeper penetration may have a greater impact on characteristic burrowing species (Ashley & Marshall, 2007).	Characterising species quickly recolonise disturbed areas where the sediment in the area remains coarse sand, and are tolerant of some sediment transport. However, the community would be less tolerant of heavy deposition of fine sediment resulting in a permanent change to the seabed (Ashley & Marshall, 2007).	This biotope is only found in infralittoral sandbanks and sandwaves and other areas of mobile medium-coarse sand. Characterizing species burrow or live within the sediment and would not be able to survive if the substratum type was changed to either rock/hard artificial type or fine sediment (Ashley & Marshall, 2007).
Arctica islandica	Mortality or shell damage can be caused by fishing trawls and has been linked to the decline in the SNS population. Recovery of this slow growing, long-lived species is low (Tyler-Walters & Sabatini, 2017).	*A. islandica* has been shown to migrate to the surface through up to 1.5m of deposited spoil with no mortality or impact on growth or population structure. It is therefore considered not sensitive (Tyler-Walters & Sabatini, 2017).	A change to natural or artificial hard substratum would remove the sedimentary habitat required by the species (Tyler-Walters & Sabatini, 2017).
KEY	Low Sensitivity	Medium Sensitivity	High Sensitivity

Table 8-2 Indicative sensitivity of receptors to seabed disturbance

8.2.1.2 Indirect impacts

The suspension of sediment into the water column associated with the project activities discussed in Section 8.1.1 will result in temporarily increased suspended solids concentrations, and where redeposition occurs, subsequent changes to the physical - and potential changes to the chemical - characteristics of the seabed.

The scale of impact will depend upon the nature of the sediment being redistributed, the sedimentary characteristics of the area where it is redeposited, and the abundance and type of benthos present, including their ability to move away from the area of operations, and resilience to increased water column turbidity or smothering.

Benthic communities inhabiting the infralittoral and circalittoral seabed habitats found in the project area are likely be exposed to disturbance from moderately strong currents and periodic wave action (Section 3.2.1), resulting in natural disturbance through mobilisation and transport of seabed sediments. This is supported by the presence of sand ripples and megaripples throughout the proposed pipeline route. Many of the dominant species identified on the proposed pipeline route are tolerant of smothering, including the polychaete *S. bombyx* and the bivalve molluscs *F. fabula* and *A. alba* (Gardline, 2018a and references therein).

The seabed habitats that would be disturbed by project activities, and any individual *A. islandica* present, have Low sensitivity to increased suspended solids and sediment redeposition, except for the biotope '*Ophiothrix fragilis* and/or *Ophiocomina nigra* brittlestar beds on sublittoral mixed sediment'. This biotope, which was recorded at one survey station (ENV4, KP5.13), has Medium sensitivity to smothering, although the characterising species may benefit from small increases in suspended matter (Table 8-2).

The geographic extent of sediment mobilisation from project activities is likely to be limited by the low proportion of fine material along the pipeline route. Unlike finer sediments, larger particles of sand and gravel will not disperse far and will redeposit rapidly close to the source of disturbance, orientated in the direction of (predominantly) tidal currents at the time. The limited increase in suspended fine material, settling out from the water column outside these areas, may increase food availability.

Impacts from exposure to contaminants as a result of sediment mobilisation and redeposition are possible. The pipeline survey showed elevated concentrations of hydrocarbons and heavy metals, above background, at several stations along the pipeline route, but only concentrations of vanadium and tin were sufficiently high to potentially have biological impacts (Section 3.2.3.3). However, impacts from exposure to sediment contamination are unlikely because the benthic community present are naturally exposed to existing contamination in the sediment. The area over which sediment and associated contaminants could be dispersed will also be small and would be unlikely to change the sediment chemistry of adjacent seabed areas.

Given the small area of temporary seabed disturbance relative to the extent of the identified sublittoral sediment habitats in Dogger Bank SAC and the wider SNS, and the ability of seabed communities to recover, the significance of the impacts associated with temporary disturbance on seabed communities has been assessed as **medium**. Temporary seabed disturbance is therefore not expected to impact the achievement of the Conservation Objectives of the Dogger Bank SAC or the Southern North Sea SAC.

8.2.1.3 Fish spawning and nursery grounds

As discussed previously, a number of species of fish are known to spawn within the vicinity of the proposed development with others using it as a nursery area.

Increased suspended solid concentrations and sediment deposition is unlikely to affect fish species that are broadcast spawners because they release the eggs and sperm into the water column, after which they are widely dispersed. Any juveniles present would be sufficiently mobile to move away from the disturbed area. Sediment deposition does, however, have the potential to impact spawning grounds for species that lay their eggs on particular types of seabed, including herring and sandeel, if the seabed is disturbed during the spawning season. Deposited sediment has the potential to smother demersal eggs resulting in mortality. It may also change the composition of the seabed to unsuitable spawning habitat.

Surveys have confirmed the presence of herring spawning grounds in the Pegasus West well area (Fugro, 2012) and reported seabed of high herring spawning potential at stations ENV1 and ENV2 near the well, and stations ENV5, ENV6, ENV11, ENV14, ENV15 and ENV20 further east on the proposed pipeline route (Gardline, 2018a) (Figure 3-14). Preferred sandeel spawning habitat has been identified at eleven of the 21 survey stations on the pipeline route, although sandeel spawning has not been confirmed (Section 3.3.3).

Project sources of seabed disturbance around the Pegasus West well location, and possibly along the proposed pipeline route, therefore have the potential to impact herring and sandeel spawning, particularly if they take place during and shortly after the spawning seasons. Herring spawning takes place between August and October, and eggs have been observed around the Pegasus West well in November 2011; sandeel spawning takes place between November and February, and eggs hatch February to March (Section 3.3.3).

Trenching and burial of the production pipeline and EHC umbilical will directly disturb the largest area of seabed (Table 8-1), potentially burying any eggs laid on surface sediments on the route. Pipeline crossings are not in close proximity to identified potential herring or sandeel spawning habitats. The direct impacts of pipeline and EHC umbilical installation are assumed to be restricted to a 10 m corridor, 5 m either side of their route centre lines. Indirect impacts associated with sediment mobilisation and redeposition, potentially resulting in smothering and mortality of eggs, will be limited by the low proportion of fine material along the pipeline route. Any changes to surface sediments, and therefore spawning habitat potential, will also be restricted to a small corridor along the proposed pipeline and EHC umbilical route(s).

Given the small area of seabed disturbance, relative to the extent of suitable spawning and nursery habitat in the SNS, any local mortality is unlikely to have an impact on populations as a whole. The significance of the impacts associated with seabed disturbance on fish has therefore been assessed as **medium**.

8.2.2 Permanent disturbance

In total, it has been calculated that up to 0.057 km^2 of seabed will be permanently disturbed by the installation of seabed infrastructure.

This will cause mortality or displacement of mobile benthic species, and direct mortality of sessile benthos that cannot move away from the impacted area. The significance of impact will depend upon the number and type of species present, including their ability to move away from the area of operations.

The seabed infrastructure will change the physical characteristics of the seabed, replacing the natural sublittoral sand, coarse and mixed sediment seabed habitats with a stable, hard substrate. This new area of hard substrate, with limited sand cover, will be colonised by new species, establishing, over time, a different benthic community within the EUNIS Circalittoral rock and other hard substrata (A4) broad habitat classification.

The area of permanent seabed disturbance relative to the extent of the identified sublittoral sediment habitats in Dogger Bank SAC and the wider SNS is small, and will not have a significant impact the achievement of the Conservation Objectives of the Dogger Bank SAC or the Southern

North Sea SAC. Therefore, the significance of the impacts associated with permanent disturbance on seabed communities has been assessed as **medium**.

8.2.3 Decommissioning phase

At CoP the Pegasus West infrastructure will be decommissioned as part of a Decommissioning Programme and in line with legislation and practices in force at that time. Decommissioning activities are likely to result in some disturbance to the seabed. Sources of disturbance could include:

- Project vessels including positioning of a JUDR for well plugging and abandonment;
- Seabed sampling for pre-decommissioning survey work;
- Localised excavation of subsea infrastructure to allow access for cutting or lifting;
- Removal and recovery of subsea infrastructure;
- Potential temporary wet storage of items following disconnection and prior to recovery; and
- An infrastructure over-trawl assessment, if required.

A Comparative Assessment will be conducted to determine the optimal option for the decommissioning of the pipeline and EHC umbilical. Following discussion with OPRED and its consultees, Spirit Energy, as operator, will meet survey requirements prior to the commencement of decommissioning activities. An Environmental Appraisal, submitted in support of the Decommissioning Programme, will assess the impacts associated the disturbance of the seabed. The activities will be further described and assessed under execute project phase permits, including a marine licence in line with advice received from OPRED at the time. It is anticipated that the area disturbed by the decommissioning activities will largely be within the area of seabed disturbance associated with installation activities.

8.3 Transboundary and Cumulative Impacts

8.3.1 Transboundary impacts

The proposed Pegasus West Development is located approximately 35 km the UK/NL jurisdictional median line at its closest point, Cygnus. Given this distance and the localised nature of the impacts resulting from the seabed disturbances, no transboundary impacts are anticipated.

8.3.2 Cumulative impacts

In isolation, the significance of the impacts associated with disturbance of the seabed by the proposed development has been assessed as **medium**. However, consideration of potential cumulative or in-combination effects from other activities and developments in the area is required by current EIA guidance (BEIS, 2017). Given that seabed disturbance would occur in the Dogger Bank SAC, designated for the protection of the Annex I seabed habitat ‘Sandbanks which are slightly covered by seawater all the time’, a wider assessment of seabed disturbance within the SAC is necessary.

8.3.2.1 Oil and gas activity

Oil and gas activity is present within the SAC, particularly in the south of the protected area where there are a number of existing platforms, pipelines and other subsea infrastructure (Figure 8-1). As well as existing infrastructure, a number of oil and gas licence blocks in the southern and central area of the SAC have been awarded in the 32nd Round for future exploration and development

(OGA,2021). The JNCC also note that decommissioning activities for some of the existing infrastructure is likely to take place in the near future (JNCC, 2018).

There are currently 13 platforms installed within the Dogger Bank SAC; these are:

- Cygnus A (three bridge-linked platforms) (Block 44/12) and B (Block 44/11);
- Cavendish (Block 43/19);
- Katy (Block 44/19);
- Kelvin (Block 44/18);
- Munro (Block 44/17);
- Murdoch (three bridge-linked platforms) (Block 44/22);
- Tyne (Block 44/18); and
- Wingate (Block 44/24)

A Decommissioning Programme for the removal to shore of the Tyne was approved in January 2019 with the decommissioning project predicted to occur over a six-year timescale which began in 2016 (Perenco 2019). Decommissioning of the Cavendish field has been approved to be undertaken over a five year period from 2019.

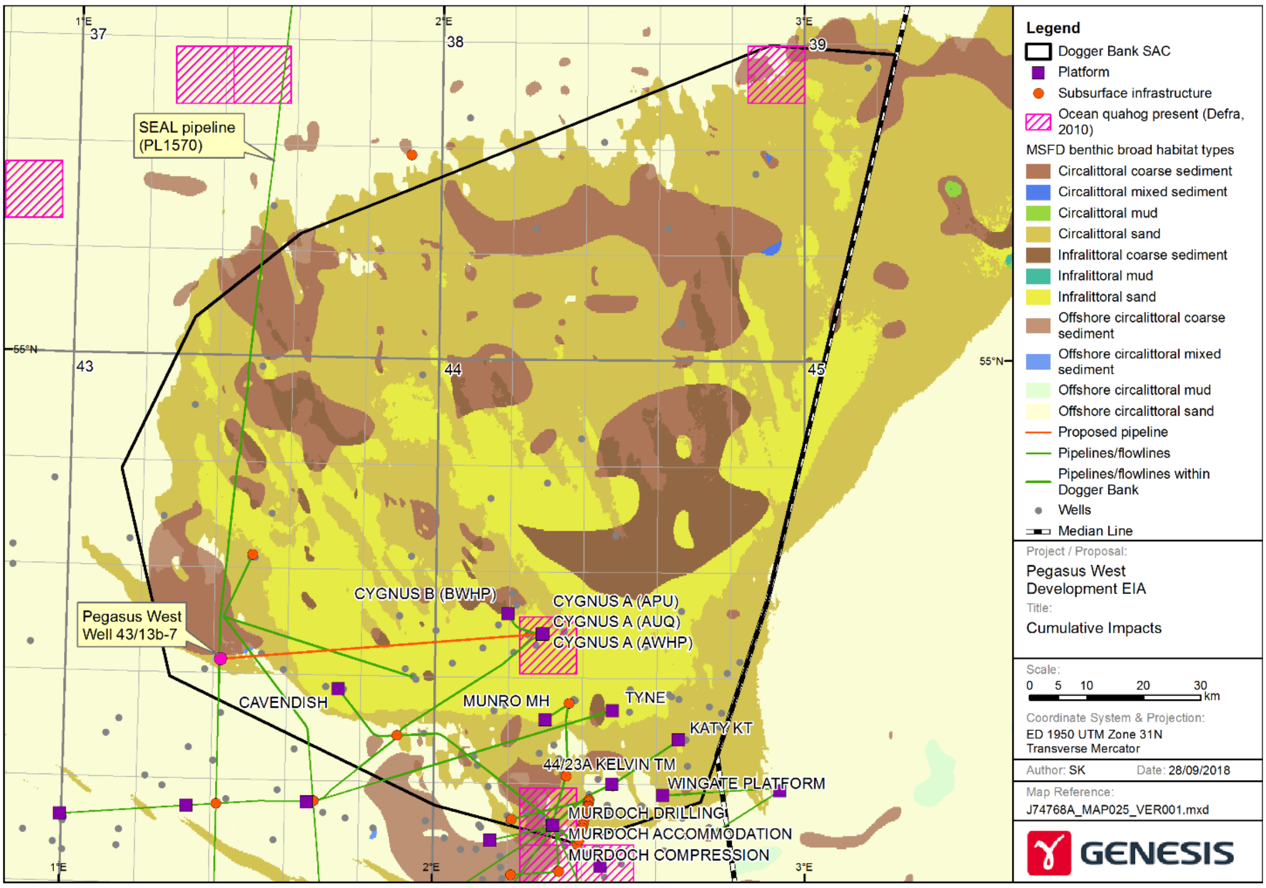


Figure 8-1 Existing oil and gas infrastructure and the proposed Pegasus West development in the Dogger Bank SAC

The average footprint of the four Cygnus platforms is 662.5 m^2 each (GDF Suez, 2011). Using this as a proxy for all platforms, the total permanent footprint of platforms in the SAC is calculated as 8,612.5 m^2 or 0.00861 km^2. It should be noted that this is a conservative estimate, given that all platforms are of a jacket construction with individual legs which do not cover the whole of the seabed underneath the platform.

Using Geographic Information Systems (GIS) data (UKOilandGasData, 2018), 33 items of existing subsea infrastructure (excluding pipelines) have been identified within the Dogger Bank SAC.

These are of varying sizes and include manifolds, SSIVs, drilling templates, skids, tees and wellheads. All of these have a permanent impact on the seabed. Assuming an average footprint of 0.00017 km^2 (based on a maximum and minimum size from the Cygnus and Katy developments, see GDF Suez, 2011; ConocoPhilips, 2011), then the total potential area of permanent impact from existing subsea infrastructure is 0.00554 km^2.

There is a total of 47 different existing pipelines/flowlines within or traversing the Dogger Bank SAC. Of these, 40 are noted as being active, two are in pre-commissioning and five are abandoned (UKOilandGasData.com, 2018). Using GIS data and analysis, it has been calculated that the total length of the pipelines/flowlines within the SAC is 679.90 km. The largest of these is the Shearwater to Bacton (Shearwater Elgin Area Line - SEAL) pipeline (PL1570) which runs between the Shell operated Shearwater and Elgin Franklin platforms and the Bacton gas terminal on the Norfolk coast. It has a diameter of 44" (112 cm) and is surface laid. The remaining pipelines are assumed to be trenched and buried.

Rock cover and other protection and stabilisation features will also have been installed at certain locations along these pipelines (e.g. pipeline crossings and trench transitions) although the exact volume and footprint of these is not known. For the Cygnus Field Development, the footprint of each pipeline crossing was calculated as 0.00336 km^2 (320 m x 10.5 m) (GDF Suez, 2011).

Using GIS, six crossings have been identified for the existing pipelines within the Dogger Bank SAC. Taking the Cygnus Field Development crossings footprint as a proxy, it can be estimated that a total area of approximately 0.02016 km^2 is permanently impacted by rock cover at the pipeline crossings. Contingency spot rock cover may also have been used along the length of each pipeline to provide additional protection and stabilisation. It is expected that this has been minimised, and exact quantities used are only known following post-lay pipeline surveys. Assuming that as a worst case 10% of each pipeline length required spot rock cover to a width of 7 m (ConocoPhilips, 2011), then excluding the Shearwater to Bacton line (which is surface laid), the total length of pipeline potentially having spot rock cover can be estimated as approximately 60.32 km with a total potential permanent impact area of 0.42223 km^2. The Shearwater to Bacton line within the SAC is 76.72 km in length and 0.00112 km diameter. The area of impact of this pipeline is calculated to be 0.08593 km^2.

The total area permanently impacted by existing pipelines and associated protection materials within the Dogger Bank SAC is therefore estimated to be approximately 0.54247 km^2, as summarised in Table 8-3.

SOURCE	AREA PERMANENTLY DISTURBED (KM^2)
Platforms	0.00861
Subsea infrastructure	0.00554
Pipelines (trenched and buried) crossings	0.02016
Pipelines (trenched and buried) spot rock cover	0.42223
Pipelines (surface laid)	0.08593
Total	0.54247

Table 8-3: Permanent seabed disturbance from existing oil and gas infrastructure within the Dogger Bank SAC

The area of the Dogger Bank SAC is 12,331 km^2 (JNCC, 2018). The total area of the SAC estimated to be permanently impacted by existing oil and gas infrastructure (0.54247 km^2) accounts for approximately 0.0044% of the SAC. Combined with the area of permanent disturbance from the proposed Pegasus West Development (0.0495 km^2) this would increase to 0.0047% of the SAC. It is assumed that seabed communities will have recovered from temporary disturbance associated with the installation of existing oil and gas infrastructure.

8.3.2.2 Other activities

The consented Dogger Bank A,B and C and Sofia Offshore Wind Farm B are located to the north of the proposed Pegasus West Development, inside the Dogger Bank SAC. Construction of Dogger Bank A and B is currently underway, with main offshore construction predicted to occur in Q2 2022. Expected operational first phase of Dogger Bank A and B is to be in 2023. Dogger Bank C is considered the third phase and will be developed on a later stage timescale (Dogger Bank 2020). The area of seabed that will be permanently disturbed by these wind farm development is summarised in Table 8-4, based on the use of monopile foundations.

WIND FARM	AREA PERMANENTLY DISTURBED (KM^2)
Dogger Bank A	3.60
Dogger Bank B	3.48
Dogger Bank C	2.79
Sofia Offshore Windfarm	2.79
Total	12.66

Table 8-4 Permanent seabed disturbance from consented wind farm infrastructure within the Dogger Bank SAC (Forewind, 2013; 2014)

The JNCC (2018) note that there is a proposal for licensing two areas for marine aggregate extraction which overlap with the Dogger Bank SAC. Data showing the current location and extent of aggregate exploration and licence areas does not indicate activity in the SAC (Crown Estate, 2018), however, these areas may be subject to activity in the future.

Five subsea telecommunications cables pass through the Dogger Bank SAC, TATA North Europe, MCCS, Tampnet, UK-Denmark 4 (out of use) and UK-Germany 6 (out of use). The approximate combined length of all cables within the SAC is 376.63 km. Assuming a maximum cable diameter of 50 mm (KIS-ORCA, 2018), then the total area of permanent impact is 0.01883 km^2.

8.3.2.3 Cumulative disturbance

Infrastructure to be installed as part of the proposed Pegasus West Development will increase the footprint of offshore infrastructure within the Dogger Bank SAC, as summarised in Table 8-5.

<table>
<tr><th>SOURCE</th><th>AREA PERMANENTLY DISTURBED (KM²)</th><th colspan="2">% OF SAC</th></tr>
<tr><td>Pegasus West</td><td>0.0495</td><td>0.00040</td><td rowspan="2">0.1031 (Planned)</td></tr>
<tr><td>Offshore wind farms</td><td>12.66</td><td>0.1027</td></tr>
<tr><td>Other oil and gas infrastructure</td><td>0.54247</td><td>0.0044</td><td rowspan="2">0.0046 (Existing)</td></tr>
<tr><td>Telecommunications cables</td><td>0.01883</td><td>0.0002</td></tr>
<tr><td>Total</td><td>13.2708</td><td colspan="2">0.1076</td></tr>
</table>

Table 8-5 Cumulative permanent seabed disturbance within the Dogger Bank SAC

Based on the information available, the area of seabed permanently disturbed by the Pegasus West Development would be a small increase to the existing area of permanent disturbance within the SAC, constituting approximately 0.0004% of the protected area (Table 8-5). The increase in permanent seabed disturbance will be minimised where possible e.g. by jet trenching the production pipeline and EHC umbilical where possible, such that the overall cumulative impacts are kept to a minimum.

Given the small additional area of permanent seabed disturbance relative to the extent of seabed habitats in the Dogger Bank SAC and wider SNS, the significance of the cumulative impact associated with permanent disturbance of seabed communities has been assessed as **low**.

8.4 Control and Mitigation Measures

The following measures will be adopted to ensure that seabed disturbance and its impacts are minimised to 'as low as reasonably practicable':

- All activities which may lead to seabed disturbance will be planned, managed and implemented in such a way that disturbance is minimised;
- Project vessels will utilise dynamic positioning systems for station keeping rather than anchors;
- Rig site surveys will be completed before locating the JUDR at Pegasus West;
- If possible, the JUDR will be positioned so that spud cans line up with existing spud can depressions;
- The production pipeline and EHC umbilical tie-back route length will be minimised;
- The area of drag of the initiation anchor, used to lay the pipeline, will be minimised;
- The use of protection and stabilisation features will be optimised; and
- Spot rock deposits will be installed in a controlled manner using a fall-pipe and ROV.

8.5 Conclusion

The principal sources of seabed disturbance associated with the Pegasus West Development project activities concern the positioning and jack-up of the JUDR, the deposition and installation of infrastructure, stabilisation and protection features, and the excavation of sediments (trenching). Of these, the largest area of impact will be from temporary disturbance associated with trenching and burial of the pipeline and EHC umbilical. The largest area of permanent seabed disturbance will be from the installation of pipeline crossings and spot rock cover. These activities will result in the redistribution of sediments, potentially resulting in mortality or physical injury to benthos and eggs laid on the seabed, and in some locations, the permanent replacement of the natural seabed habitat with a stable, hard substrate.

Standard measures to control disturbance include operational planning and equipment selection.

The species and habitats recorded in the vicinity of the Pegasus West Development are relatively widespread in the SNS. The area anticipated to be permanently disturbed represents a very small percentage of the extent of these habitats in the region and in the Dogger Bank SAC. The area that would be impacted by temporary disturbance, although larger, also represents a very small percentage of the extent of these habitats in the region and in the Dogger Bank SAC. Furthermore, the environment is subject to natural disturbance by waves and currents, and anthropogenic disturbance such as from trawling. None of the seabed communities identified in the project area has a high sensitivity to temporary seabed disturbance. Recovery would be expected to commence, through species recruitment from adjacent undisturbed areas, as soon are activities are completed.

In summary, due to the localised and relatively short duration of project activities, the limited footprint of infrastructure that will be installed on the seabed, and with the identified control and mitigation measures in place, the overall significance of the impact associated with seabed disturbance is considered to be **medium** and ‘as low as reasonably practicable’.

9. DISCHARGES AND RELEASES TO SEA

This section identifies the various sources, and assesses the impact, of planned (operational) discharges to the marine environment that will result from project activities and subsequent production operations. It also considers the potential for, and the effects of, unplanned (accidental) releases to the marine environment.

Following the adoption of appropriate control and mitigation measures, residual effects and impacts (and the risk of such impacts) are assessed in the context of the sensitivity of, and the assimilative capacity of, the receiving environment.

Note that the specific case of a large hydrocarbon release to sea is addressed separately in Section 11.

9.1 Sources

The principal planned activities, including their location and estimated duration, are described in Section 2. Of these, the general use of vessels, including the JUDR, well completion, the commissioning of subsea infrastructure, and the production of hydrocarbons have been identified as warranting further assessment in terms of the impact and potential impact of their discharges and releases.

9.1.1 Vessels

Sources of discharges and releases from vessels are:

- Planned discharges (ballast water, bilge water, treated general shipboard drainage containing residual quantities of oils and chemicals, treated sewage, grey water and food waste from accommodation and amenities); and
- Unplanned releases of small volumes of hydrocarbons or chemicals (e.g. through the drainage system). The likelihood of such releases is considered low and they are therefore not assessed further below.

9.1.2 Well completion

Sources of discharges from well completion are:

- Planned discharge of completion fluids, consisting of brine with small quantities of chemicals (e.g. corrosion inhibitor, oxygen scavenger and biocide) used to protect the well; and
- Planned discharge of reservoir hydrocarbons (if completion fluids are contaminated).

9.1.3 Subsea infrastructure commissioning

Sources of discharges from subsea infrastructure testing and commissioning are:

- Planned discharge of chemically treated, dyed seawater and MEG at Pegasus West during pipeline dewatering.

9.1.4 Production of hydrocarbons

Sources of discharges and releases from hydrocarbon production are:

- Planned discharge of production chemicals injected at the Pegasus West well, returned to

Cygnus in production fluids, and discharged to sea at Cygnus with produced water;

- Planned discharge of small quantities of Pegasus West reservoir hydrocarbons in Cygnus produced water;
- Planned discharge of small quantities of hydraulic control fluid at the Pegasus West well; and
- Unplanned releases of small volumes of hydrocarbons or chemicals (e.g. from dedicated Pegasus West hydraulic fluid or methanol storage facilities at Cygnus). The likelihood of such releases is considered low and they are therefore not assessed further below.

9.2 Impacts and Receptors

Discharges and releases have the potential to impact marine environmental receptors (water quality, plankton, benthos, fish, birds etc.), and cause acute toxic effects where they are concentrated in the immediate vicinity. They may also contribute to more widespread, long term chronic effects if they persist in the environment and bioaccumulate in the food chain.

9.2.1 Vessels

Planned operational discharges to sea from vessels will be subject to on-board control measures designed to secure compliance with the requirements of MARPOL (1973).

Project activities will comprise a maximum of 438 vessel days spread over several months (Table 2-3, Table 2-5, Table 2-9 and Table 2-10). During this time discharges will be controlled and minimised using operating procedures and systems for optimum performance, including planned preventative maintenance systems for peak operating efficiency of on-board systems for the management of drainage, effluent, ballast water and bilge water.

Although water quality will be reduced at the immediate time and location of discharge, the effects of planned vessel discharges and any small volume unplanned releases will be minimised due to the expected rapid dilution and dispersal of contaminants under ambient metocean conditions. It is considered unlikely that impacts beyond those associated with normal shipping activities will occur. Given the above, the significance of the impacts from these discharges and releases has been assessed as **low**.

9.2.2 Planned chemical discharges (excluding vessels)

Well completion operations will require the discharge of completion brine with small quantities of chemicals by the JUDR. These chemical discharges will be in compliance with the conditions of a well intervention chemical permit.

Pipeline testing and commissioning operations may require the use and discharge of chemicals used to mitigate the risks of corrosion or bacterial growth, whilst a dye may be added to assist in leak detection. These would be discharged at the seabed during pipeline dewatering, along with chemicals used to inhibit hydrate formation when production from Pegasus West commences. These chemical discharges will be in compliance with the conditions of a pipeline chemical permit.

Chemicals injected into production fluids at the Pegasus West well to maintain process efficiency (Section 2.7.4), will be discharged to sea at Cygnus with produced water if they partition into the water phase, rather than the hydrocarbon phase during separation. These chemicals are likely to include methanol, KHI and corrosion inhibitor. Small quantities of hydraulic control fluid will also be released to sea during hydrocarbon production when hydraulic valves actuate at the Pegasus West well.

All planned chemical use and discharge will be permitted under the Offshore Chemicals

Regulations 2002 (OCR). Chemical discharges are expected to rapidly disperse and dilute under ambient metocean conditions. Chemical permits, which will include an environmental risk assessment for planned discharges, will be obtained prior to execution, and when the exact chemical products and quantities are known.

Spirit Energy aims to minimise the impact of the chemicals used/discharged during its operations. As such, and as part of the chemical permitting process, Spirit Energy sets internal targets to reduce the number of chemicals used with a substitution warning and/or product warnings. Wherever possible, and where they are compatible with the Cygnus host facilities, chemicals will be chosen that are PLONOR (Pose Little Or No Risk to the environment) or are of HQ <1. All CHARMable chemicals (Chemical Hazard and Risk management) chemicals that are discharged will be further assessed by calculating a Risk Quotient (RQ), where an RQ >1 indicates a possible risk of the discharge causing harm to the marine environment. This condition initiates further investigation of the chemical to determine whether an alternative chemical or application method can be used which produces a lower RQ.

Based on current methodologies there are no chemicals planned for use and/or discharge that significantly differ from those routinely used in offshore oil and gas operations.

Given the above, the significance of the impact of planned chemical discharges has been assessed as **low**.

9.2.3 Planned hydrocarbon discharges (excluding vessels)

Discharges of oil to sea are controlled and permitted under the OPPC Regulations 2005.

Well completion operations may require the discharge to sea of small quantities of Pegasus West reservoir hydrocarbons from the JUDR if they have contaminated completion fluids. Spirit Energy will apply for a term Oil Discharge Permit should this be required. Completion fluids would be captured and tested for hydrocarbon content, treated if required, and then discharged to sea in compliance with the permitted conditions.

During the production phase, Pegasus West may contribute to existing discharges of produced water and dispersed hydrocarbon at Cygnus. OSPAR Recommendation 2001/1 (as amended) requires installations to achieve a 30 mg/l performance standard for oil in produced water discharged to sea and this is included in the Oil Discharge Permit as a regulatory limit.

Formation water is water naturally trapped in oil and gas reservoirs, a proportion of which, despite efforts to produce hydrocarbons selectively, can be brought to the surface mixed with hydrocarbons. This water may also comprise metals and organic compounds such as dissolved hydrocarbons, organic acids and phenols. Formation water production is not expected, but is possible in later field life (Section 2.7.3). However, any increase in produced water as a result of the Pegasus West tie-back has been determined to be within the capacity of the existing Cygnus produced water management system.

If formation water breakthrough were to occur, Pegasus West would be expected to increase oil in produced water discharges at Cygnus. However, based on the worst case forecast and an oil in produced water concentration of 30 mg/l, Pegasus West would increase the oil in produced water discharged at Cygnus in 2026 by only 0.38 Te (Table 9-1). The worst case combined oil in produced water discharge at Cygnus, in 2026, would be 1.09 Te, of which Pegasus West would contribute *c*. 35%. Put into context, the total mass of oil discharged in produced water by installations on the UKCS was 2,000 Te in 2016 (OGUK, 2017).

YEAR	SOURCE	Produced Water (m3 per year)	Oil in Produced Water (Te)
2026	Cygnus	23,478	0.70
	Pegasus West	12,320	0.38
	Combined	36,298	1.09

Table 9-1 Worst case forecast peak oil in produced water discharges (based on 30 mg/l)

The Cygnus life Oil Discharge Permit will be updated to include Pegasus West production.

Following its discharge to sea, produced water undergoes several weathering processes, partly influenced by the behaviour of the discharge plume which may be dense and sink towards the seabed or buoyant and rise to the surface. The effluent dilutes rapidly upon discharge to well-mixed seawater. Low molecular weight organic compounds will either volatilise into the air or be degraded by micro-organisms present in seawater. Many constituents will precipitate on discharge (e.g. certain metals). Higher molecular weight organic particles adsorb onto suspended solids and sediment. Individually or collectively, these processes tend to reduce concentrations of produced water compounds in the receiving environment and thereby decrease their potential toxicity and bioavailability to marine organisms (OGP, 2005).

Research into the effects of produced water discharges has focused on components that could result in chronic biological effects, in particular PAHs and high molecular weight phenols. PAHs are known to have mutagenic, carcinogenic and teratogenic properties. However, many marine organisms have the ability to metabolise and detoxify PAHs at the concentrations found in the receiving environment. In the laboratory, high molecular weight phenols can be shown to exhibit endocrine disruption (Bakke *et al*., 2013 and references therein). Such components may disturb reproductive functions, and affect several chemical, biochemical and genetic biomarkers.

Bakke *et al*., (2013) have reviewed a number of studies carried out to determine the impact of produced water discharges. They concluded that these discharges do not have a significant impact on plankton or fish species as harmful exposure to produced water is not sufficiently widescale or the population influence from locally affected individuals is not large enough. They also found that most studies supported the conclusion that any significant impacts on benthic animals will be limited to within 1 km of the discharge.

Given the above, the significance of the impact of planned hydrocarbon discharges has been assessed as **low**.

9.2.4 Decommissioning phase

Some discharges to sea are likely to occur during the decommissioning of Pegasus West at the EoFL. These may include the following discharges:

- Planned MARPOL-compliant discharges from vessels associated with the decommissioning activities;
- Planned discharges associated with well abandonment;
- Planned discharges resulting from the disconnection/cutting of the production pipeline, EHC umbilical, tie-in spools etc.;
- Planned discharges resulting from disconnection and recovery of seabed infrastructure; and
- Unplanned releases of small volumes of hydrocarbons or chemicals from project vessels.

Discharges to sea resulting from the decommissioning activities will be described, and their impacts assessed, in an Environmental Appraisal submitted in support of the Decommissioning Programme.

In addition to chemical discharges, there is potential for some discharge of scale and debris during well abandonment. Any inventory contaminated with reservoir hydrocarbons will be removed or treated to reduce concentrations to permittable levels prior to discharge, in accordance with industry practices, legislation and guidance at the time.

9.2.5 Transboundary and cumulative impacts

The proposed Pegasus West Development is located *c*. 35 km the UK/NL jurisdictional median line at its closest point, Cygnus. Given this distance and the localised nature and small volume of discharges and releases to sea, no transboundary impacts are anticipated.

Cumulative impacts resulting from discharges and releases to sea are considered unlikely. Impacts are expected to be localised and short-term with rapid dispersion, dilution and degradation of pollutants. Given this, the significance of the cumulative impact of discharges and small releases to sea has been assessed as **low**.

9.3 Control and Mitigation Measures

The following measures will be adopted to ensure that the impacts associated with discharges and releases to sea are minimised to ‘as low as reasonably practicable’:

- The JUDR and other project vessels will be subject to audits ensuring compliance with UK legislation and the Spirit Energy Marine Operations and Vessel Assurance Standard (SPT-MAL-GEN-STA-0010);
- All project vessels used will be MARPOL-compliant;
- Procedures and systems for the minimisation of waste and effluent generation from vessels (maintained as required under the contract with the subcontractor) will be implemented;
- Procedures and systems for the management of ballast and bilge water from vessels (maintained as required under the contract with the subcontractor) will be implemented;
- Accident prevention measures will be in place on vessels in order to minimise the potential for accidental spillages of hydrocarbons or other polluting materials;
- Vessels will have an approved SOPEP in place;
- Vessels will be selected and audited to ensure that effective operational systems and onboard control measures are in place;
- Vessel use will be optimised by minimising the number required, and their length of time on site;
- Where technically feasible the selection of PLONOR chemicals, or chemicals with a low HQ or RQ will be prioritised, and the use of chemicals with a substitution warning will be avoided;
- Discharges to sea will be conducted in compliance with regulations and permit conditions; and
- Lessons learnt from previous project scopes will be reviewed and implemented with regards to discharges to sea.

9.4 Conclusion

The principal sources of discharges and releases to sea associated with the proposed Pegasus West Development activities concern the use project vessels, well completion, the installation of subsea infrastructure, and the production of hydrocarbons through the Cygnus host facility.

The vessels' work programme comprises a total of *c*. 438 individual vessel days spread over a period of several months. Discharges from vessels during this time are expected to be rapidly dispersed and diluted under prevailing metocean conditions.

During well completion and subsea infrastructure installation chemicals that pose the minimum risk to the environment will be, where possible, selected. All planned chemical use and discharge will be risk assessed and permitted under the OCR, and the chemicals that will be discharged are routinely used in offshore oil and gas operations. All discharges would be expected to rapidly disperse and dilute under prevailing metocean conditions.

Similarly, planned hydrocarbon discharges will be minimised, but where necessary they will be permitted under the OPPC Regulations. Pegasus West production is not expected to substantively increase discharges of produced water and associated dispersed oil at Cygnus and even under the worst case, increases will be small and of limited duration. Hydrocarbon discharges are also expected to rapidly disperse and dilute under prevailing metocean conditions.

In summary, due to the localised and short duration, or intermittent nature of activities, and with the identified control and mitigation measures in place, the overall significance of the impact of discharges and releases to sea is considered to be **low**.

10. WASTE

This section identifies, and assesses the impact of the management of, waste likely to be generated as a result of project activities and subsequent hydrocarbon production.

Following the adoption of appropriate control and mitigation measures, residual effects and impacts are assessed with regard to the sensitivity of known receptors in the receiving environment.

10.1 Regulatory Requirements

The regulatory framework governing the handling and management of waste is based on the revised Waste Framework Directive (Council Directive (EU) 2018/851). Following UK withdrawal from the EU, the requirements of the directive have been retained in England and Wales via the 2020 Waste (Circular Economy) (Amendment) Regulations and the Waste and Environmental Permitting, (legislative Functions and Amendments) Regulations 2020 (EU Exit) and Waste regulations (Wales) (Miscellaneous Amendments) (EU Exit).

The overriding aim is to ensure that waste management is carried out without endangering human health and without harming the environment. Article 4 also states that the waste management hierarchy shall be applied as a priority order in waste prevention and management legislation and policy.

The Waste (England and Wales) (Amendment) Regulations 2012 outline the requirement for collection, transport, recovery and disposal of waste. It sets out the principles of the waste management hierarchy which should be considered when treating and handling waste.

Whether a material or substance is determined as a 'waste' is determined under EU law. The EU Waste Framework Directive defines waste as:

"*any substance or object which the holder discards or intends or is required to discard*".

Materials disposed of onshore must comply with the relevant health and safety, pollution prevention, waste requirements and relevant sections of the Environmental Protection Act 1990. Consent to transfer waste to the United Kingdom shore is not required but Duty of Care (under the Environment Protection Act 1990) makes it the waste producer's responsibility to ensure that waste is only transferred to an appropriately licensed carrier holding a Waste Carrier Registration. Transfer of Controlled Waste requires a Transfer Note to be completed (or Consignment Note in the case of Special Waste). The Transfer Note details the type and quantity of waste, from whom and to whom the waste has been transferred, the category of authorised person to whom the waste has been consigned, relevant licence numbers, time, place and date of transfer.

Waste management assessment should follow the hierarchy shown in Figure 10-1, in line with relevant legislation, permits and consents.

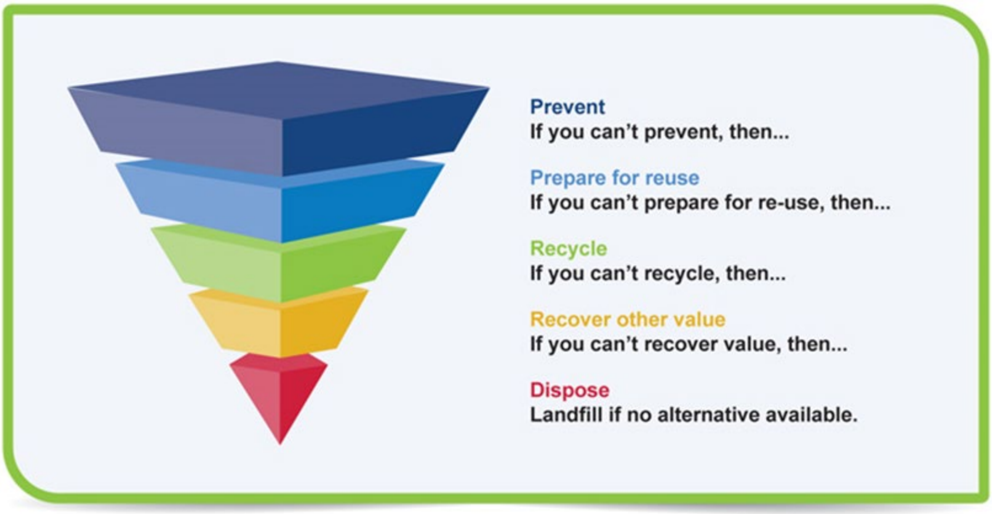


Figure 10-1 Waste management hierarchy

Onward transportation of waste or materials must also follow applicable legislation, such as the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009, a highly prescriptive regulation governing the carriage of dangerous goods by road.

10.2 Sources

10.2.1 Vessels

Waste will be generated from project vessels and will be managed in line with the individual vessel Waste Management Plan (WMP) and in accordance with MARPOL requirements, which regulate discharges of waste to sea from ships. All wastes will be properly segregated, and solid waste transported to shore for preferential re-use, then recycling, and finally recovery and disposal by licenced waste management facilities in accordance with the waste management hierarchy.

10.2.2 Well completion

Drilling rigs generate various waste products during routine operations including LOTBM contaminated cuttings, waste oil, chemical and oil contaminated water, and scrap metal. However, the JUDR will not undertake any drilling and will only re-enter the Pegasus West well to install a subsea wellhead system. Therefore, waste produced from well completion activities will be limited and will not include cuttings. There will be some discharge of liquid waste streams to sea under permit, described in Section 9.

Waste will be minimised by use of appropriate procurement controls, and all wastes will be properly segregated for preferential re-use, then recycling, and finally recovery and disposal. The appointed waste management contractor will supply monthly reports of waste sent to shore and will complete Controlled Waste Transfer Notes as required, and records of monthly disposals will be maintained. Waste Management Duty of Care audits will also be carried out.

10.2.3 Subsea infrastructure installation

Installation and commissioning activities, including of subsea infrastructure and Cygnus topside modifications, will routinely generate a number of wastes including scrap metal, wooden crates, etc. The installation and commissioning of subsea infrastructure will involve some discharge of liquid waste streams to sea under permit, described in Section 9.

10.2.4 Topside modifications

The topside modifications are not expected to result in a change to the current waste streams produced at Cygnus, although there may be a temporary increase in the quantity of some wastes. Waste will be minimised by use of appropriate procurement controls, and all wastes will be properly segregated for preferential re-use, then recycling, and finally recovery and disposal, in accordance with the Cygnus WMP.

10.2.5 Production of hydrocarbons

On Cygnus, general waste streams are segregated by personnel at source, and manually segregated in to the appropriate labelled waste receptacle ready to be transferred to shore for preferential re-use, then recycling, and finally recovery and disposal. The management of waste associated with Pegasus West production on Cygnus will be integrated in the existing Cygnus waste management procedures and the Cygnus WMP. In the production phase, Pegasus West is not expected to result in a change to the current waste streams produced at Cygnus, and any increase in the quantities of waste produced will be negligible.

10.3 Impacts and Receptors

The potential impacts from waste management are principally associated with the onshore environment and landfills. The impacts typically include:

- Use of sometimes scarce landfill space (resource use);
- Degradation of local/regional air quality as a result of emissions from onshore transport;
- Potential degradation of the water environment if any leachate is produced by the landfill site and reaches surface water and/or groundwater; and
- Nuisance to the local community from traffic, odour and visual impacts.

Where possible, materials brought to shore which cannot be reused will be recycled. The impacts associated with recycling will occur at existing processing plants, and may include:

- Degradation of local/regional air quality as a result of emissions from transport;
- Degradation of local/regional air quality as a result of plant emissions;
- Degradation of the water environment (surface water and groundwater) associated with any discharges from processing plant; and
- Nuisance to the local community from traffic and visual impacts.

Only existing permitted facilities (under the Environmental Permitting regime (England) or the Pollution Prevention and Control regime (Scotland)) will be used and for those permits to have been approved, the impacts to air, land, water and to the local community, will have already been assessed as acceptable.

Well completion and the installation and commissioning of subsea infrastructure will involve some discharges of liquid waste streams to sea from vessels under permit. These are described and assessed in Section 9.

Therefore, the significance of the impact of project waste production has been assessed as **low**.

10.3.1 Decommissioning phase

Decommissioning activities will generate hazardous and non-hazardous waste that will need to be managed to ensure appropriate disposal and minimise waste to landfill. Non-hazardous materials, likely to include metals (steel, aluminium), plastics and concrete will be kept separately from any potentially hazardous substances (mainly hydrocarbon or chemical residues). Recovered materials will be transported to a shore base for light processing and then transferred to appropriate licenced waste management facilities.

Spirit Energy will develop and implement a WMP in advance of the activities to identify, quantify (where possible) and assess available waste management options for waste resulting from decommissioning activities. Materials will be preferentially re-used or recycled in accordance with the waste management hierarchy (Figure 10-1).

10.3.2 Transboundary and cumulative

It is expected that waste generated as a result of project activities will be transported to waste management facilities in the UK for recycling or disposal. Therefore, no transboundary impacts are anticipated.

The quantities of waste that will be generated by the proposed Pegasus West Development project are limited. Waste will be managed in line with existing procedures and therefore significant cumulative impacts are considered unlikely. On this basis, the significance of the cumulative impact of waste has been assessed as **low**.

10.4 Control and Mitigation Measures

The following measures will be adopted to minimise the waste impacts of waste produced to 'as low as reasonably practicable':

- The volume of waste produced will be minimised by the use of appropriate procurement controls;
- The principles of the waste management hierarchy will be applied during all activities;
- Existing Cygnus and vessel WMPs will be strictly followed;
- All waste will be properly segregated to avoid cross-contamination;
- Only licenced waste management facilities will be used; and
- Monthly reporting of waste sent to shore will be undertaken.

10.5 Conclusion

The quantities of waste produced by proposed Pegasus West Development project activities will be limited. All wastes returned to shore will be handled and disposed of in accordance with legislation, WMPs and the waste management hierarchy. Only fully permitted waste management facilities will be used.

Given the limited quantities of waste that will be produced and the application of identified control and mitigation measures, the overall significance of the impact of the management of project waste is considered to be **low**.

11. LARGE RELEASE TO SEA

A large unplanned hydrocarbon release has been identified as the project-related accidental event with the greatest environmental risk. This section identifies the potential sources of a large, unplanned release to the marine environment in connection with the project activities and subsequent hydrocarbon production, and assesses the potential impacts of the identified worst case.

Following the adoption of appropriate prevention and response measures, the overall risk of impact presented by the identified worst case release is assessed in terms of probability of occurrence, and the consequences given the sensitivity of, and the assimilative capacity of, the receiving environment.

11.1 Sources

The principal planned project activities, including their location and estimated duration, are described in Section 2. Of these, the general use of vessels, well completion and the production of hydrocarbons have been identified as the only activities warranting further assessment in terms of the risk that they present of a large hydrocarbon release.

11.1.1 Vessels

Large releases of diesel to sea could occurs as a result of:

- Loss of structural integrity of storage tanks following a collision with another vessel or fixed facility; or
- Loss of structural integrity of storage tanks following corrosion or mechanical failure.

11.1.2 Well completion and production of hydrocarbons

Large releases of reservoir fluids to sea could occur as a result of:

- A blowout during well completion, or a loss of well control during production; or
- A rupture of the production pipeline (e.g. as a result or a dropped object).

11.1.3 Modelling of a large release of diesel from a project vessel

Project vessels will introduce the risk of a release of diesel fuel to sea, and the project vessel expected to carry the largest diesel inventory is the JUDR.

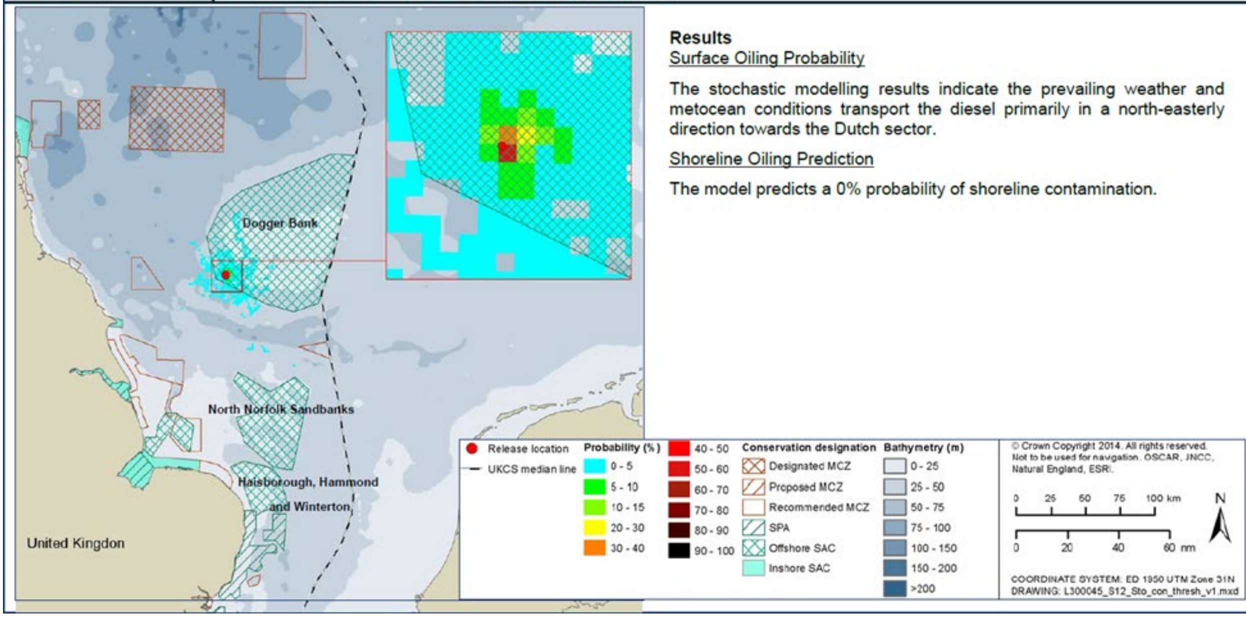
An instantaneous release of 563 m^3 of diesel from a JUDR was previously modelled for the Pegasus West Appraisal Drilling OPEP (Centrica, 2014). The probability however of such a release was considered to be ‘very unlikely’ (meaning that a rare combination of factors would be required for an event to occur) owing to the procedural (vessels’ management systems) and operational controls that were to be applied.

This probability is based on a collision risk assessment undertaken for Pegasus West appraisal drilling which concluded that the annual ship collision frequency was 4.7×10^{-4} collisions per year, corresponding to a collision return period of *c.* 2,130 years. This is below the historical average ship collision frequency for offshore installations on the UKCS (Anatec, 2014). At Cygnus, collision risk is lower, at 1.0×10^{-4} collisions per year, or a collision every 9,900 years on average (Anatec, 2011).

Given that the JUDR and subsea infrastructure installation vessels would be working on the project within an established 500 m safety zone (and for substantially less than a year), and that only a small proportion of collisions can be expected to result in a large release of diesel, the likelihood of such a release is considered to be lower than for a well blowout (Section 11.1.4). Furthermore, the total quantity of hydrocarbon released from a well blowout would also be larger than from a worst case diesel release. The overall risk from a vessel diesel release is therefore considered lower than from a well blowout.

Modelling of the worst case release of diesel from a JUDR at Pegasus West predicted only localised surface oiling and no contamination of the shoreline (Centrica, 2014) (Figure 11-1). Similarly, previous modelling of an instantaneous release of 750m^3 of diesel at Cygnus showed only localised surface oiling with no diesel reaching the shoreline or median line (GDF Suez, 2011).

Hydrocarbon Type	Diesel	Latitude	54° 31' 17.412" N	Sea Surface Temp.	8°C
Release Rate	563m^3 (Instantaneous)	Longitude	01° 25' 09.112" E	Air Temp.	10°C
Model Profile	Surface release – multi-year statistic (January – December)				



Results

Surface Oiling Probability

The stochastic modelling results indicate the prevailing weather and metocean conditions transport the diesel primarily in a north-easterly direction towards the Dutch sector.

Shoreline Oiling Prediction

The model predicts a 0% probability of shoreline contamination.

Figure 11-1 Modelling results for a JUDR diesel release at Pegasus West (Centrica, 2014)

11.1.4 Modelling of a large release of condensate from a well blowout

A release at surface of reservoir hydrocarbons of an estimated 430 m^3/d for a period of 95 days (the time it could take to source and mobilise a drilling rig and drill a relief well, with no decline in the release rate) following a blowout during Pegasus West well completion, was modelled as the worst case.

The probability however of such a blowout is considered to be ‘unlikely’ (meaning that a rare combination of factors would be required for an event to occur) owing to the procedural (the JUDR’s management systems) and operational controls that will be applied. The International Association of Oil and Gas Producers (OGP) has issued datasheets (OGP, 2010) on well blowout frequencies. The blowout frequency for a gas well completion operation to a North Sea standard is one in every 1.4×10^{-4} operations (or one blowout for every 7,143 completion operations). The likelihood of a blowout occurring at a maximum flow rate, or for an extended period, or during production is lower still.

11.1.5 Oil spill fate and trajectory modelling

Appendix C presents the modelling carried out using the Oil Spill Contingency and Response (OSCAR) model developed by The Foundation for Scientific and Industrial Research (SINTEF), to support the assessment of the environmental risk of a surface well blowout at the Pegasus West well. The Appendix introduces the OSCAR model; provides a description of the methodology applied including release parameters, hydrocarbon characteristics and metocean data; describes the thresholds applied; and presents the results.

OSCAR supports two different types of model runs: stochastic (probabilistic modelling) and deterministic. The stochastic modelling feature of OSCAR allows for a spill scenario to be modelled multiple times over different weather conditions, with the results from each individual stochastic run being aggregated, and a number of statistical parameters computed. The stochastic model results that have been utilised in this assessment report are:

- The probability of condensate above a threshold thickness of 0.3 μm on the sea surface;
- The probability of oil above 10 ppb being present in the water column; and
- The probability of any condensate (i.e. no threshold applied) arriving on the shoreline.

It is important to note that the stochastic modelling results do not represent a single spill scenario but rather show the aggregation of results computed by running the spill scenario multiple times over different weather conditions.

To analyse a single spill scenario, the deterministic mode of OSCAR allows for the spill scenario to be modelled over a single specified time interval and outputs can be presented in terms of key parameters such as oil thickness on the sea surface, and concentrations on the shoreline, in the sediment and in the water column. Table 11-1 summarises the well blowout scenario modelled.

Scenario and Location	Hydrocarbon Type	Initial Release Rate	Release Duration[1]	Total Quantity Released	Release Temperature
Surface blowout 54°31'20.02" N 001°25'14.358"E	Condensate	430 m^3/d	95	40,850 m^3	78˚C
1. Total model duration included an additional 30 days following the end of the release.					

Table 11-1 Release parameters

11.1.5.1 Fate of hydrocarbons (mass balance)

Condensate does not persist in the marine environment, as illustrated in Figure 11-2. Over half (51%) of the condensate evaporates (17,320 Te), 25% (8,344 tonnes) biodegrades, 23% (8,074 Te) goes into the sediment and only a small percentage remains in the water column (0.8%, 379 Te) or at the surface (<0.1%, 14 Te) after 125 days.

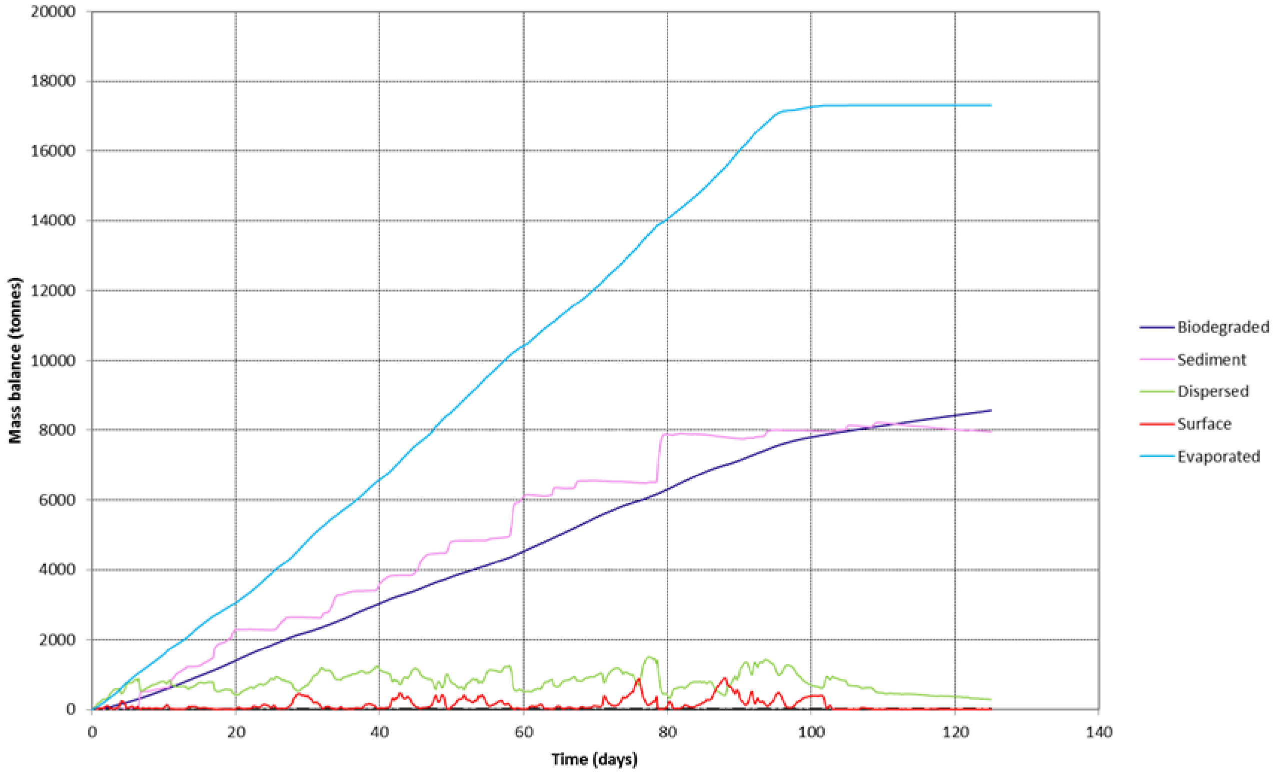


Figure 11-2 Fate of condensate over time (mass balance)

11.1.5.2 Condensate on the surface

A surface thickness threshold of >0.3 μm is the minimum surface thickness identified by the Bonn Agreement Oil Appearance Code (BAOAC) capable of producing a visible rainbow surface sheen. This threshold value was chosen as that above which potential significant environmental impacts may begin to occur (Appendix C).

The probability of surface hydrocarbons of thickness above 0.3 μm is modelled to be >90% up to *c.* 25 km from the release source, >50% up to *c.* 30 km from the source, and possible (0-10%) up to 76 km from the source. The area of the surface sheen is relatively limited in extent as would be expected for a condensate release, and would not cross the median line (Figure 11-3).

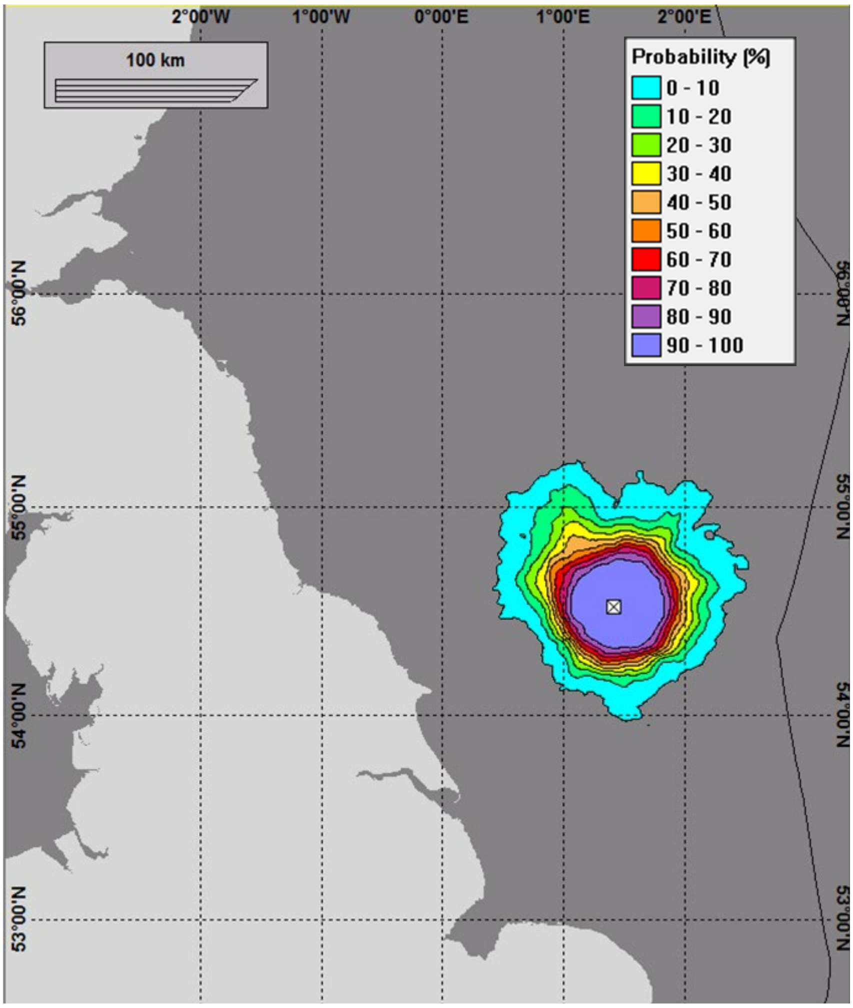


Figure 11-3 Probability of a surface sheen >0.3 μm (stochastic)

11.1.5.3 Condensate on the shoreline

The modelling predicts that there is a low probability of condensate beaching on the east coast of England, as far north as Berwick Upon Tweed or as far south of the Suffolk coast. Flamborough Head on the Yorkshire coast has the highest probability of beaching (28%) (Figure 11-4). The probability is less than 10% for most other areas, but for occasional stretches of the coast to the north of the Humber estuary, and on the coasts of Lincolnshire, Norfolk and north Suffolk. The minimum arrival time for most areas is in excess of 30 days, with the exception of a few isolated locations on the Norfolk coast where the condensate is predicted to reach the coast in around 12 days. No threshold has been applied to the shoreline oil density, therefore any mass of condensate, however small, is shown in the model results. Almost half the modelled scenarios did not result in any onshore oiling, and no condensate was predicted to reach non-UK shorelines.

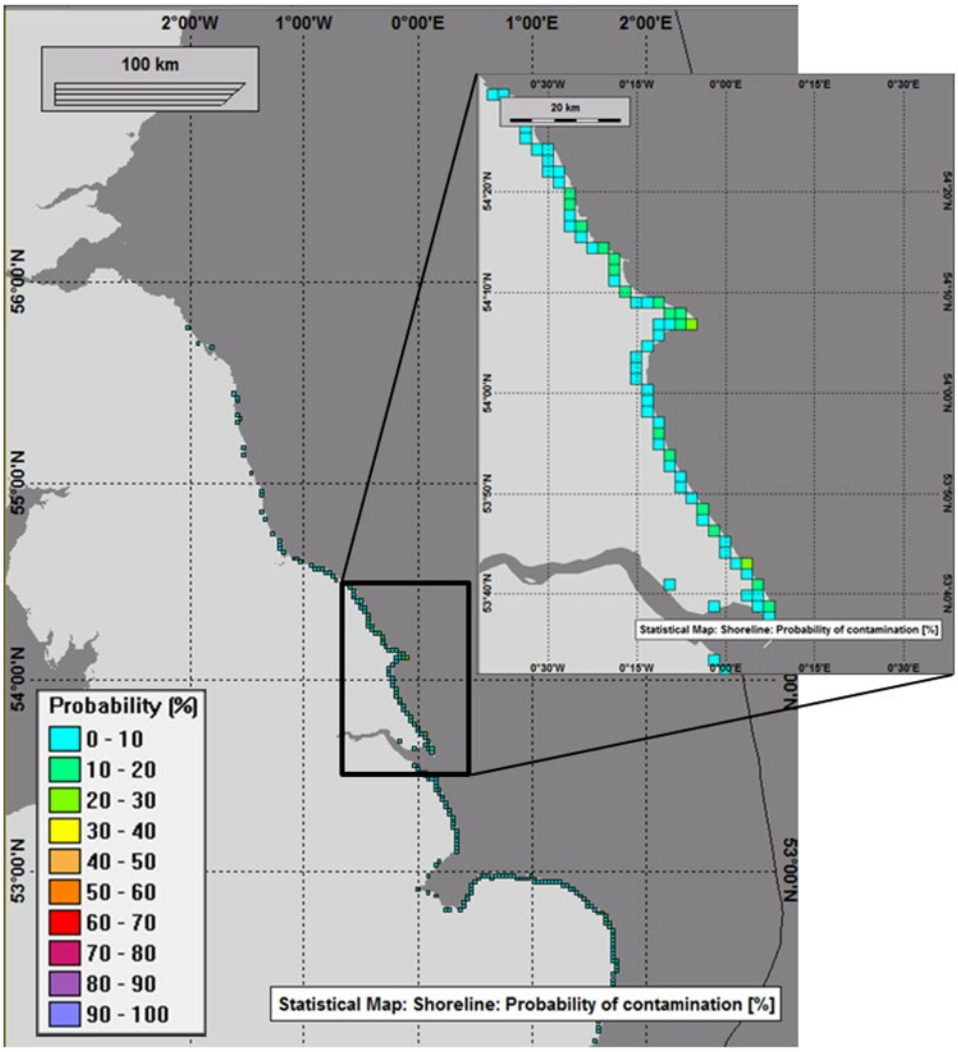


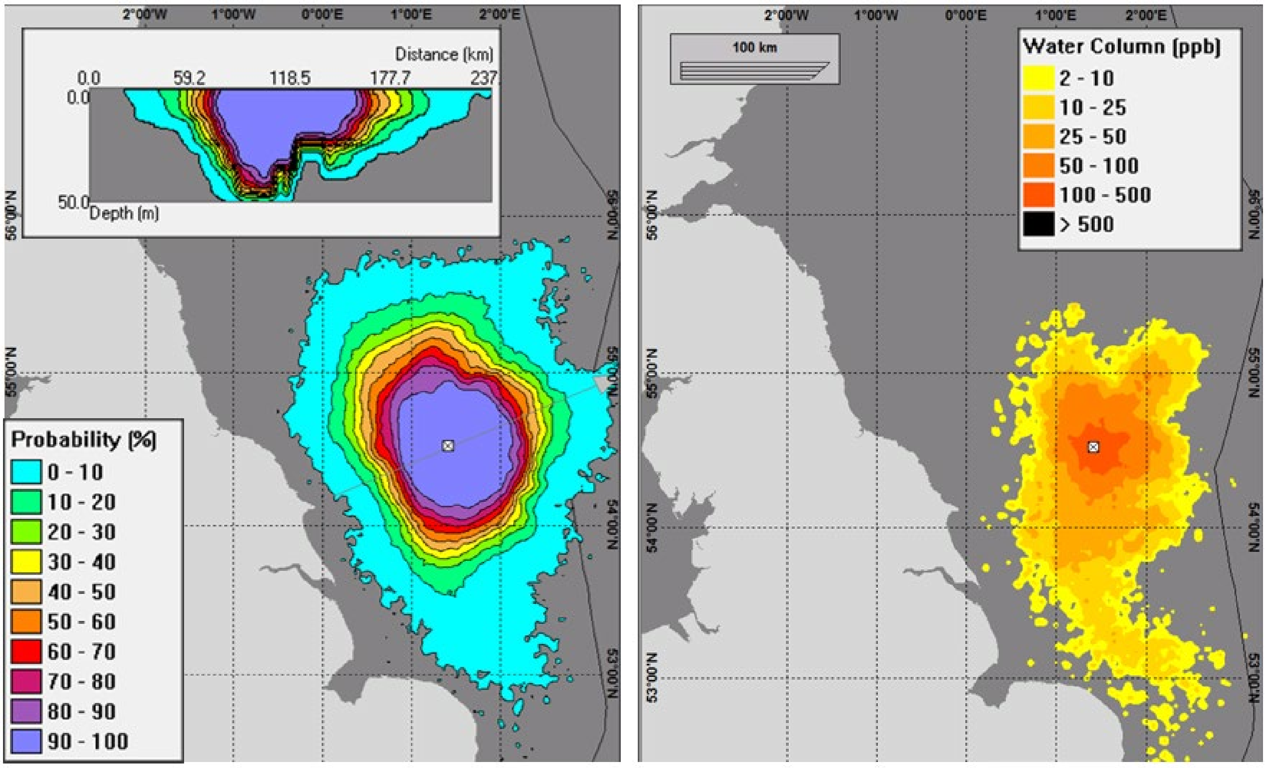
Figure 11-4 Probability of condensate beaching (no threshold, stochastic)

Where condensate is predicted to reach the shoreline, it would do so in very small quantities. To investigate the worst case shoreline condensate concentrations, a single deterministic scenario was modelled corresponding to the individual stochastic simulation that resulted in the greatest mass of condensate arriving onshore. Under this worst case, there are locations which are few and far between, where condensate reaches shore at a maximum concentration of around 2 g/m^2 and generally at concentrations of less than 0.5 g/m^2. This is well below the 100 g/m^2 threshold above which impacts are considered potentially significant (Appendix C).

11.1.5.4 Condensate in the water column

A concentration of oil in water above 10 ppb is the threshold above which negative impacts on biological receptors are considered possible. This threshold is based on the No Observed Effect (NOEC) concentration highlighted by Patin (2004), and is conservative given the range of standards reported in the literature.

The probabilities of condensate concentrations ≥ 10 ppb in the water column are shown in Figure 11-5. The modelling predicted that the area where there is a 90% to 100% probability of condensate in the water column at a concentration greater than 10 ppb extends between 37 km and 47 km from the blowout location (Figure 11-5) and to a depth of *c.* 40 m, meaning it would be likely to interact with seabed sediments. There is a low probability (<8%) that condensate in the water column would cross the median line. Deterministic modelling predicted that the total water column volume impacted by a condensate concentration greater than 10 ppb would be *c.* 383 km^3.



a) b)

<u>Figure 11-5 a) Probability of water column impacts at concentrations ≥ 10 ppb (stochastic) and b) Maximum oil concentration in water column (deterministic)</u>

11.1.5.5 Deposition of oil in sediment

A mass of oil of 50 mg per 1 kg of sediment (50 mg/kg) has been determined as the level above which toxic effects on benthic fauna may begin to be discernible. This threshold was adopted by OSPAR in the context of Oil Based Mud (OBM) contamination (OSPAR, 2006; UKOOA 1999). This equates to 5 g/m^2 assuming that the oil will distribute through a 5 cm sediment layer and assuming a sediment density of 2.0 Te/m^3.

The deposition of condensate in seabed sediments has been assessed using a deterministic model, predicting that the area of sediment within which the threshold of 5 g/m^2 (50 mg/kg) would be exceeded would be extremely limited (*c.* 56 km^2). No areas exceed 10 g/m^2 (Figure 11-6).

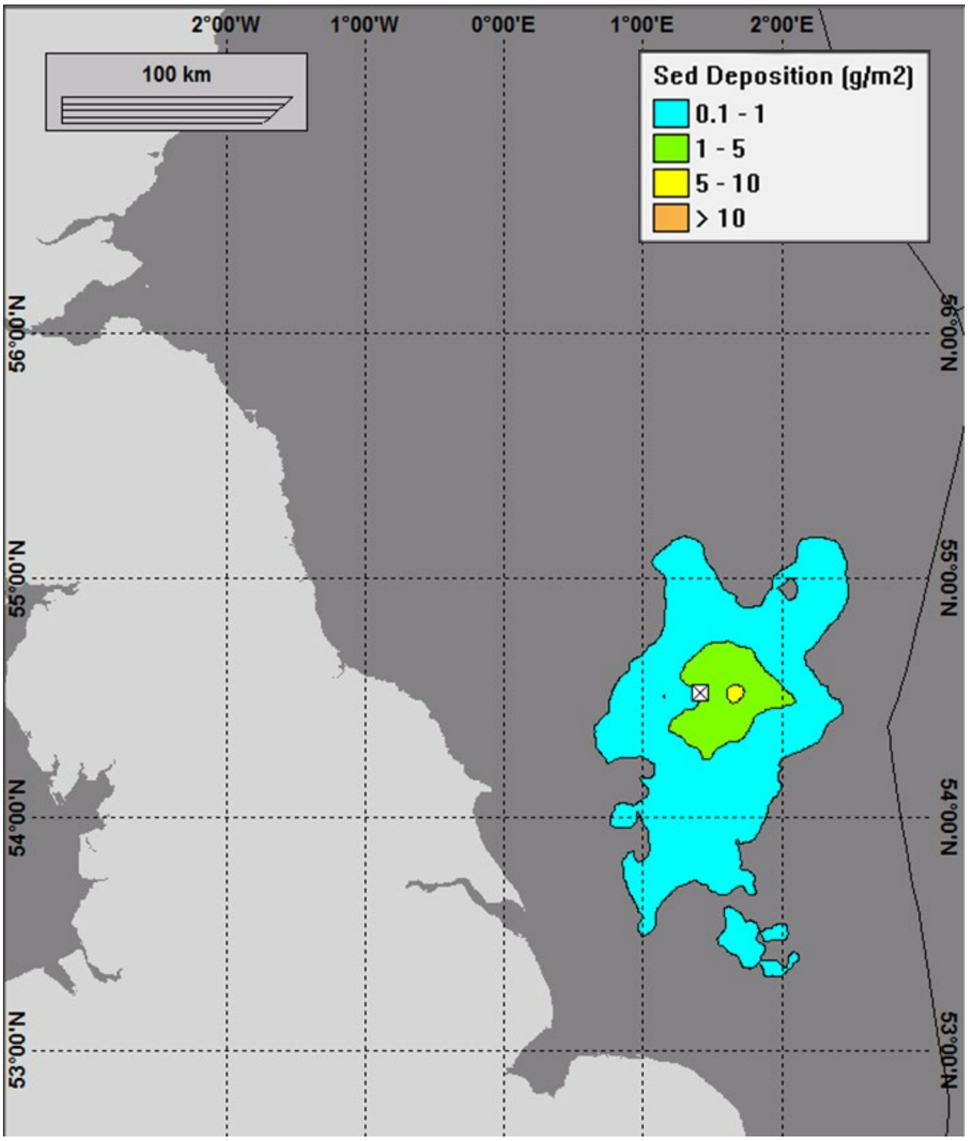


Figure 11-6 Deposited condensate in sediment (deterministic)

11.2 Impacts and Receptors

This section assesses the impacts of the worst case large hydrocarbon release by considering the modelling results in relation to the receptors that could be impacted.

11.2.1 Water quality

Released condensate with be dispersed over a wide area by wind, waves and currents. Low viscosity hydrocarbons like condensate may disperse naturally through the water column, particularly in the presence of breaking waves, where they are rapidly diluted (ITOPF, 2014a). Condensate has very high levels of light hydrocarbons and therefore evaporates quickly from the sea surface on release. The low asphaltene content prevents emulsification, reducing its persistence in the environment as shown in Figure 11-2. Thirty days after the end of the release, only 0.8% (*c.* 379 Te) of the condensate released would remain in the water phase, and dilution, dispersion and biodegradation would continue to reduce concentrations of condensate in the water column. Modelling results show that water quality would be impacted over a large area, above the threshold above which negative impacts on biological receptors are considered possible, but significant concentrations of condensate would not reach coastal waters.

Given the above, the significance of impacts on water quality from a large hydrocarbon release has been assessed as **medium**.

11.2.2 Sediment quality

The mean THC in sediment along the production pipeline route is 2.6 µg/g compared to a SNS average of 4.34 µg/g (UKOOA, 2001). In the scenario modelled, a 56 km^2 area of seabed within the Dogger Bank SAC would be exposed to condensate deposition in excess of 5 g/m^2. A wider area of seabed sediments around this could, with the addition of condensate to hydrocarbons already in sediments, exceed the SNS average, and reach levels where toxic effects on benthic fauna may begin to be discernible (Section 11.2.4). However, the condensate would be expected to continue to disperse and biodegrade over time, eventually returning to SNS background levels.

Given the above, the significance of impacts on sediment quality from a large hydrocarbon release has been assessed as **medium**.

11.2.3 Plankton

The planktonic community is composed of a range of microscopic plants (phytoplankton) and animals (zooplankton) that drift with the oceanic currents. As hydrocarbon can float on the water's surface and disperse within the ocean as it weathers, plankton may be exposed to both floating hydrocarbon slicks and to small dissolved droplets of hydrocarbon in the water column (Cormack, 1999; Almeda *et al*., 2013).

Changes in the patterns of distribution and abundance of phytoplankton can have a significant impact on the entire ecosystem (Ozhan *et al*., 2014). Both oil and oil biodegradation can impact phytoplankton in the immediate vicinity of a spill. Hydrocarbon slicks can inhibit air-sea gas exchange and reduce sunlight penetration into the water, both essential to photosynthesis and phytoplankton growth (González *et al*., 2009). The PAHs in the oil also affect phytoplankton growth, with responses ranging from stimulation at low concentrations (1 mg/l i.e. 1,000 ppb) to inhibition at higher concentrations (100 mg/l i.e. 100,000 ppb) (Harrison *et al*., 1986).

Zooplankton at the surface are thought to be particularly sensitive to oil spills due to their proximity to high concentrations of dissolved hydrocarbon and to the additional toxicity of photo-degraded hydrocarbon products at this boundary (Bellas *et al*., 2013). Following an oil spill zooplankton may suffer from loss of food resources in addition to the toxic effects from direct exposure, resulting in mortality or impaired feeding, growth, development, and reproduction (Blackburn *et al*., 2014 and references therein).

The limited swimming ability of the free-floating early life stages (meroplankton i.e. eggs and larvae) of invertebrates such as echinoderms, molluscs and crustaceans renders them unable to escape oil-polluted waters. These early life stages are more sensitive to pollution than adults and their survival is critical to the long-term health of the adult populations (Blackburn *et al*., 2014 and references therein).

However, impacts on plankton populations from hydrocarbon releases are typically short term and localised. Zooplankton biomass was documented in the month following the Tsesis oil spill off the coast of Sweden in 1977 (1,000 Te of medium grade fuel oil) with biomass levels being re-established within five days (Johansson *et al*., 1980). Plankton populations are abundant and widespread, with high rates of reproduction. Typically, recruitment from adjacent areas not affected by the release is sufficient to replace losses (IPIECA-IOGP, 2015).

Given the above, the significance of impacts on plankton from a large hydrocarbon release has been assessed as **low**.

11.2.4 Benthos

As described in Section 11.1.5.5, it is considered that toxic effects on benthic fauna may begin to be discernible at concentrations of oil in sediment above 5 g/m^2. The modelling predicted that the area of sediment within which this threshold would be exceeded would be extremely limited (*c.* 56 km^2), and that sediment concentrations would not exceed 10 mg/kg. It is likely that, as in the result of deterministic modelling, the area of potential toxic effects on benthos would be within the Dogger Bank SAC.

In response to hydrocarbon exposure, benthic fauna can either move, tolerate the pollutant (with associated impacts on the overall health and fitness), or die (Gray *et al*., 1988; Lee and Page, 1997). The response to hydrocarbons by benthic species differs depending on their life history and feeding behaviour, as well as the ability to metabolise toxins, especially PAH compounds. However, severe oil pollution typically causes initial massive mortality and lowered community diversity, followed by extreme fluctuations in populations of opportunistic mobile and sessile fauna (Suchanek, 1993).

The EBS found that the habitats in the project area are dominated by polychaetes, with species composition varying according to variations in the proportions of sand and gravel in the sediment. Dominant species where the polychaete *S. bombyx*, the amphipod *B. elegans* and the molluscs *F. fabula* and *A. alba*, with other polychaete species also common (Gardline, 2018a).

Generally, infaunal polychaetes are particularly effected by oil pollution (Suchanek, 1993). However, their recolonization of effected areas varies. Some species decrease in abundance after an oil spill whilst others may be the first colonisers in the aftermath of oil spill die-offs (Blackburn *et al*., 2014 and references therein). Some polychaetes contribute to biodegradation of oil in sediments whilst some have different abilities to metabolise contaminants (Bauer et al., 1988; Driscoll and McElroy, 1997).

The different response of polychaetes to oil pollution is likely a consequence of their different feeding strategies and trophic relationships in benthic environments. For example, *Capitella capitata* has been found to be amongst the first colonisers in the aftermath of a spill. This species thrives in the absence of competition and is a non-selective deposit feeder consuming detritus and algae and benefitting from organic pollution. In contrast *Heteramalla sarsi* is a predatory polychaete that feeds on benthic amphipods. Numbers of this species dropped to less than 5 % of their pre-spill biomass following the 1977 Tseis oil spill in the Baltic Sea. This decrease in polychaetes was in correlation with a decrease observed in amphipods in the region (Elmgren *et al*., 1983), indicating that amphipods like *B. elegans* are sensitive to hydrocarbons. Polychaetes of the family Spionidae, which includes *S. bombyx*, have been observed to decrease after a spill, then recover quickly, although they did not recover as quickly as *C. capitata*. *S. bombyx* is therefore considered to have low sensitivity to hydrocarbon contamination (Ager, 2005).

Burrowing bivalves and small crustaceans called amphipods can be sensitive to even brief exposures of relatively low hydrocarbon concentrations (IPIECA-IOGP, 2015; Suchanek, 1993). Amphipods are possibly especially sensitive to the effects of local pollution because of their low dispersal rate, limited mobility and lack of a planktonic larval stage. However, the bivalve mollusc *A. alba*, one of the most common species in the project area, has very low sensitivity to hydrocarbons. Its population was apparently resilient to the presence of hydrocarbons in areas affected by the 1978 Amoco Cadiz oil spill (Budd, 2007).

The area of potential impacts on benthos following the modelled worst case hydrocarbon release would be limited to an area of *c.* 56 km^2, equivalent to 0.45% of the Dogger Bank SAC. In this area, sediment condensate contamination would only just exceed the threshold of 5 g/m^2 (50 mg/kg) above which toxic effects on benthic fauna may begin to be discernible.

Given the limited extent and relatively low levels of seabed contamination, and the widespread distribution of benthic habitats and species found in the project area, the significance of impacts on benthos from a large hydrocarbon release has been assessed as **medium**.

11.2.5 Fish

As described in Section 11.1.5.4, a concentration of oil in water above 10 ppb is the threshold above which negative impacts on biological receptors are considered possible.

Exposure of fish to hydrocarbons can occur either through uptake across the gills or skin or direct ingestion of oil or oiled prey. Pelagic species, which spend the majority of their life-cycle in the water column, are likely to receive the highest exposure to oil that remains near the surface, whereas demersal fish species, associated with the seabed, are more exposed to particle-bound contaminants.

The chemical components of light oils, including condensate, have a high biological availability and toxic impacts are more likely than from a heavy crude. At exposure levels lower than those sufficient to cause mortality, contamination may lead to sub-lethal effects such as impaired feeding and reproduction (ITOPF, 2014a).

The likelihood of fish mortality from open water oil spills is small (IPIECA-IOGP, 2015). Significant effects on wild stocks have seldom been detected and fish are thought to actively avoid hydrocarbons (ITOPF, 2014a). Once the hydrocarbon disappears from the water column fish generally lose contamination from their tissues quickly due to their ability to metabolise accumulated hydrocarbons very rapidly (Krahn *et al.*, 1993).

A condensate release could have the potential to impact fish spawning success because the eggs and larvae of many species are more sensitive to hydrocarbon toxins than adult fish. The eggs and larvae of broadcast spawners, which are widely dispersed, could be exposed to condensate in the water column and modelling of a Pegasus West well blowout shows contamination of the water column over a large area (Section 11.1.5.4). Fish species that are demersal spawners, could be exposed to condensate deposited on the seabed (Section 11.1.5.5). Although the area of potential seabed impacts would be small, it could include areas of herring and sandeel spawning habitat (Section 3.3.3).

However, the localised mortality of eggs and larvae which may occur following a spill rarely impacts wider populations. Even a large spill, coinciding with a geographically isolated spawning event, would be extremely unlikely to expose a notable proportion of the adult stock to a sustained lethal dose of hydrocarbons. For example, oil from the 1989 Exxon Valdez spill reached the spawning grounds of Pacific herring (*Clupea pallasii*) which lay their eggs on kelp in shallow coastal waters, but the spill was shown to have had no significant effect on the herring population (IPIECA-IOGP, 2015). Marine organisms are adapted to acute local impacts by the production of vast surpluses of eggs and larvae, and recruitment from outside the affected area (ITOPF, 2014a; IPIECA-IOGP, 2015). Fish species present in the SNS, as described in Section 3.3.3, form part of larger populations, such that impacts on individuals would not have a significant impact at a population level.

Given the above, the significance of impacts on fish from a large hydrocarbon release has been assessed as **low**.

11.2.6 Seabirds

Seabirds are particularly sensitive to the effects of surface oil pollution, and some oil pollution incidents have resulted in mass mortality of seabirds (e.g. Munilla *et al*., 2007; Votier *et al*., 2005). Mortality occurs from the ingestion of oil, which results in liver and other organ failure, as well as contamination of plumage, which destroys the insulating properties, leading to hypothermia (Alonso-Alvarez *et al*., 2007). However, the impact of oil pollution on seabird populations is not depends on the numbers of seabirds at sea around the pollution incident. It also has an unequal effect on different seabird species, with diving seabirds such as seaducks (*Anatidae*), divers (*Gaviidae*), cormorants (*Phalacracoracidae*), grebes (*Podicepididae*) and auks (*Alcidae*) more susceptible than more aerial species such as gulls (*Laridae*) (Webb, 2016).

Susceptible species tend to spend a greater proportion of their time on the sea and have limited ability to locate alternate feeding sites. At the population level, species with small or geographically limited populations, a low potential reproductive rate (productivity), and low adult survival rates are additionally sensitive due to their limited ability to recover (Webb, 2016).

Seabird sensitivity to surface oil pollution is considered very high in the project area in June, and extremely high in July and between November and January (Figure 3.11).

The probability of a visible surface sheen with a thickness > 0.3 µm is predicted to extend as far as 25 km from the Pegasus West well location with 90-100 % probability (Figure 11-3, Figure 11-7). A sheen thickness > 0.3 µm is the minimum thickness expected to produce negative impacts on sea life encountering oil at the sea surface.

The most sensitive month for seabirds to surface oil pollution is July (Section 3.3.4). Figure 11-7 shows the SOSI data in relation to the probability of a surface sheen at a concentration that is expected to have a negative impact on birds (> 0.3 µm). Therefore, in the event of a well blowout at Pegasus West, or any large hydrocarbon release in July, significant impacts on seabirds are possible.

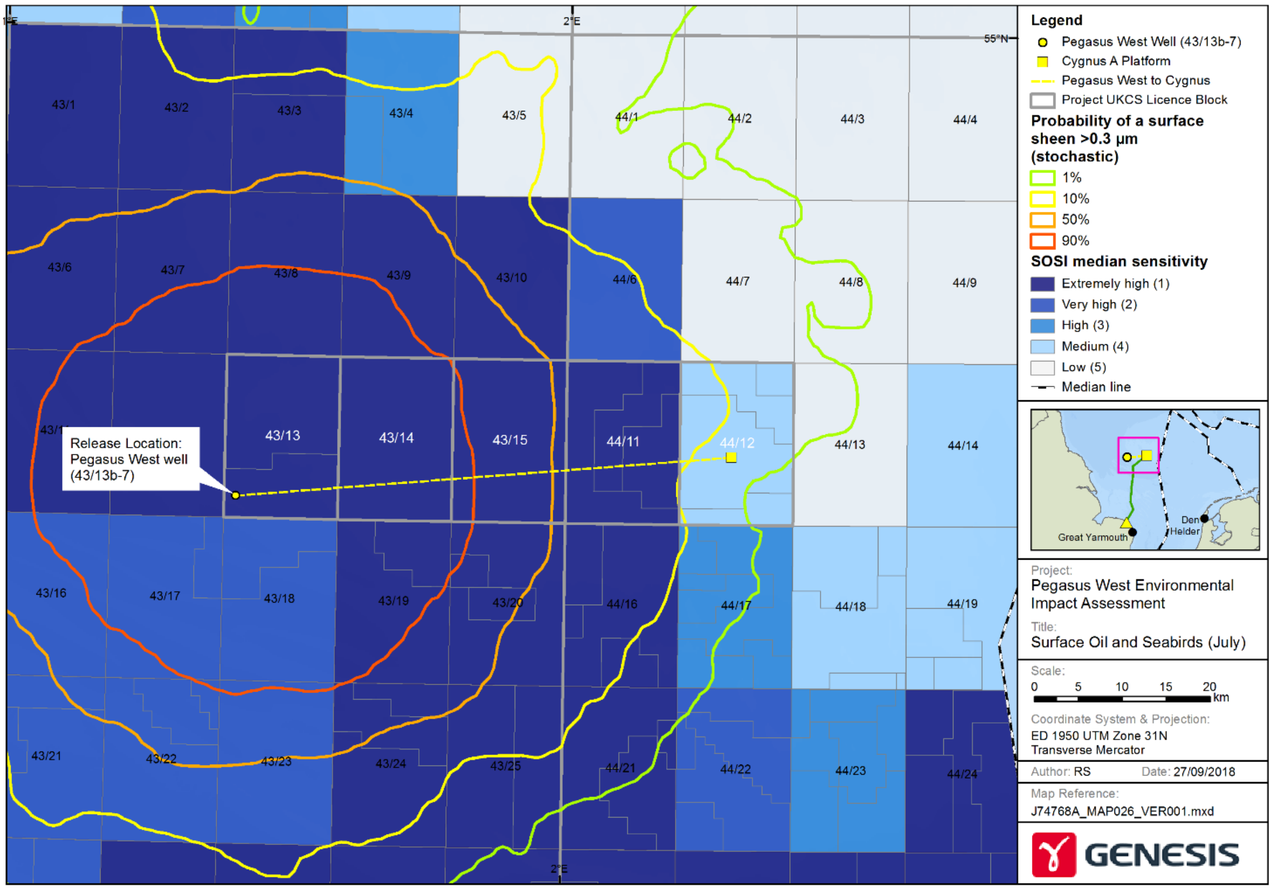


Figure 11-7 Probability of a surface sheen from a well blowout compared to seabird sensitivity to surface oil in July (JNCC, 2017a)

In the event of a well blowout condensate would evaporate from the surface a matter of days following the end of the release (Figure 11-2). Nevertheless, the release could continue for a considerable length of time (up to 95 days). The area potentially impacted by a release (albeit with low probability) coincides with areas of extremely high seabird sensitivity, and a relatively low exposure time is needed to compromise a bird.

Given the above, the significance of impacts on seabirds from a large hydrocarbon release has been assessed as **medium**.

11.2.7 Marine mammals

Marine mammals may be exposed to hydrocarbons either internally (swallowing contaminated water, consuming prey containing oil based chemicals, or inhaling of volatile oil related compounds) or externally (swimming in oil or oil on skin and body).

The effects of hydrocarbon on marine mammals are dependent upon species but may include:

- Hypothermia due to conductance changes in skin or fur;
- Toxic effects and secondary organ dysfunction due to ingestion of oil, congested lungs;
- Damaged airways;
- Interstitial emphysema due to inhalation of oil droplets and vapour;
- Gastrointestinal ulceration and haemorrhaging due to ingestion of oil during grooming and

feeding;

- Eye and skin lesions from continuous exposure to oil;
- Decreased body mass due to restricted diet; and
- Stress due to oil exposure and behavioural changes.

The harbour porpoise has been estimated to occur in the project area at densities of up to 3 or more individuals per km^2 over the summer period (Heinänen and Skov, 2015). Other marine mammals regularly occurring in the project area at relatively low densities are white beaked dolphin and grey seal, with the minke whale a frequent seasonal visitor.

There is little documented evidence of cetacean behaviour being affected by hydrocarbon spills. Evidence suggests they do not necessarily avoid slicks. Observations of bottlenose dolphins suggest that they did not detect a hydrocarbon sheen and that although they detected a slick, they did not avoid travelling through it (Smultea and Wursig, 1995). Similarly, gray whales *Eschrichtius robustus* have been observed to swim through oil seeps off California (Evans, 1982). Lack of an olfactory system likely contributes to the difficulty cetaceans have in detecting oil. Waves and darkness can reduce their visual ability at the surface and it is possible that individuals could resurface within a fresh slick and find it difficult to locate hydrocarbon-free water (Matkin *et al*., 2008). In the months following the Exxon Valdez spill there were numerous observations of gray whales, harbour porpoises, Dall's porpoises and killer whales swimming through light to heavy crude oil sheens. Stressed or panicking cetaceans tend to move faster, breathe more rapidly and therefore surface more frequently into oil and increase exposure (Harvey and Dahlheim, 1994).

Cetaceans have smooth skins with limited areas of pelage (hair covered skin) or rough surfaces. Hydrocarbon tends to adhere to rough surfaces, hair or calluses of animals, so contact may cause only minor adherence. However, cetaceans can be susceptible to inhaling hydrocarbon and hydrocarbon vapour when they surface to breathe. This may lead to damaging of the airways, lung ailments, mucous membrane damage or even death. Following the Deepwater Horizon oil spill, bottlenose dolphins in the northern Gulf of Mexico have shown depressed reproductive success rates (Kellar *et al*., 2017), increased incidence of adrenal gland and lung lesions (Venn-Watson *et al*., 2015), change in immune function compatible with an increase in bacterial infections such as bacterial pneumonia (De Guise *et al*., 2017). These changes are compatible with those documented in other species following exposure to oil or PAHs.

Baleen whales which "filter feed" are more likely to ingest hydrocarbon than toothed cetaceans which most commonly occur in the project area. The likelihood that a feeding cetacean would ingest a sufficient quantity of hydrocarbon to cause sublethal damage to its digestive system, or to present a toxic body burden, is low (IPIECA-IOGP, 2015). Similarly, hydrocarbon content in prey is unlikely to be present in sufficient quantities to be toxic to a cetacean, and most would be metabolized quickly. Ingestion of subtoxic quantities may have subtle, chronic effects, and there is potential for PAHs to accumulate in tissues of whales before they are eventually metabolized, and for contaminants to be passed to juveniles through the mother's milk.

Seals are vulnerable to oil pollution because they spend much of their time near the surface and regularly haul out on beaches. Seals have been seen swimming in hydrocarbon slicks during several documented spills (Geraci and St. Aubins, 1990). Most seals scratch themselves vigorously with their flippers but do not lick or groom themselves, so are less likely to ingest hydrocarbon from skin surfaces. However, a seal mother trying to clean an oiled pup may ingest hydrocarbon, and it is pups that are most vulnerable to hydrocarbon spills when it reaches breeding colonies on the shoreline. Furthermore, seals use smell to identify their young in a large colony. If the mother cannot identify its pup because it's scent has been masked by hydrocarbons, this can result in abandonment and starvation.

Oil can impact on the mucous membranes that surround the eyes and line the oral cavity, respiratory surfaces, anal and urogenital orifices of seals. This can cause corneal abrasions, conjunctivitis and ulcers. Consumption of oil-contaminated prey will lead to the accumulation of hydrocarbons in tissues and organs. Lesions characteristic of hydrocarbon toxicity where found in the brains of seals exposed to the Exxon Valdez spill (Spraker *et al*. 1994).

In the event of a well blowout, condensate would evaporate from the surface a matter of days following the end of the release (Figure 11-2). Nevertheless, the release could continue for a considerable length of time (up to 95 days). The area potentially impacted by a release (albeit with low probability) coincides with areas of relatively high harbour porpoise densities in the summer months. Harbour porpoise and all other cetacean species found in UK waters have EPS status. Although cetacean mortality as a direct result of contact with condensate is unlikely, there is potential for sub-lethal impacts on individuals. Seals exposed to condensate could also suffer-sub-lethal effects, however, condensate would be unlikely to reach coastal haul out sites and if it did, would not be at sufficient concentrations to significantly impact seals.

Given the protected status of marine mammals (Section 3.4.5) and the relatively high density of harbour porpoise during the summer period, the significance of impacts on marine mammals from a large hydrocarbon release has been assessed as **medium**.

11.2.8 Offshore protected areas

Three offshore protected areas could be affected by hydrocarbon released as a result of a well blowout at the Pegasus West well location, as summarised in Table 11-2.

PROTECTED AREA	PROBABILITY OF OILING ABOVE IMPACT THRESHOLD (%)			SIGNIFICANCE OF POTENTIAL IMPACT	
	Surface	Water column	Sediment		
Dogger Bank SAC	100	100	100	M	The conservation objectives of the site are for the qualifying feature (Sandbanks which are slightly covered by seawater all the time) to be in favourable condition. Some impacts on associated communities are possible in a small proportion of qualifying habitat, although the habitat itself should not be impacted in the long term (Section 11.2.4).
Southern North Sea SAC	100	100	100	M	The conservation objectives of the site are to avoid deterioration of the habitats of the harbour porpoise or significant disturbance to the harbour porpoise. There is potential for sub-lethal impacts on individuals (Section 11.2.7).
North Norfolk Sandbanks and Saturn Reef SAC	0	17.5	0	L	The qualifying feature of this SAC is ‘Sandbanks which are slightly covered by seawater all the time’. No impacts on seabed sediments and therefore no impacts on the qualifying feature are predicted.

Table 11-2 Potential impacts on offshore protected areas

Given the above, the significance of impacts on offshore protected areas from a large hydrocarbon release has been assessed as **medium**.

11.2.9 Coastal protected areas

There is a low probability that, in the unlikely event of a large hydrocarbon release from a well blowout, condensate could reach coastal protected areas. Of these, the highest probability of hydrocarbon beaching is within the Flamborough Head SAC, the Flamborough Head and Bempton Cliffs SPA and the Flamborough and Filey Coast potential SPA (pSPA) (Table 11-3).

PROTECTED AREA	WORST CASE PROBABILITY OF IMPACT
Flamborough Head SAC, Flamborough Head and Bempton Cliffs SPA Flamborough and Filey Coast pSPA	28%
Holderness Inshore MCZ	23%
Humber Estuary SAC and SPA	19%
Wash and North Norfolk Coast SAC and SPA	14%
Outer Thames Estuary SPA	13%
Cromer Shoal Chalk Beds MCZ	11%
Gibraltar Point SPA	10%

Table 11-3 Coastal protected areas with ≥10% probability of hydrocarbon contamination in the event of a well blowout

However, as discussed in Section 11.1.5.3, the quantity of hydrocarbon that could reach coastal protected areas is well below the threshold above which impacts are considered potentially significant. Given the above, the significance of impacts on coastal protected areas from a large hydrocarbon release has been assessed as **low**.

11.2.10 Fisheries and aquaculture

As discussed in Section 11.2.5, localised mortality of eggs and larvae which may occur following a spill rarely impacts wider fish stocks, and adult fish are relatively resilient to hydrocarbon spills. More significant impacts may be found near shore, where hydrocarbons can accumulate and exposure, particularly of intertidal and shallow subtidal benthos, caged animals and seafood products that are cultivated in fixed locations (ITOPF, 2014b). At mariculture sites, mortality has occurred only in the most serious cases of hydrocarbon contamination, and impacts are generally sublethal, sometimes resulting in tainting or the product with an unpleasant hydrocarbon 'taste' which effectively renders the seafood inedible and thereby unfit for market. This may result in economic losses for a fishery (IPIECA-IOGP, 2015).

Fishing effort in the project area is relatively low when compared to other areas of the UKCS and dominated by demersal trawling targeting demersal fish species.

The nearest mariculture sites and designated shellfish waters to the proposed Pegasus West Development are *c.* 176 km to the south-west, on the north Norfolk coast. The maximum probability of condensate reaching these areas (beaching) following a worst case blowout from the Pegasus West well is 14%, and concentrations would be well below the threshold above which impacts are considered potentially significant (Section 11.1.5.3).

Given the above, the significance of impacts on fisheries and aquaculture from a large hydrocarbon release has been assessed as **low**.

11.2.11 Local communities

The smell and appearance of stranded oil may be a nuisance to people living on the affected shoreline. Coastal tourism is an important industry in some areas, particularly in the warmer months. Following a worst case release, areas with the highest modelled probability of shoreline contamination include the Yorkshire coast (up to 28%), with probabilities less than 10% for most other areas, but for occasional stretches of the coast to the north of the Humber estuary, and on the coasts of Lincolnshire, Norfolk and north Suffolk.

Given the low probability of condensate beaching, and the low concentrations that would reach the shoreline, the significance of impacts on local communities from a large hydrocarbon release has been assessed as **low**.

11.2.12 Transboundary and cumulative impacts

The proposed Pegasus West Development is *c.* 35 km from the UK/NL jurisdictional median line at its closest point, Cygnus. The modelled worst case release at the Pegasus West well, *c.* 89 km from the median line, predicts that surface condensate would not cross the median line or contaminate seabed out with the UKCS. There is a small probability (<8%) of condensate in the water column crossing the median line at concentrations above 10 ppb. Therefore, the significance of transboundary impacts from a large hydrocarbon release has been assessed as low.

The blowout frequency for a gas well completion operation to a North Sea standard is one in every 1.4×10^{-4} operations (or 1.4 blowouts for every 10,000 completion operations). Similarly, the annual ship collision frequency at Pegasus West, which would have the potential to result in a large hydrocarbon release, has been estimated at approximately one collision *c.* every 2,130 years. Given the low likelihood of such a release, the overall risk of transboundary impacts has also been assessed as **low** and 'as low as reasonably practicable'.

Furthermore, given that large hydrocarbon releases are extremely rare, no cumulative impacts are anticipated.

11.2.13 Natural disasters

Some natural disasters could increase the risk of a large hydrocarbon release occurring at the proposed Pegasus West Development. For example, an earthquake could lead to damage to the subsea infrastructure and potential loss of well control. The likelihood of an earthquake of sufficient magnitude to impact seabed infrastructure on the UKCS is however extremely remote.

Climate change effects, such as sea level change and extreme weather events, are not considered to increase the risk of a large hydrocarbon release. Infrastructure is engineered to withstand extreme weather events and the JUDR has procedures in place for making safe and shutting down operations during extreme weather, along with emergency procedures in the event of rig damage.

11.2.14 Major Environmental Incident Assessment

The Offshore Installations (Offshore Safety Directive) (Safety Case etc) Regulations 2015 (SCR 2015) apply to oil and gas operations on the UKCS. The primary aim of SCR 2015 is to reduce the risks from Major Accident Hazards (MAHs) to the health and safety of the workforce employed on offshore installations or in connected activities. The Regulations also aim to increase the protection of the marine environment and coastal economies against pollution and ensure improved response mechanisms in the event of such an incident.

As part of the introduction of the SCR 2015 regulations there is now a requirement to include environmental information in the Safety Case that was not previously required. For example, the potential for a Major Environmental Incident (MEI) as a consequence of a major accident must be considered, assessed, and included in the Safety Case. A Major Accident (MA) is an event that results in loss of life or serious personal injury to persons on an offshore installation or engaged in an activity on, or in connection with it. It could involve a fire, explosion, structural damage, loss of well control or release of a dangerous substance. A MEI is the result of a major accident which is likely to result in significant adverse effects on the environment as defined by the Environmental liability Directive (2004/35/EC).

The likelihood of a major release of condensate from the Pegasus West well or the tieback to Cygnus is very low. A large hydrocarbon release at the JUDR from a well blowout during well completion is likely to qualify as a MAH and has been identified as the worst case event in terms of potential environmental impact. As discussed in this section the significance of the impacts from a well blowout range from low to medium, and therefore the assessment concludes that impacts would not be of sufficient magnitude to qualify as a MEI.

11.3 Control and Mitigation Measures

The following measures will be adopted to ensure that the risk and impacts of releases, including large hydrocarbon releases, are minimised to ‘as low as reasonably practicable’:

- Activities will be carried out by trained and competent offshore crews and supervisory teams;
- An approved OPEP to manage releases, including large hydrocarbon releases, will be in place prior to any activities being undertaken;
- A co-ordinated industry oil spill response capability will be available;

Well completion-specific measures:

- A robust BOP pressure and functional testing regime will be in place as well as visual integrity checks;
- A TOOPEP or an update to the existing Cygnus OPEP for Pegasus West well completion will be in place covering well completion operations;

Subsea infrastructure installation-specific measures:

- All vessel activities will be planned, managed and implemented in such a way that vessel durations in the field are minimised;
- Spirit Energy’s existing marine procedures will be adhered to minimise risk of hydrocarbon releases; and
- Shipboard Oil Pollution Emergency Plans (SOPEPs) will be in place for project vessels.

Commissioning and production-specific measures:

- A DHSV will enable isolation of the reservoir;
- Cygnus facilities will be protected by a combination of a topside Emergency Shutdown Valve (ESDV) and a SSIV;
- The production pipeline will be protected by pressure alarms which can assist leak detection; and
- Releases, including large hydrocarbon releases associated with Pegasus West production, will be managed under the Cygnus OPEP.

11.4 Conclusion

Sources of a potential unplanned large volume release to sea are associated with a loss of diesel containment from a vessel (including the JUDR), or a loss of reservoir hydrocarbons (condensate) from the Pegasus West well as a result of a well blowout or from the Pegasus West production pipeline as a result of a rupture. Of these, the worst case in terms of the volume and duration of release would be a well blowout.

Condensate does not persist in the marine environment. Spill modelling shows that the extent of surface oiling, and of seabed sediment contamination, would be relatively small and that the probability of condensate reaching shore is low. When all receptors are taken into account the worst case environmental impact associated with a large release to sea is considered to be **medium** (Table 11-4).

RECEPTOR	IMPACT
Water quality	Medium
Sediment quality	Medium
Plankton	Low
Benthos	Medium
Fish	Low
Seabirds	Medium
Marine mammals	Medium
Offshore protected areas	Medium
Coastal protected areas	Low
Fisheries and aquaculture	Low
Local communities	Low

Table 11-4 Summary of significance of impacts to receptors

A large hydrocarbon release is considered to be ‘unlikely’ owing to the procedural (the JUDR’s management systems) and operational controls that will be applied. The blowout frequency for a gas well completion operation to a North Sea standard is one in every 1.4×10^{-4} operations (equivalent to one blowout for every 7,143 completion operations), and a blowout during production would be much less likely. Similarly, the annual ship collision frequencies at Pegasus West and Cygnus, which would have the potential to result in a large hydrocarbon release, have been estimated at one collision every 2,130 years or less (Anatec, 2011; 2014).

Given the low likelihood of such a release, and following the application of control and mitigation measures, the overall risk of impacts from a large hydrocarbon release is considered to be **medium** and ‘as low as reasonably practicable’.

12. CONCLUSIONS

This ES has assessed the proposed tie-back of the Pegasus West well to the Cygnus gas development. Spirit Energy plans to re-enter and complete the Pegasus West well and install a subsea wellhead including Xmas tree and WPS. This will be connected to a new approximately 56.512 km pipeline and umbilical, installed between Pegasus West and the Cygnus Alpha process and utilities platform. The pipeline and umbilical will be trenched and buried (jetting) for the majority of the pipeline route, except for (i) a *c*. 4 km length (between KP4.350 - KP8.383) where they will remain on the seabed and be protected by rock (ii) at each end of the pipeline route, where the production pipeline and EHC umbilical will be protected by a combination of rock cover and mattresses. Pipeline crossings will be constructed using concrete mattresses and deposited rock. The pipeline and umbilical will transition out of their respective trenches as they approach the pipeline crossings and be surface laid and protected with mattresses and rock cover. Installation of spot rock cover may also be required at locations on the pipeline route. Dedicated reception facilities will be installed on Cygnus which will integrate Pegasus West production in to the Cygnus hydrocarbon processing and export systems.

The impacts and potential impacts (risks) associated with physical presence, energy use and atmospheric emissions, underwater sound, seabed disturbance, discharges and releases to sea, waste and a large hydrocarbon release have been evaluated (on a scale of 'low', 'medium' and 'high' significance) given the application of industry standard control and mitigation measures.

The proposed Pegasus West Development is located within two protected areas, the Dogger Bank SAC designated to protect 'sandbanks which are slightly covered by sea water all the time', and the Southern North Sea cSAC designated to protect harbour porpoise. A summary of the environmental sensitivities of the receiving environment local to the Pegasus West Development project is presented in Section 3.

Table 12-1 summarises the significance of the identified impacts. The significance of the impacts of all planned activities, following the application of control and mitigation measures, was considered low, with the exception of those associated with the permanent physical presence of installed seabed infrastructure (specifically the 500 m safety zone around the Pegasus West well) and seabed disturbance, the impacts of which are considered medium.

The temporary physical presence of project vessels, including the JUDR, may result in navigational restriction and hazard to shipping, prevention of commercial fishing, and behavioural disturbance to marine mammals and seabirds. However, vessel use will be optimised, existing levels of shipping in the vicinity are low to moderate and fishing effort in the project area is relatively low. The Lighthouse Board and fishing industry will be informed of relevant vessel activities and locations, and all vessels will have legally required navigation aids.

Atmospheric emissions are expected to disperse rapidly and dilute to background concentrations, resulting in localised and short term impacts only on air quality.

Sources of underwater sound arising from the use of vessels are not sufficient to cause physical injury to potentially sensitive receptors including marine mammals and certain species of fish. They may be temporarily displaced from, or reduce foraging effort in, areas in close proximity to vessels, but this would not be significant given the area of similar available habitat.

Discharges and releases to sea are expected to rapidly disperse and dilute under ambient metocean conditions. Planned chemical discharges will be risk assessed under the chemical permitting process, and the chemicals that will be discharged are routinely used in offshore oil and gas operations. Planned hydrocarbon discharges will be limited and in compliance with oil discharge permits. Pegasus West production is not expected to substantively increase discharges of produced water and associated dispersed oil at Cygnus and even under the worst case, increases will be small and of limited duration.

The quantities of waste produced will be limited. All wastes returned to shore will be handled and disposed of in accordance with legislation, WMPs and the waste management hierarchy, and only fully permitted waste management facilities will be used.

ASPECT	ACTIVITY/EVENT	SIGNIFICANCE
Physical Presence	Project vessel use.	Low
	Subsea infrastructure installation.	Medium
Energy Use and Atmospheric Emissions	Project vessel use.	Low
	Pegasus West production.	
Underwater Sound	Use of vessels for subsea construction and installation activities, and the JUDR for well completion activities.	Low
Seabed Disturbance	Jack-up of JUDR, installation of subsea infrastructure and associated protection or stabilisation features.	Medium
Discharges and Releases to Sea	Project vessel use.	Low
	Well completion.	
	Subsea infrastructure testing and commissioning.	
	Pegasus West production.	
Waste	Project vessel use.	Low
	Well completion.	
	Installation and commissioning (of subsea infrastructure and Cygnus topside modifications).	
	Pegasus West production.	
Large Release to Sea	Large release of diesel from a project vessel	Medium
	Large release of condensate from a well blowout	

Table 12-1 Summary of impact significance following mitigation

Conclusions with respect to the impacts of the physical presence of installed subsea infrastructure, seabed disturbance and an unplanned large hydrocarbon release, considered to have impacts of medium significance, are summarised below.

12.1 Physical Presence

Installed subsea infrastructure has the potential to prevent commercial fishing from its vicinity (by the use of safety exclusion zones), and/or to present a snagging hazard to fishing vessels using demersal gears.

The fishing effort in the project area is relatively low when compared to other areas of the UKCS. The fishing activity that does take place is dominated by demersal trawling, where fishing gear is towed across the seabed such that it may come in to contact with structures on the seabed. This can result in damage to seabed infrastructure, fishing gear and fishing vessels.

The implementation of a 500 m safety zone at Pegasus West will exclude fishing from an area of seabed of approximately 0.785 km^2 which is considered very small relative to that available for exploitation in the wider SNS. However, fishing will be excluded from this area for a relatively long period of time (likely to be several years throughout the production phase and until decommissioning is complete), and therefore the significance of the impact of prevention of commercial fishing operations associated with the physical presence of subsea infrastructure is considered to be **medium** and ‘as low as reasonably practicable’.

12.2 Seabed Disturbance

Seabed habitats, including sandbanks which are slightly covered by seawater all the time, have the potential to be impacted by planned project activities, particularly those that result in seabed disturbance.

The principal source of seabed disturbance associated with project activities concern the positioning (jacking-up) of the JUDR, and the installation of infrastructure. Of these, the largest area of impact will be from temporary disturbance associated with trenching and burial of the pipeline and umbilical. The largest area of permanent seabed disturbance will be from the installation of pipeline crossings and spot rock cover. These activities will result in the redistribution of sediments, potentially resulting in mortality or physical injury to benthos and eggs laid on the seabed, and in some locations, the permanent replacement of the natural seabed habitat with a stable, hard substrate.

Standard measures to control seabed disturbance include operational planning and equipment selection, and the area impacted will be minimised.

The species and habitats recorded in the vicinity of the proposed Pegasus West Development potentially fall under the definition of ‘sandbanks which are slightly covered by seawater all of the time’, particularly in areas less than 20 m LAT. None of the seabed communities identified in the project area have a high sensitivity to temporary seabed disturbance, in part because they are subject to natural disturbance by waves and currents, and they will be expected to recover through species recruitment from adjacent undisturbed areas. Project sources of seabed disturbance have the potential to impact herring and sandeel spawning, particularly if they take place during and shortly after the spawning seasons. Given the small area of seabed disturbance, relative to the extent of suitable spawning and nursery habitat in the SNS, any local mortality is unlikely to have an impact on populations as a whole.

The area where project infrastructure would result in a permanent change to the natural seabed habitat with a stable, hard substrate is small and a very small proportion of the extent of these habitats in the SNS and the Dogger Bank SAC. Therefore, the proposed project is not considered to have a significant impact on the achievement of the Conservation Objectives of the Dogger Bank SAC.

Similarly, seabed disturbance will not have a significant impact on the achievement of the Conservation Objectives of the Southern North Sea cSAC, which are to avoid deterioration of the habitats of the harbour porpoise or significant disturbance to the harbour porpoise.

The overall significance of the impact associated with seabed disturbance is therefore considered to be **medium** and ‘as low as reasonably practicable’.

12.3 Large Hydrocarbon Release

Sources of a potential unplanned large volume release to sea are associated with a loss of diesel containment from a vessel (including the JUDR), or a loss of reservoir hydrocarbons (condensate) from the Pegasus West well as a result of a well blowout or from the Pegasus West pipeline as a result of a rupture. Of these, the worst case in terms of the volume and duration of release would be a well blowout.

The area potentially impacted by a release coincides with areas of very high seabird sensitivity to surface oil pollution in the month of June, and extremely high sensitivity in the month of July and between the months of November and January. Impacts on the conservation features of the Dogger Bank SAC, designated due to the presence of the Annex I seabed habitat ‘sandbanks which are slightly covered by seawater all of the time’, and on the Southern North Sea cSAC, designated to protect harbour porpoise populations and their habitats, are possible.

Spill modelling suggests that, for a worst case, a relatively small area of seabed could be contaminated with hydrocarbons at concentrations just above the threshold above which toxic effects on benthic fauna may begin to be discernible. Many of the most abundant benthic species in the project area have low sensitivity to hydrocarbon contamination, but some species may be impacted. The area of potential impacts on benthos following the modelled worst case hydrocarbon release is approximately 56 km^2, if inside the Dogger Bank SAC, equivalent to 0.45% of its area.

Harbour porpoise are present at relatively high densities in the project area during the summer period. Mortality of marine mammals as a direct result a project-related large hydrocarbon release is unlikely but there is potential for sub-lethal impacts on individuals as a consequence of inhaling or ingesting hydrocarbons. However, in the unlikely event of a large hydrocarbon release, it would be unlikely to have a significant impact on the achievement of the Conservation Objectives of the Dogger Bank SAC or the Southern North Sea cSAC.

When all receptors are taken into account the worst case environmental impact associated with a large release to sea is considered to be medium.

A large hydrocarbon release is considered to be ‘unlikely’ owing to the procedural (the JUDR’s management systems) and operational controls that will be applied. The blowout frequency for a gas well completion operation to a North Sea standard is one in every 1.4×10^{-4} operations (equivalent to one blowout for every 7,143 completion operations), and a blowout during production would be much less likely.

Given the low likelihood of such a release, and following the application of control and mitigation measures, the overall risk of impacts from a large hydrocarbon release is considered to be **medium** and ‘as low as reasonably practicable’.

12.4 Overall Conclusion

Overall, the EIA concludes that the significance of impacts as a consequence of the proposed Pegasus West Development project activities is generally **low**, but is **medium** for activities that disturb the seabed and where fishing will be excluded from the Pegasus West 500 m safety zone due to the physical presence on installed subsea infrastructure. The risk of impacts from a worst case large hydrocarbon release is considered to be **medium** and ‘as low as reasonably practicable’. Generally, the impacts identified are considered localised and short term with low potential for long term or transboundary and cumulative impacts. The proposed Pegasus West Development does not contradict any marine planning objectives or marine planning oil and gas policies.

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A APPENDIX A: EAST OFFSHORE MARINE PLAN

The UK Marine Policy Statement (MPS) provides the policy framework for the marine planning system. Marine plans put into practice the policies identified in the MPS, informing decision-making for any activity or development which is in, or impacts on, a marine area. The UK is divided into marine planning regions, 11 in English waters, and the proposed Pegasus West Development is located in the East Offshore Marine Plan area.

A.1 Objectives

Objectives for the East Inshore and East Offshore Marine Plans are listed in Table A-1, with an assessment of the impacts of the proposed development against each.

OBJECTIVE		Applicable (Y/N)	ASSESSMENT AGAINST OBJECTIVE
1	To promote the sustainable development of economically productive activities, taking account of spatial requirements of other activities of importance to the East marine plan areas.	Y	The proposed Pegasus West Development will be economically productive. Spatial requirements of other activities have been assessed in Section 5 Physical Presence.
2	To support activities that create employment at all skill levels, taking account of the spatial and other requirements of activities in the East marine plan areas.	Y	The proposed Pegasus West Development will create/maintain employment. Spatial requirements of other activities have been assessed in Section 5 Physical Presence.
3	To realise sustainably the potential of renewable energy, particularly offshore wind farms, which is likely to be the most significant transformational economic activity over the next 20 years in the East marine plan areas, helping to achieve the United Kingdom's energy security and carbon reduction objectives.	N	N/A
4	To reduce deprivation and support vibrant, sustainable communities through improving health and social well-being.	Y	The proposed Pegasus West Development will create/maintain employment. No significant negative impacts on local communities is anticipated (Section 5 Physical Presence; Section 11 Large Hydrocarbon Release).
5	To conserve heritage assets, nationally protected landscapes and ensure that decisions consider the seascape of the local area.	N	There are no known cultural heritage features in the vicinity of the proposed Pegasus West Development or impacts on the seascape of the area, given the development is a subsea development 107 km from the coast.
6	To have a healthy, resilient and adaptable marine ecosystem in the East marine plan areas.	Y	The ES has assessed potential impacts on component receptors of the marine ecosystem in the vicinity of the proposed Pegasus West Development. Impacts are not considered to compromise the functioning of the marine ecosystem.
7	To protect, conserve and, where appropriate, recover biodiversity that is in or dependent upon the East marine plan areas.	Y	The ES has assessed potential impacts on component receptors of the marine ecosystem in the vicinity of the proposed Pegasus West Development. Habitats and species within the footprint of project activities may be impacted, but these habitats and species are widespread in the marine plan area.

OBJECTIVE		Applicable (Y/N)	ASSESSMENT AGAINST OBJECTIVE
8	To support the objectives of Marine Protected Areas (and other designated sites around the coast that overlap, or are adjacent to the East marine plan areas), individually and as part of an ecologically coherent network.	Y	The proposed Pegasus West Development is within two protected areas. Impacts on the protected features of these protected areas have been assessed (primarily Section 7 Underwater Sound, Section 8 Seabed Disturbance and Sections 11 Large Release to Sea). No significant adverse impacts on the achievement of the Conservation Objectives for these protected areas are anticipated.
9	To facilitate action on climate change adaptation and mitigation in the East marine plan areas.	Y	Fuel use associated with project vessels and the JUDR be minimised as far as possible.
10	To ensure integration with other plans, and in the regulation and management of key activities and issues, in the East marine plans, and adjacent areas.	N	N/A. Competent Authority responsibility.
11	To continue to develop the marine evidence base to support implementation, monitoring and review of the East marine plans.	Y	An environmental survey has been completed in the proposed Pegasus West Development area to inform the assessment of environmental impacts.

Table A-1 Assessment against Objectives for the East Inshore and East Offshore Marine Plans (MMO, 2014)

The proposed Pegasus West Development does not contradict any of the East Inshore and East Offshore Marine Plan objectives.

A.2 Oil and Gas Policies

The proposed development, as described in this ES, is assessed against the East Offshore Marine Plan oil and gas policies in Table A-2.

POLICY		Y/N	ASSESSMENT AGAINST POLICY
1	Proposals within areas with existing oil and gas production should not be authorised except where compatibility with oil and gas production and infrastructure can be satisfactorily demonstrated.	Y	The proposed subsea tie-back to Cygnus is fully compatible the existing oil and gas infrastructure. Guidance suggests this policy applies primarily to other sectors (MMO, 2014).
2	Proposals for new oil and gas activity should be supported over proposals for other development.	Y	There are no known proposals for other development that coincide with the proposed Pegasus West Development area.

Table A-2 Assessment against the East Inshore and East Offshore Marine Plan Oil and Gas Policies (MMO, 2014)

The proposed Pegasus West Development does not contradict any of the East Inshore and East Offshore Marine Plan oil and gas policies.

B APPENDIX B: ENVIRONMENTAL IMPACT IDENTIFICATION

Item	Activity	Aspect	Impacts / Potential Impacts (on receptors)	Existing Controls / Mitigation	Receptors: Habitats / Species: Plankton	Benthic communities	Fish	Marine mammals	Seabirds	Protected areas	Air / Sediment: Air quality	Sediment (seabed)	Water: Water quality	Built Env. / Societal: Fisheries	Shipping	Other sea users	Local communities	Resource use	Ranking accounting for controls/mitigation (worst case): Extent	Duration	Impact	Consequence (RA)	Likelihood	Risk	Actions / Comment
1. VESSEL USE (Jack up drilling rig, pipelay vessel, trenching vessel, anchor handling tug, guard vessels, DSV, CSV, survey vessels, supply vessels, rock installation vessel, HLV)																									
1.1	Presence of vessels on site and transit from and to port.	Physical presence	Potential impact on other sea users including shipping and fishing vessels, windfarms and oil/gas infrastructure. Navigation hazard, restriction of fishing operations, disturbance to birds / cetaceans.	• Consultation with the NFFO; • The fishing industry will be informed of relevant vessel activities and locations using Kingfisher Information Services; • A Notice to Mariners will be circulated prior to JUDR mobilisation; • Notice will be sent to Trinity House of any movements associated with the mobilisation and demobilisation of the JUDR; • All vessels will adhere to COLREGS and will be equipped with navigational aids, including radar, lighting and AIS (Automatic Identification System) etc.; • Vessel use will be optimised by minimising the number required, and their length of time on site; • The JUDR will abide by CtL conditions; • The JUDR will be equipped with navigational aids and aviation obstruction lights system, as per the Standard Marking Schedule for Offshore Installations; • An ERRV will patrol the Pegasus West area for the duration of well completion activities;				x						x	x				2	2	4				Shipping density is low around Pegasus West and the west part of the pipeline, moderate in the middle sections of the pipeline and high around Cygnus. Fishing activity is generally low, slightly higher at the Cygnus end of pipeline.
1.2	Fuel combustion (i.e. burning of diesel) and generation of power resulting in exhaust emissions (CO_2, CO, SO_x, NO_x, etc.).	Emissions to air	Minor contribution to climate change, acidification and photochemical smog (compared to overall activity in the North Sea). Unlikely to exceed UK and EU Air Quality Standards	• The JUDR and other project vessels will be subject to audits ensuring compliance with UK legislation and the Spirit Energy Marine Operations and Vessel Assurance Standard (SPT-MAL-GEN-STA-0010); • Vessel use will be optimised where possible by minimising the number of vessels required, and their length of time on site; and • Vessels will be operated where possible in modes that allow for economical fuel use.							x								2	2	4				
1.3	Fuel use for power generation	Resource use	Use of fuel / energy resource.															x	1	2	2				
1.4	Vessel operations including engines and thruster (DP) use.	Underwater sound	Generated sound has the potential to disturb marine mammals and fish, temporarily displacing them from the area. They are expected to return once the vessel(s) has left the area.	• Machinery, tools and equipment will be in good working order and well-maintained (as required under the contract with the subcontractor); and • Vessel use will be optimised where possible by minimising the number of vessels required, and their length of time on site.			x	x		x									2	2	4				Cetacean abundance relatively low except for harbour porpoise, observed frequently in the region. Density higher in the summer in the project area, up to as high as 3 individuals per km^2 at the Pegasus West end of the pipleine. Inside harbour porpoise cSAC. No injury, possibly short term avoidance.
1.5	Vessel sewage, bilge and ballast water discharges.	Discharges to sea	Water quality in immediate vicinity of discharge will be reduced, but effects are usually minimised by rapid dilution in massive receiving body of water. Organic enrichment and chemical contaminant effects in water column and seabed sediments. Possible introduction of invasive species from ballast water discharge.	• The JUDR and other project vessels will be subject to audits ensuring compliance with UK legislation and the Spirit Energy Marine Operations and Vessel Assurance Standard (SPT-MAL-GEN-STA-0010); • All project vessels used will be MARPOL-compliant; • Procedures and systems for the minimisation of waste and effluent generation from vessels (maintained as required under the contract with the subcontractor) will be implemented; • Procedures and systems for the management of ballast and bilge water from vessels (maintained as required under the contract with the subcontractor) will be implemented; • Vessels will be selected and audited to ensure that effective operational systems and onboard control measures are in place; and • Vessel use will be optimised by minimising the number required, and their length of time on site.	x	x	x	x	x	x		x	x						1	2	2				

Item	Activity	Aspect	Impacts / Potential Impacts (on receptors)	Existing Controls / Mitigation	Receptors: Habitats / Species						Receptors: Air / Sediment		Receptors: Water	Receptors: Built Env. / Societal					Ranking accounting for controls/mitigation (worst case)						Actions / Comment
					Plankton	Benthic communities	Fish	Marine mammals	Seabirds	Protected areas	Air quality	Sediment (seabed)	Water quality	Fisheries	Shipping	Other sea users	Local communities	Resource use	Extent	Duration	Impact	Consequence (RA)	Likelihood	Risk	
1.6	General operational hazardous and non-hazardous waste.	Waste	Effects associated with onshore disposal are dependent on the nature of the site or process. Landfills - land take, nuisance, emissions (methane), possible leachate, limitations on future land use. Treatment plants - nuisance, atmospheric emissions, potential for contamination of sites.	• The volume of waste produced will be minimised by the use of appropriate procurement controls; • The principles of the waste management hierarchy will be applied during all activities; • Existing Cygnus and vessel WMPs will be strictly followed; • All waste will be properly segregated to avoid cross-contamination; • Only licenced waste management facilities will be used; and • Monthly reporting of waste sent to shore will be undertaken.							x	x	x				x	x	1	2	2				
1.7	Unplanned event. Major oil / chemical (e.g. fuel oil and diesel) release (potentially due to vessel collision).	Large release to sea	Pollution of water column and sediment, threat to biodiversity, harm to surrounding ecosystems, flora and fauna. Consequential impacts on protected areas, fisheries and local communities.	• Activities will be carried out by trained and competent offshore crews and supervisory teams; • An approved OPEP to manage releases, including large hydrocarbon releases, will be in place prior to any activities being undertaken; • A TOOPEP or an update to the existing Cygnus OPEP for Pegasus West well completion will be in place covering well completion operations; • All vessel activities will be planned, managed and implemented in such a way that vessel durations in the field are minimised; • Spirit Energy's existing marine procedures will be adhered to minimise risk of hydrocarbon releases; and • Shipboard Oil Pollution Emergency Plans (SOPEPs) will be in place for project vessels.	x	x	x	x	x	x	x	x	x	x			x		4	2	8	2	2	4	Shipping density is low around Pegasus West and the west part of the pipeline, moderate in the middle sections of the pipeline and high around Cygnus. Fishing activity is generally low, slightly higher at the Cygnus end of pipeline. Seabird vulnerability to surface oil in extremely high in the area in July, and also between November and January. Maximum fuel inventory to be determined. Ranked based on birds being the most sensitive. Cygnus ES and Pegasus West Appraisal drilling OPEP do not predict beaching from a diesel release. CRA that was undertaken for the PW 2014 appraisal well states a frequency of 4.7 x 10-4 or 'unlikely' (3) on the Spirit risk matrix. The risk is reduceed one level since not every collision would result in a major diesel release to sea.
2. WELL COMPLETION (including siting and operation of the JUDR)																									
2.1	Presence of Jack up drilling rig.	Physical presence	Potential impact on other sea users including shipping and fishing vessels, windfarms and oil/gas infrastructure. Navigation hazard, restriction of fishing operations, disturbance to birds / cetaceans.	• Consultation with the NFFO; • The fishing industry will be informed of relevant vessel activities and locations using Kingfisher Information Services; • A Notice to Mariners will be circulated prior to JUDR mobilisation; • Notice will be sent to Trinity House of any movements associated with the mobilisation and demobilisation of the JUDR; • All vessels will adhere to COLREGS and will be equipped with navigational aids, including radar, lighting and AIS (Automatic Identification System) etc.; • Vessel use will be optimised by minimising the number required, and their length of time on site; • The JUDR will abide by CtL conditions; • The JUDR will be equipped with navigational aids and aviation obstruction lights system, as per the Standard Marking Schedule for Offshore Installations; • An ERRV will patrol the Pegasus West area for the duration of well completion activities;				x						x	x	x			2	1	2				Shipping density is low around Pegasus West and the west part of the pipeline, moderate in the middle sections of the pipeline and high around Cygnus. Fishing activity is generally low, slightly higher at the Cygnus end of pipeline.

Item	Activity	Aspect	Impacts / Potential Impacts (on receptors)	Existing Controls / Mitigation	Receptors: Habitats / Species						Air / Sediment		Water	Built Env. / Societal					Ranking accounting for controls/mitigation (worst case)						Actions / Comment
					Plankton	Benthic communities	Fish	Marine mammals	Seabirds	Protected areas	Air quality	Sediment (seabed)	Water quality	Fisheries	Shipping	Other sea users	Local communities	Resource use	Extent	Duration	Impact	Consequence (RA)	Likelihood	Risk	
2.2	Fuel combustion (i.e. burning of diesel) and generation of power for well intervention activities resulting in exhaust emissions (CO2, CO, SOx, NOx, etc.).	Emissions to air	Minor contribution to climate change, acidification and photochemical smog (compared to overall activity in the North Sea). Unlikely to exceed UK and EU Air Quality Standards	• The JUDR and other project vessels will be subject to audits ensuring compliance with UK legislation and the Spirit Energy Marine Operations and Vessel Assurance Standard (SPT-MAL-GEN-STA-0010); • Vessel use will be optimised where possible by minimising the number of vessels required, and their length of time on site; and • Vessels will be operated where possible in modes that allow for economical fuel use.							x								2	1	2				
2.3	Flaring for well cleanup and testing resulting in exhaust emissions (CO2, CO, SOx, NOx, etc.).	Emissions to air	Minor contribution to climate change, acidification and photochemical smog (compared to overall activity in the North Sea). Unlikely to exceed UK and EU Air Quality Standards Short clean up period.	• Flaring will be optimised where possible to minimise emissions; and • No cold venting.							x								3	1	3				
2.4	Fuel use for power generation	Resource use: e.g chemicals and diesel.	Use of non-renewable fuel / energy resource.	See 2.2.														x	1	2	2				
2.5	Noise and vibration during well completion operations. No conductor piling - wellhead already in place.	Underwater sound	Generated sound has the potential to disturb marine mammals and fish, temporarily displacing them from the area. They are expected to return once the vessel(s) has left the area.	• Machinery, tools and equipment will be in good working order and well-maintained (as required under the contract with the subcontractor); and • Vessel use will be optimised where possible by minimising the number of vessels required, and their length of time on site.			x	x		x									2	2	4				Cetacean abundance relatively low except for harbour porpoise, observed frequently in the region. Density higher in the summer in the project area, up to as high as 3 individuals per km2 at the Pegasus West end of the pipeline. Inside harbour porpoise cSAC. No injury, possibly short term avoidance. CEFAS herring spawning Block 43/13 (Pegasus West) period of concern for drilling from August to October.
2.6	Positioning (and jack up) of jack up drilling rig.	Seabed disturbance	Seabed disturbance in a small area due to jack-up rig footprint resulting in potential impact to benthic flora and fauna. Temporary suspended solids.	• All activities which may lead to seabed disturbance will be planned, managed and implemented in such a way that disturbance is minimised; • Rig site surveys will be completed before locating the JUDR at Pegasus West; • If possible, the JUDR will be positioned so that spud cans line up with existing spud can depressions;		x	x			x		x	x	x					2	3	6				Survey reports mixture of circalittoral sand and circalittoral coarse sediment (sand, gravel, occasional cobble) habitats. Sensitivity to both physical abrasion and sedimentation is low with full recovery in 2 years. Sensitivity to permanent change is high. Dogger Bank SAC area = 12,331km2. Environmental surveys in the area identified no Annex I habitats or Annex II species.
2.7	Planned discharge to sea of completion chemicals, required for well recompletion. Discharged fluids contaminated with reservoir hydrocarbons (including drop out from flaring).	Discharges to sea (filtered brine, completion chemicals)	Water quality in immediate vicinity of discharge will be reduced, but effects are usually minimised by rapid dilution in massive receiving body of water. Chemical contaminant effects in water column and seabed sediments.	• Where technically feasible the selection of PLONOR chemicals, or chemicals with a low HQ or RQ will be prioritised, and the use of chemicals with a substitution warning will be avoided; • Discharges to sea will be conducted in compliance with regulations and permit conditions	x	x	x	x	x	x		x	x						2	2	4				
2.8	General operational hazardous and non-hazardous waste. No significant waste streams - typically domestic.	Waste	Effects associated with onshore disposal are dependent on the nature of the site or process. Landfills - land take, nuisance, emissions (methane), possible leachate, limitations on future land use. Treatment plants - nuisance, atmospheric emissions, potential for contamination of sites.	See 1.6.							x	x	x				x	x	1	2	2				No significant additional waste generated by the jack up during will completion so assessed as vessel waste impacts.

Item	Activity	Aspect	Impacts / Potential Impacts (on receptors)	Existing Controls / Mitigation	Receptors														Ranking accounting for controls/mitigation (worst case)						Actions / Comment
					Habitats / Species						Air / Sediment		Water	Built Env. / Societal											
					Plankton	Benthic communities	Fish	Marine mammals	Seabirds	Protected areas	Air quality	Sediment (seabed)	Water quality	Fisheries	Shipping	Other sea users	Local communities	Resource use	Extent	Duration	Impact	Consequence (RA)	Likelihood	Risk	
2.9	Unplanned event. Major condensate/gas release (potentially due to well blowout).	Large release to sea	Pollution of water column and sediment, threat to biodiversity, harm to surrounding ecosystems, flora and fauna. Consequential impacts on protected areas, fisheries and local communities. Primarily a gas well with some condensate.	• A robust BOP pressure and functional testing regime will be in place as well as visual integrity checks; and • A TOOPEP or an update to the existing Cygnus OPEP for Pegasus West well completion will be in place covering well completion operations	x	x	x	x	x	x	x	x	x	x			x		4	2	8	2	3	6	Seabird vulnerability to surface oil in extremely high in the area in July, and also between November and January. Risk based on blowout frequency for offshore gas well completion operation to North Sea standards - 1.4 × 10-4 (OGP, 2010).
3. SUBSEA INFRASTRUCTURE INSTALLATION																									
3.1	Physical presence of subsea infrastructure (Xmas tree and wellhead protection structure (WPS), Hydraulic, chemical and electrical jumpers, pipeline, umbilical, tie-in spools, SSIV in Cygnus 500m zone, spot rock protection, mattresses, grout bags - including at crossings.	Physical presence	Navigation hazard, restriction of fishing operations, snagging risk to fishing nets . Ca. 4 km rock berm, for surface laid section of lines, two crossings midline that could impact on fishing and spot rock cover. A new 500 m exclusion zone being added at Pegasus.	• The pipeline and umbilical will be trenched and buried for the majority of their length to minimise interactions with fishing gear; • Guard vessels will be in deployed for the period when the pipeline and umbilical are on the seabed prior to burial; • All permanently unburied subsea infrastructure will be located within the existing Cygnus 500 m safety zone, or that which will be established at the Pegasus West well, and will be designed to be 'fishing friendly' or over-trawlable; • All subsea infrastructure installed outwith 500 m safety zones will either be buried or designed to be over-trawlable (e.g. at third party pipeline crossings);		x	x			x		x		x					2	4	8				Fishing activity is generally low, slightly higher at the Cygnus end of pipeline. Mostly demersal trawls. Ranked focusing on socio-economic receptors - excluded for 500m zone area for 'medium to long term'.
3.2	Consumption of finite materials (e.g. steel) during construction of pipelines and other subsea infrastructure.	Resource use	Use of non-renewable resources (e.g. steel) during construction of pipelines and other subsea infrastructure.	• The production pipeline and umbilical tie-back route length will be minimised														x	1	4	4				
3.3	Noise and vibration during installation operations.	Underwater sound	Generated sound has the potential to disturb marine mammals and fish, temporarily displacing them from the area. They are expected to return once the vessel(s) has left the area. No piling of any structures. Assessing noise of rock emplacement in chutes.	• Machinery, tools and equipment will be in good working order and well-maintained (as required under the contract with the subcontractor); and • Vessel use will be optimised where possible by minimising the number of vessels required, and their length of time on site.			x	x		x									2	1	2				Marine mammal abundance relatively low except for harbour porpoise, observed frequently in the region. Density higher in the summer in the project area, up to as high as 3 individuals per km2 at the PW end of the pipleine. Inside harbour porpoise cSAC. No injury, possibly short term avoidance.
3.4	Disturbance associated with installation of subsea infrastructure. Area of impact based on two separate trenches (1 for pipeline, one for umbilical). Initiation anchor (10 te anchor with a 10m radius drag) will be recovered after pipeline is installed.	Seabed disturbance (temporary)	Seabed disturbance, loss of habitat/creation of different habitat, temporary suspended solids, loss of benthic organisms.	• All activities which may lead to seabed disturbance will be planned, managed and implemented in such a way that disturbance is minimised; • Project vessels will utilise dynamic positioning systems for station keeping rather than anchors; • The production pipeline and umbilical tie-back route length will be minimised; • The opportunity of laying the production pipeline and umbilical in the same trench for part or all of the route will be sought; • The area of drag of the initiation anchor, used to lay the pipeline, will be minimised; • The use of protection and stabilisation features will be optimised; and		x	x			x		x	x	x					4	3	12				Surveys report a mixture of circalittoral sand and circalittoral coarse sediment (sand, gravel, occasional cobble) habitats around Pegasus West. Along the pipeline route these habitats occur as well as areas of infralittoral coarse sediment, infralittoral fine sand and circalittoral mixed sediment. Wher the seabed in<20m LAT these habitats fall under the description of Annex I habitat 'sandbanks which are slightly covered by seawater all of the time'. Sensitivity to permanent change is high. Dogger Bank SAC area = 12,331km2. Footprint assumed a corridor width of 10 m along the umbilical trench and along the pipeline trench. Ranked taking into account of area of SAC area temporarily disturbed (approx 0.01%).

Item	Activity	Aspect	Impacts / Potential Impacts (on receptors)	Existing Controls / Mitigation	Receptors: Habitats / Species						Air / Sediment		Water	Built Env. / Societal					Ranking accounting for controls/mitigation (worst case)						Actions / Comment
					Plankton	Benthic communities	Fish	Marine mammals	Seabirds	Protected areas	Air quality	Sediment (seabed)	Water quality	Fisheries	Shipping	Other sea users	Local communities	Resource use	Extent	Duration	Impact	Consequence (RA)	Likelihood	Risk	
3.5	Disturbance associated with installation of subsea infrastructure.	Seabed disturbance (permanent)	Loss of habitat/creation of different habitat. Spot rock cover, pipeline crossings, wellhead and protection structure, surface laid spools, SSIV, mattresses. Introduction of hard structures to a mostly sandy environment.	• Spot rock deposits will be installed in a controlled manner using a fall-pipe and ROV.		x	x					x							3	3	9				Decommissioning anticipated in less than 20 years.
3.6	Discharge of chemicals (e.g. corrosion inhibitor during dewatering of pipelines; hydraulic fluid during subsea valve testing/operation.	Discharges to sea	Water quality in immediate vicinity of discharge will be reduced, but effects are usually minimised by rapid dilution in massive receiving body of water. Chemical contaminant effects in water column and seabed sediments.	• Where technically feasible the selection of PLONOR chemicals, or chemicals with a low HQ or RQ will be prioritised, and the use of chemicals with a substitution warning will be avoided; Discharges to sea will be conducted in compliance with regulations and permit conditions	x	x	x	x	x	x		x	x						2	2	4				Free flooding during pipelay, adding chemicals (including corrision inhibitor) once line installed, discharged to sea prior to commencement of production. Dewatering by pig deployed from Cygnus, pig receiver near Pegasus well to push out the inhibited seawater. Pig pushed with nitrogen.
4. CYGNUS TOPSIDE MODIFICATIONS (including possible Jack-Up Accommodation Barge at Cygnus)																									
4.1	Installation of: Topsides Umbilical Termination Unit (TUTU), Chemical injection package, Hydraulic power unit, Master control station for well Electrical power unit, Reception module (250 te weight - requires a HLV - ENVID assumes holds position by DP).	Resource use	Use of non-renewable fuel / energy resource; steel etc.															x	1	4	4				
4.2	General operational hazardous and non-hazardous waste.	Waste	Effects associated with onshore disposal are dependent on the nature of the site or process. Landfills - land take, nuisance, emissions (methane), possible leachate, limitations on future land use. Treatment plants - nuisance, atmospheric emissions, potential for contamination of sites.	• The volume of waste produced will be minimised by the use of appropriate procurement controls; • The principles of the waste management hierarchy will be applied during all activities; • Existing Cygnus and vessel WMPs will be strictly followed; • All waste will be properly segregated to avoid cross-contamination; • Only licenced waste management facilities will be used; and • Monthly reporting of waste sent to shore will be undertaken.							x	x	x				x	x	1	2	2				Limited waste streams. Primarily domestic.
4.3	Unplanned event. Dropped object.	Seabed disturbance	Seabed disturbance in a small area within 500 m zone resulting in potential impact to benthic flora and fauna. Temporary suspended solids.	• Lifting plans in place.	x	x	x	x	x	x		x	x						1	3	3	1	3	3	Ranked excluding interaction with a pipeline. Small impacted seabed area close to Cygnus.
4.4	Unplanned event. Release of gas / condensate for Cygnus, potentially from pipeline ruptured by a dropped object associated with PW modifications (e.g. reception module).	Large release to sea	Primarily gas released with small quantities of condensate. Pollution of water column and sediment, threat to biodiversity, harm to surrounding ecosystems, flora and fauna. Consequential impacts on protected areas, fisheries and local communities.	• Lifting plans in place; • A DHSV will enable isolation of the reservoir; • Cygnus facilities will be protected by a combination of a topside Emergency Shutdown Valve (ESDV) and a SSIV; • Pipelines will be protected by pressure alarms which can assist leak detection; and • Releases, including large hydrocarbon releases associated with Pegasus West production, will be managed under the Cygnus OPEP.	x	x	x	x	x	x		x	x	x					3	1	3	1	2	2	Likelihood takes account of likelihood of it hitting the pipeline (not just likelihood of dropped object)

SPIRIT ENERGY

Item	Activity	Aspect	Impacts / Potential Impacts (on receptors)	Existing Controls / Mitigation	Receptors: Habitats / Species						Receptors: Air / Sediment		Receptors: Water	Receptors: Built Env. / Societal					Ranking accounting for controls/mitigation (worst case)						Actions / Comment
					Plankton	Benthic communities	Fish	Marine mammals	Seabirds	Protected areas	Air quality	Sediment (seabed)	Water quality	Fisheries	Shipping	Other sea users	Local communities	Resource use	Extent	Duration	Impact	Consequence (RA)	Likelihood	Risk	
5. COMMISSIONING, START UP & PRODUCTION																									
5.1	Additional power generation (fuel combustion) required on Cygnus? Resulting in exhaust emissions (CO_2, CO, SOx, NOx, etc.).	Emissions to air	Minor contribution to climate change, acidification and photochemical smog (compared to overall activity in the North Sea). Unlikely to exceed UK and EU Air Quality Standards. No new power generation equipment required at Cygnus for PW and no step change increase in emissions. However, extended Cygnus life will increase cumulative emissions at the installation.	• Combustion emissions controls under the Cygnus PPC permit and EUETS permit / EUETS trading scheme.							x								1	4	4				
5.2	Discharge of small quantities of hydraulic fluid at Pegasus West. Discharge chemicals injected at tree (Corrosion inhibitor, Methanol/Kinetic hydrate inhibitor mix, wax inhibitor), produced hydrocarbons, naturally occurring heavy metals through Cygnus produced water discharge.	Discharges to sea	Water quality in immediate vicinity of discharge will be reduced, but effects are usually minimised by rapid dilution in massive receiving body of water. Chemical contaminant effects in water column and seabed sediments. All other discharges are at Cygnus.	• Existing capacity of Cygnus produced water system is sufficient to managed fluids produced from PW. • Where technically feasible the selection of PLONOR chemicals, or chemicals with a low HQ or RQ will be prioritised, and the use of chemicals with a substitution warning will be avoided; and • Discharges to sea will be conducted in compliance with regulations and permit conditions;	x	x	x	x	x	x		x	x						1	4	4				Any increase in discharges at Cygnus are unlikely to be detectable, with the possible exception of an increase in methanol discharge. However, methanol is a PLONOR chemical (poses little or no threat to the environment). No NORM anticipated from Pegasus West. This may merit reassessment if the Pegasus field is further developed.
5.4	Unplanned event. Pegasus flowline rupture and subsequent release of condensate/gas.	Large release to sea.	Pollution of water column and sediment, threat to biodiversity, harm to surrounding ecosystems, flora and fauna. Consequential impacts on protected areas, fisheries and local communities.	• A DHSV will enable isolation of the reservoir; • Cygnus facilities will be protected by a combination of a topside Emergency Shutdown Valve (ESDV) and a SSIV; and • Pipelines will be protected by pressure alarms which can assist leak detection	x	x	x	x	x	x	x	x	x	x			x		3	1	3	1	2	2	Seabird vulnerability to surface oil in extremely high in the area in July, and also between November and January. Ranked assuming worst case of whole pipeline inventory released between the SSIV at Cygnus and the PW tree isolation valve.
5.5	Unplanned event. Snagging or dragging of Pegasus West wellhead, connection tee, spools etc.	Seabed disturbance	Local water quality deterioration, impacts on marine flora and fauna.	• All permanently unburied subsea infrastructure will be located within the existing Cygnus 500 m safety zone, or that which will be established at the Pegasus West well, and will be designed to be 'fishing friendly' or over-trawlable; and • All subsea infrastructure installed outwith 500 m safety zones will either be buried or designed to be over-trawlable (e.g. at third party pipeline crossings);		x	x			x		x	x	x					2	3	6	2	2	4	Fishing activity is generally low, slightly higher at the Cygnus end of pipeline. Demersal trawls commonly used.
5.6	Unplanned event. Pegasus West subsea control system failure resulting in a release to sea of hydraulic fluid	Release to sea	Water quality in immediate vicinity of discharge will be reduced, but effects are usually minimised by rapid dilution in massive receiving body of water. Chemical contaminant effects in water column and seabed sediments.	• Integrity management systems, inspection and maintenance; • Use of water-based / low toxicity hydraulic fluid; and • Fail-closed valves.	x	x	x	x	x	x		x	x						1	1	1	1	3	3	

C APPENDIX C: OIL SPILL MODELLING

C.1 Introduction

C.1.1 Scope and Objectives of Oil Spill Modelling

This Appendix describes the modelling undertaken in order to determine the environmental risk associated with the accidental release of hydrocarbons at the proposed Pegasus Field. A single well blowout scenario has been modelled using the Oil Spill Contingency and Response (OSCAR) model (v10.0) developed by The Foundation for Scientific and Industrial Research (SINTEF).

The objectives of the modelling are to understand:

- Where the hydrocarbons are likely to travel;
- How the hydrocarbons are likely to disperse over time (both on the sea surface and in the water column);
- The extent to which hydrocarbons are likely to arrive on any shoreline;
- Where hydrocarbon concentrations could exceed certain thresholds on the sea surface, in the water column and in sediments; and
- The significance of the potential environmental impacts.

C.1.2 Overview of Modelling Methodology

When crude oil is spilled on the surface of the sea it is subjected to a number of processes including: spreading, evaporation, dissolution, emulsification, natural dispersion, photo-oxidation, sedimentation and biodegradation. The fate and effect of crude oil are dependent on the chemical and physical properties of the oil, and the physico-chemical changes to which the oil is subjected. These vary depending on the oil type, the volume spilled and the prevailing weather and sea conditions. Some of these changes lead to its disappearance from the sea surface while others, for example emulsification, may cause it to become more persistent.

The various processes that oil is subjected to after a release at sea are highlighted in Figure D 1. These processes are all modelled in the OSCAR oil spill modelling software to predict the fate and behaviour of discharged hydrocarbons over time.

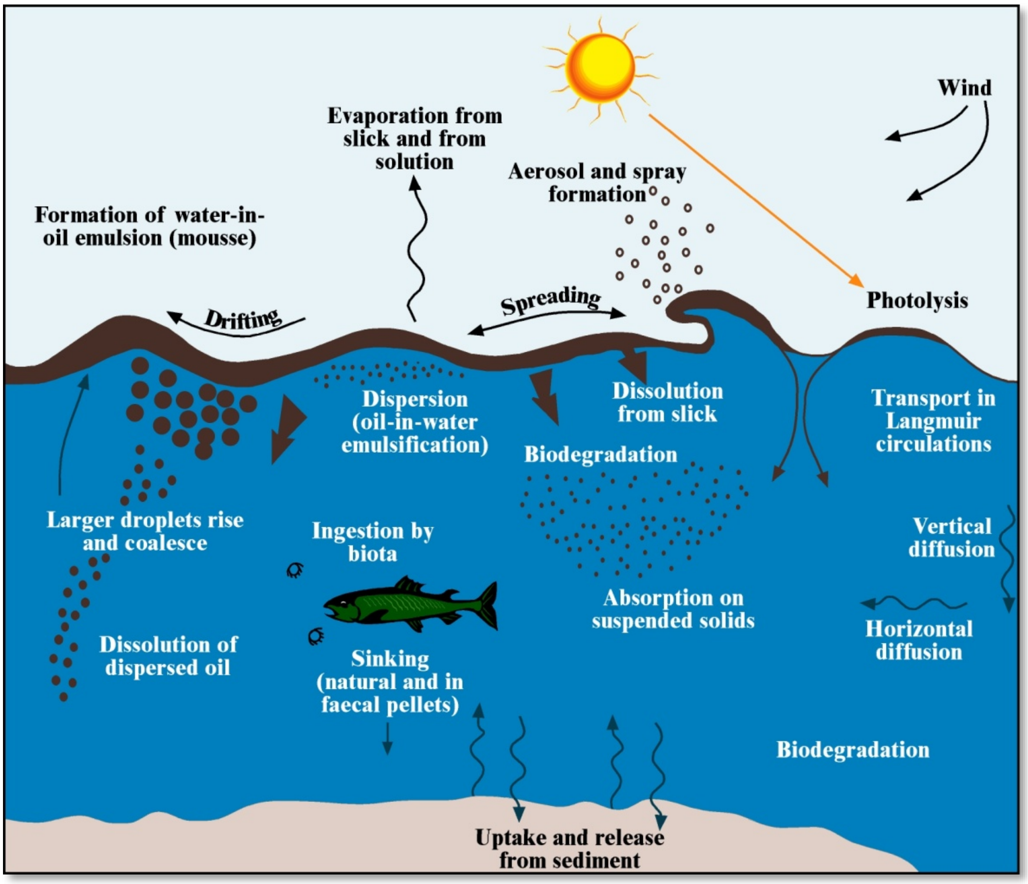
OSCAR supports two different types of model runs: stochastic runs (probabilistic modelling) and deterministic runs. The stochastic modelling feature of OSCAR allows for a spill scenario to be modelled multiple times over different weather conditions, with the results from each individual stochastic run being aggregated, and a number of statistical parameters computed. The stochastic modelling results presented in this Appendix examine:

- The probability of oil above a predefined threshold appearing on the sea surface;
- The probability of oil above a predefined threshold being present throughout the water column; and
- The probability of oil arriving on the shoreline.

It is important to note that the stochastic modelling results do not represent a single spill scenario but rather show the aggregation of results computed by running the spill scenario multiple times over different weather conditions.

To analyse a single spill scenario, the deterministic mode of OSCAR allows for the spill scenario to be modelled over a single specified time interval and outputs can be presented in terms of key parameters such as oil thickness on the sea surface, concentrations on the shoreline, in the sediment and in the water column. One deterministic scenario was selected based on the individual stochastic run which gives the worst case shoreline oiling (i.e. the greatest mass of condensate arriving onshore). The deterministic model results presented in this Appendix examine:

- The maximum thickness of oil appearing on the sea surface;
- The maximum concentrations of oil present in the water column;
- The maximum concentrations of oil reaching the shoreline; and
- The maximum concentrations of oil being deposited in the sediment.



Source: adapted from Koops *et al.*, 1985

Figure C-1 Fate and Behaviour of Spilled Hydrocarbons at Sea

C.2 Model Input Data

C.2.1 Release Parameters

The main release parameters for the well blowout scenario are summarised in Table C-1. In the unlikely event of a blowout, the release would likely be at the sea surface given that well completion is being undertaken from a jack up rig and therefore the blowout preventer (BOP) is located close to the rig floor (as opposed to the BOP on a semi-submersible rig which is located at the seabed).

The well blowout scenario was modelled using the same estimated release duration as was used for the Pegasus West Appraisal Drilling OPEP (Centrica, 2014). The release duration was based on the upper estimated time to source and mobilise a rig, drill a relief well, and kill and cement the well. The anticipated times to complete these activities are shown in Table C-2 and is estimated to be 95 days in total. The model was run for an additional 30 days after the blowout was terminated to determine the ongoing fate of the hydrocarbons following cessation of the release.

The discharge rate was based on an unconstrained release from the single producer well from the 8.5-inch reservoir section– i.e. the release would occur through the 9.625" production casing. This represented a worst-case for quantity of hydrocarbon released. The oil discharge rate was taken as 430 m^3/d and it was assumed that the rate would not decline over time.

As required by BEIS, the model assumed no intervention (i.e. no response efforts were included in the modelling). The results in terms of estimated impacts can therefore be considered to be conservative.

Table C-1 Release Parameters

Scenario and location	Hydrocarbon type	Initial release rate	Release duration[1]	Total quantity released	Release temperature
Surface blowout 54°31'20.02" N 001°25'14.358"E	Condensate	430 m^3/d	95	40,850 m^3	78°C
1. Total model duration included an additional 30 days following the end of the discharge.					

Table C-2: Estimated timeline to kill well and terminate blowout

Event	Duration (days)
Locate rig, suspend previous well, rig move to well relief location	20
Prepare for drilling	14
Drill and case a relief well	59
Perform kill	2
Total	**95**

C.2.2 Hydrocarbon Characteristics

When oil is released in the sea it is subjected to a number of processes including spreading, evaporation, dissolution, emulsification, natural dispersion, sedimentation and biodegradation. The fate and effect of oil are dependent on the chemical and physical properties of the oil, which are taken into account in the modelling. OSCAR includes a database with various oil types; from this database a suitable analogue needs to be selected to represent the Pegasus condensate, as explained below and in Table C-3.

The key hydrocarbon properties of the Pegasus condensate that were applied to the model are shown in Table D-3. The Lavrans condensate was selected as the best analogue given that specific gravity, viscosity, wax content and asphaltene content were all relatively good matches. The pour point for Lavrans is lower than the Pegasus pour point, i.e. Lavrans condensate will flow at a lower temperature than Pegasus and potentially spread further than Pegasus, therefore representing a worst case. Given the likely temperature at the spill site of around 9°C Pegasus condensate will be flowing (pour point of 6°C) and therefore the difference is not considered likely to result in significant differences in behaviour.

In addition to the properties shown in table D-3, the gas oil ratio (GOR) and gas density are also input into the model. The anticipated condensate to gas ratio (CGR) following a stock tank flash ranges from 4 to 6 bbl/mmscf (Spirit Energy email 15/08/2018). The worst case of 6 bbl/mmscf, is equivalent to a GOR of 29,684 (unitless). Gas density is 0.65 kg/m^3.

Table C-3: Properties of Pegasus Condensate and selected OSCAR Analogue

Oil type	API (°)	Specific Gravity	Viscosity (cP)	Pour point (°C)	Wax content (% wt)	Asphaltene content (% wt)
Pegasus Condensate	50.53	0.7766	1.4 at 13°C[1]	6	4.4	<0.05
OSCAR analogue Lavrans Condensate	-	0.7890	2.0 at 13°C	-6	6	0.01

1 converted from kinematic viscosity provided by Spirit

C.2.3 Metocean Data

The OSCAR model takes into account the effect of various environmental factors such as bathymetry, current and wind speed and direction, water column salinity and temperature, as well as seabed and coastal sediment types.

C.2.3.1 Bathymetry

The bathymetry data used in the OSCAR model is based on the Sea Topo 8.2 and International Bathymetric Chart of the Atlantic Ocean (IBCAO) databases (Jakobsson *et al*., 2008). This is considered to be the best available bathymetry data at the time of writing.

C.2.3.2 Current data

3D water current data supplied by OGA was used in the model covering the years 2008 (October) to 2013 and was obtained by the Hybrid Co-ordinated Ocean Model (HYCOM). The dataset contains 3D ocean currents with a temporal resolution of one day i.e. the currents change speed and direction at daily intervals.

C.2.3.3 Wind data

Wind data supplied by OGA was used in the model covering the years 2008 (October) to 2013. This data was sourced from HYCOM, and is the equivalent data set to the current data as detailed above.

C.2.3.4 Temperature and salinity data

The variation in salinity between surface and seabed is taken from the Marine Scotland National Marine Plan interactive (NMPi) database (Scottish Government, 2018), which are provided as annual mean values. In the region of interest this average value was 35 parts per thousand (ppt) both at the sea surface and near the seabed. The sea temperature profile was taken from the Basis of Design (BoD) (Centrica, 2017)) and was set to 9.9°C at the sea surface, decreasing to 9.4°C at the seabed (annual means).

C.2.4 Output Thresholds

Models such as OSCAR are capable of tracking the fate of oil in smaller and smaller concentrations and masses (over time and space), beyond the point at which oil represents a significant risk or is even detectable against background levels. In order to ensure the model outputs are proportionate to the risks, while still retaining a precautionary approach, output thresholds are normally applied to thicknesses of surface oil and to concentrations in the water column.

The thresholds adopted in the modelling are explained in the following sections.

C.2.4.1 Surface thickness

A surface thickness threshold of 0.3 μm has been adopted. This corresponds to the minimum oil thickness expected to produce a rainbow sheen (see Table C-4). Oil below this value becomes unlikely to be visible in many conditions and under 0.04 μm it is considered "not visible" even under good conditions. Available data on the significance of oil sheen thickness to birds, indicates that a thickness of 0.1 μm could cause adverse structural changes in feathers (O'Hara and Morandin, 2010), but concludes that the amount of oil encountered is more important than the thickness.

Stochastic outputs from oil spill models may report the presence of oil which may only have been present on the surface momentarily, potentially giving a false impression of potential impact. This is particularly true in the latter stages of a spill when oil is present in very small masses that are transient between the surface and the water column.

The BEIS OPEP guidelines (BEIS, 2017) state that oil spill model results must be displayed to an oil thickness of 0.3 μm and therefore this threshold has been adopted for the current study.

Table C-4: Bonn Agreement Oil Appearance Code

Code	Appearance description	Layer thickness (μm)	Litres per km^2
1	Sheen (silver/grey)	0.04 – 0.3	40 – 300
2	Rainbow	0.3 – 5.0	300 – 5,000
3	Metallic	5.0 – 50	5,000 – 50,000
4	Discontinuous true oil colour	50 – 200	50,000 – 200,000
5	Continuous true oil colour	> 200	> 200,000

Source: Bonn Agreement, 2009

C.2.4.2 Oil in water concentration

A range of standards for oil in water have been considered, as shown in Table D-5.

Table C-5: Standards for Oil Concentration in the Water Column

Region	Source	Context	Parameter	Standard
North Sea and North East Atlantic	OSPAR Agreement 2014/05 (OSPAR, 2014)	Predicted no-effect concentrations (PNEC) of substances in produced water	Dispersed oil	No Observed Effect Concentration (NOEC) 70.5 μg/l (70.5 ppb)
International	Patin, 2004	Fate and effect of crude oil spills	Total Petroleum Hydrocarbons (TPH)	NOEC 10 μg/l (10 ppb)
Norway	SINTEF	Pre-defined toxicity levels of oil components in OSCAR database	Any hydrocarbon component	Acute toxicity PNEC 50 - 15,500 ppb. Chronic toxicity PNEC 5 ppb - 1,550 ppb

A total oil in seawater (in the water column) concentration above 10 ppb has been used as the threshold for the current model. This is based on the NOEC highlighted by Patin (2004). The NOEC is the level at which biological effects are either absent or manifest themselves as primary (mostly reversible) physiological and biochemical responses. A threshold of 10 ppb is considered conservative given the range of standards reported in the literature.

C.2.4.3 Shoreline oil density

No threshold has been applied within the model to the shoreline oil density as in the interest of transparency it is considered best practice to report all shoreline oiling (however small) in the results.

In order to allow an assessment of impacts when reviewing model outputs, a mass of oil on the shoreline above 100 g/m^2 has been considered as potentially significant. This is considered to be an impact threshold for oiling of birds by the US Army Corps of Engineers (2003) and is reinforced by McCay (2009) who notes that 100 g/m^2 would be enough to coat benthic epifaunal invertebrates living on hard substrates in intertidal habitats, thus compromising the animals. It also inferred from the level of ‘light’ oiling defined by ITOPF Technical Information Paper 6 (ITOPF, 2014c).

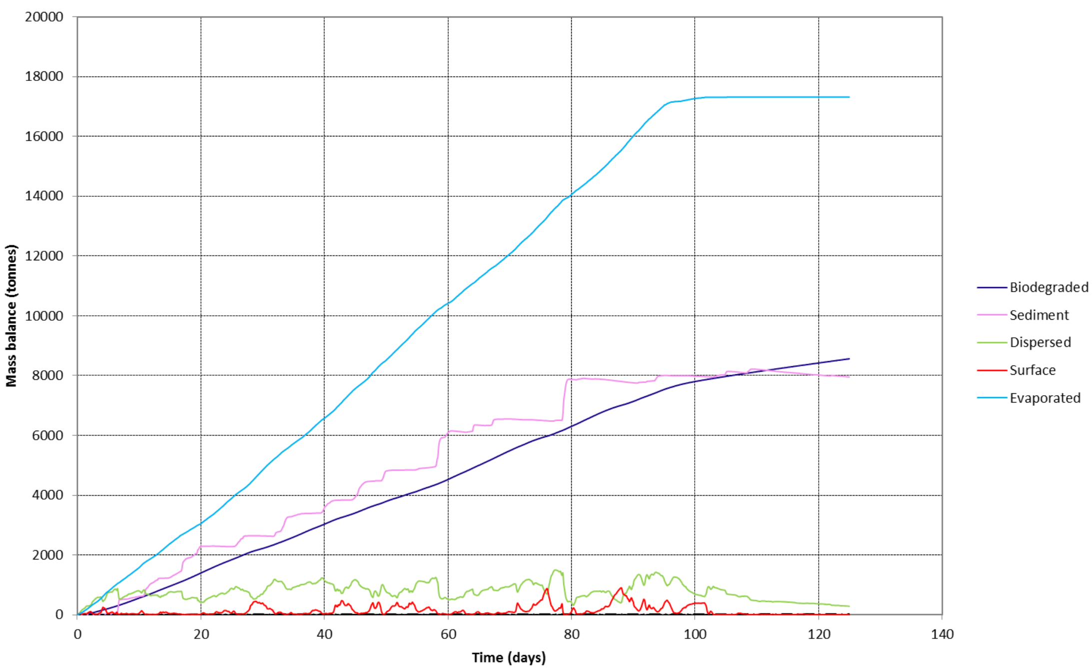
C.2.4.4 Oil in sediment

No threshold has been applied to sediment concentrations in the model. However, in order to allow an assessment of impacts when reviewing model outputs, a mass of oil of 50 mg per 1 kg of sediment (50 mg/kg), has been taken as the level above which toxic effects on benthic fauna may begin to be discernible. This threshold was adopted by OSPAR (OSPAR, 2006 and UKOOA 1999) in the context of Oil Based Mud (OBM) contamination. Given that deposition will distribute vertically through the surface of the seabed, this equates to 5 g of oil per 1 m^2 of seabed (5 g/m^2) assuming that the oil will distribute through a 5 cm sediment layer and assuming a sediment density of 2.0 t/m^3. Thus, 5 g/m^2 is adopted as the threshold above which toxic effects are considered to begin to be discernible.

C.3 Model Outputs

C.3.1 Fate of Hydrocarbons (Mass Balance)

Figure C-2 shows the mass balance over time both as tonnes (a) over time and (b) as a percentage.



(a)

(b)

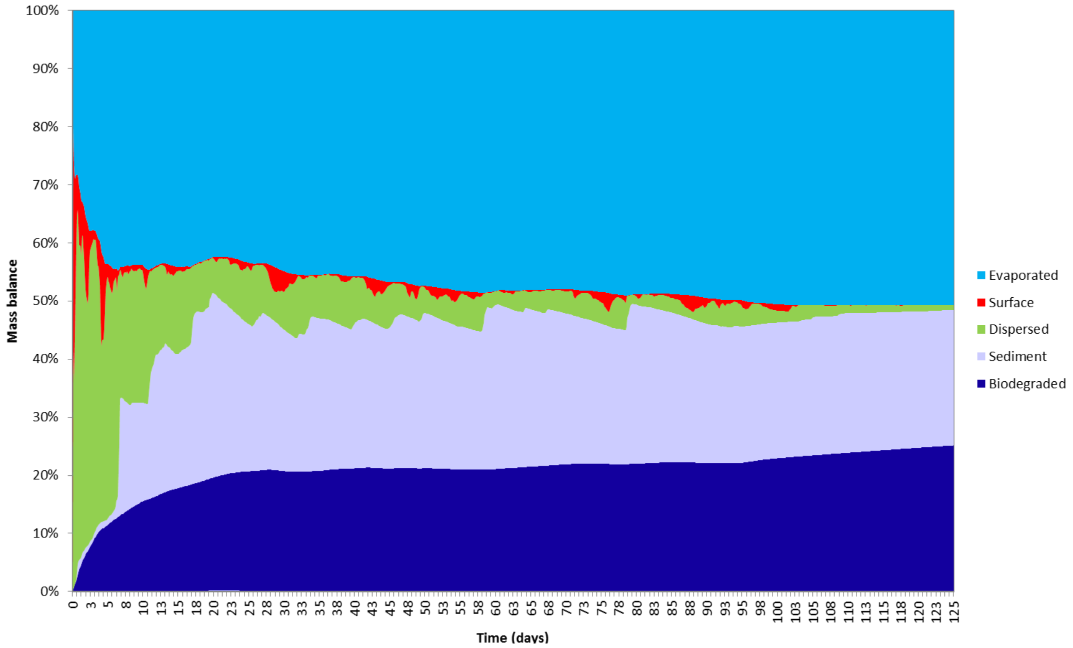


Figure C-2: Mass Balance (deterministic)

Approximately 51% (17,320 tonnes) of the condensate evaporates, 25% (8,344 tonnes) biodegrades, 23% (8,074 tonnes) goes into the sediment and only a small percentage remains in the water column (0.8%, 379 tonnes, shown as dispersed oil in Figure C-2) or at the surface (<0.1%, 14 tonnes) by the end of the modelling run.

The mass balance is obtained from a deterministic run rather than the stochastic runs, in order to include the level of oil in the sediment (in stochastic runs this is not calculated and is effectively shown as oil "outside" the model).

C.3.2 Oil on the Sea Surface

The probability of a visible surface sheen with a thickness greater than 0.3 µm is shown in Figure C-3. The results were obtained from the stochastic modelling simulations and represent the aggregation of results from 100 different stochastic runs of the well blowout scenario. This visible surface sheen is predicted to extend *c.* 25 km with a 90-100 % probability and up to 76 km at 0-10% probability, from the source of the spill. The area of the surface sheen is relatively limited in extent as would be expected from a condensate.

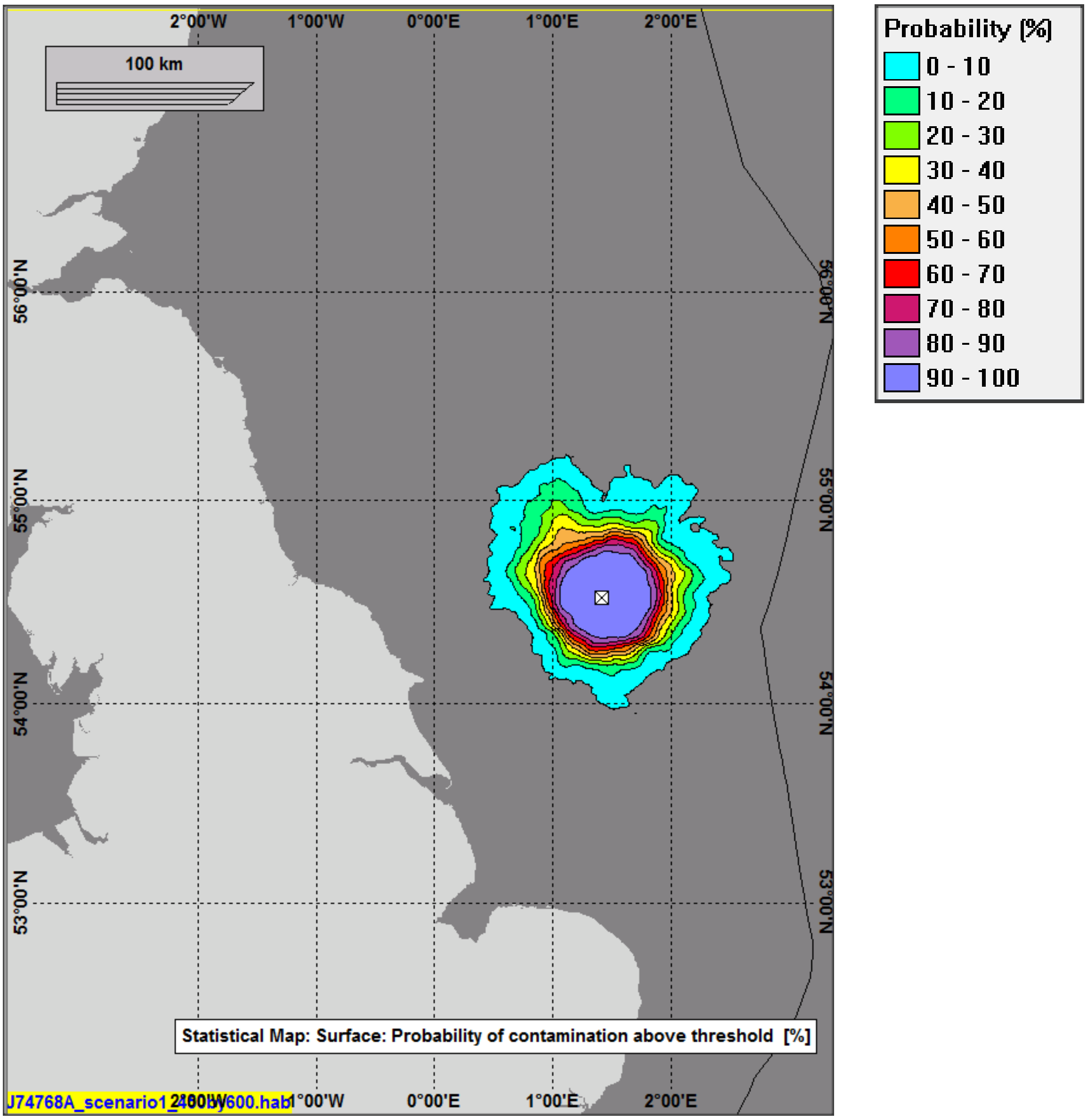


Figure C-3: Probability of a surface sheen >0.3 µm (stochastic)

A deterministic model was run in order to assess the impact to the sea surface. Figure C-4 shows these results for the total sea surface area impacted by condensate over the duration of the whole model (swept path).

The modelling predicts that the total sea surface area impacted by condensate above a thickness of 0.3 µm is *c*. 4,200 km^2. The maximum thickness predicted anywhere at the sea surface is 3 µm immediately adjacent to the blowout location.

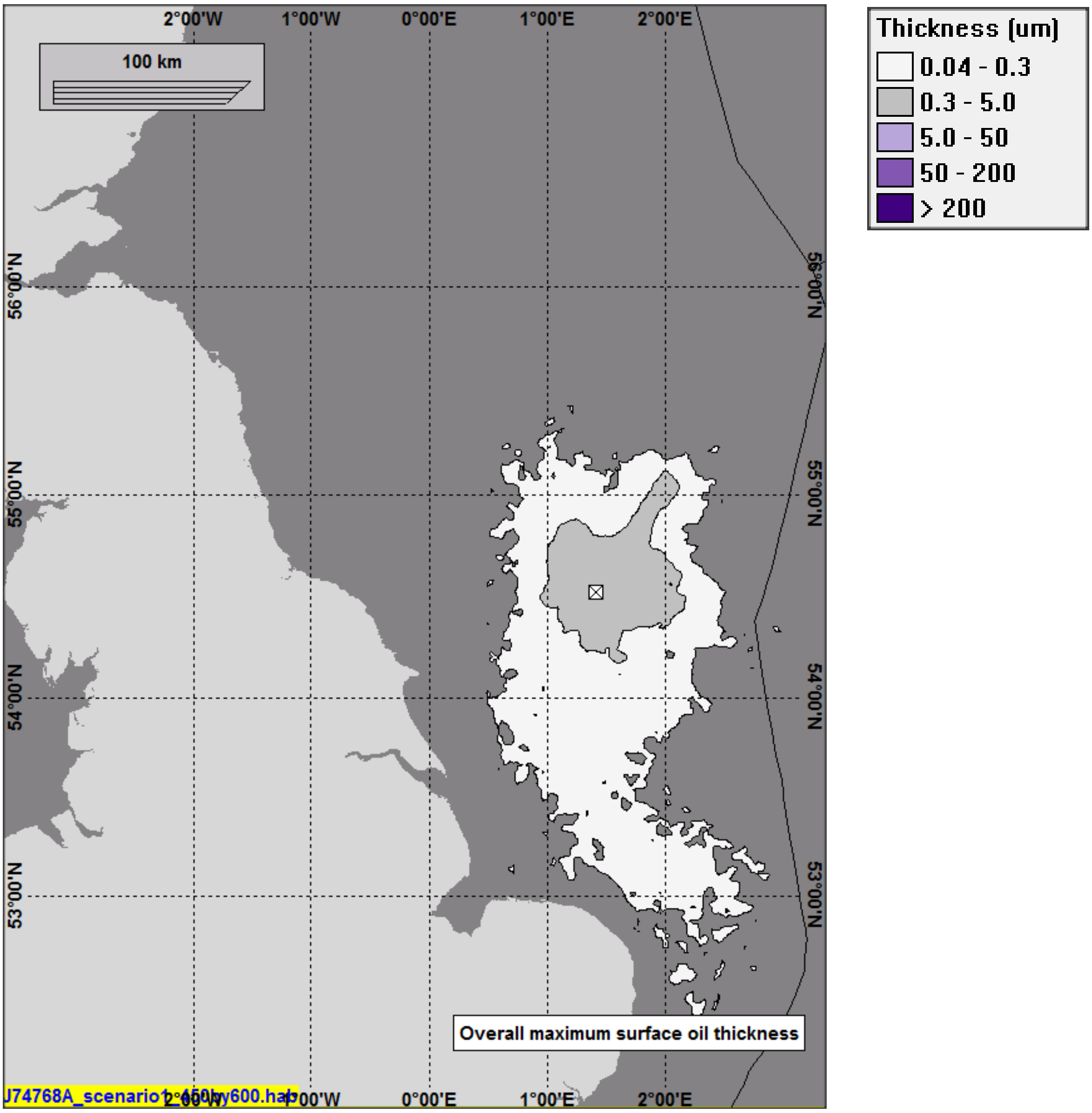


Figure C-4: Thickness of condensate at sea surface (deterministic)

Note: Thicknesses below 0.3 μm are not necessarily visible and will likely represent isolated patches of condensate separated by unaffected sea surface. No threshold was applied in the deterministic run.

C.3.3 Shoreline Oil

The modelling predicts that there is the possibility of beaching on the English coast. The probability of beaching is shown in Figure D-5. There are short sections of coast showing a probability greater than 20% (maximum 28%) around Flamborough Head and north of the Humber River (Yorkshire), and further short sections of the Yorkshire, Lincolnshire, Norfolk and Suffolk coasts with probabilities greater than 10%, however, for the majority of the coastline the probability of condensate reaching the coast is less than 10%. No beaching is predicted north of Berwick or south of the Suffolk coast. The minimum arrival time for most areas is in excess of 30 days, with the exception of a few isolated locations on the Norfolk coast where the condensate is predicted to reach the coast in around 12 days.

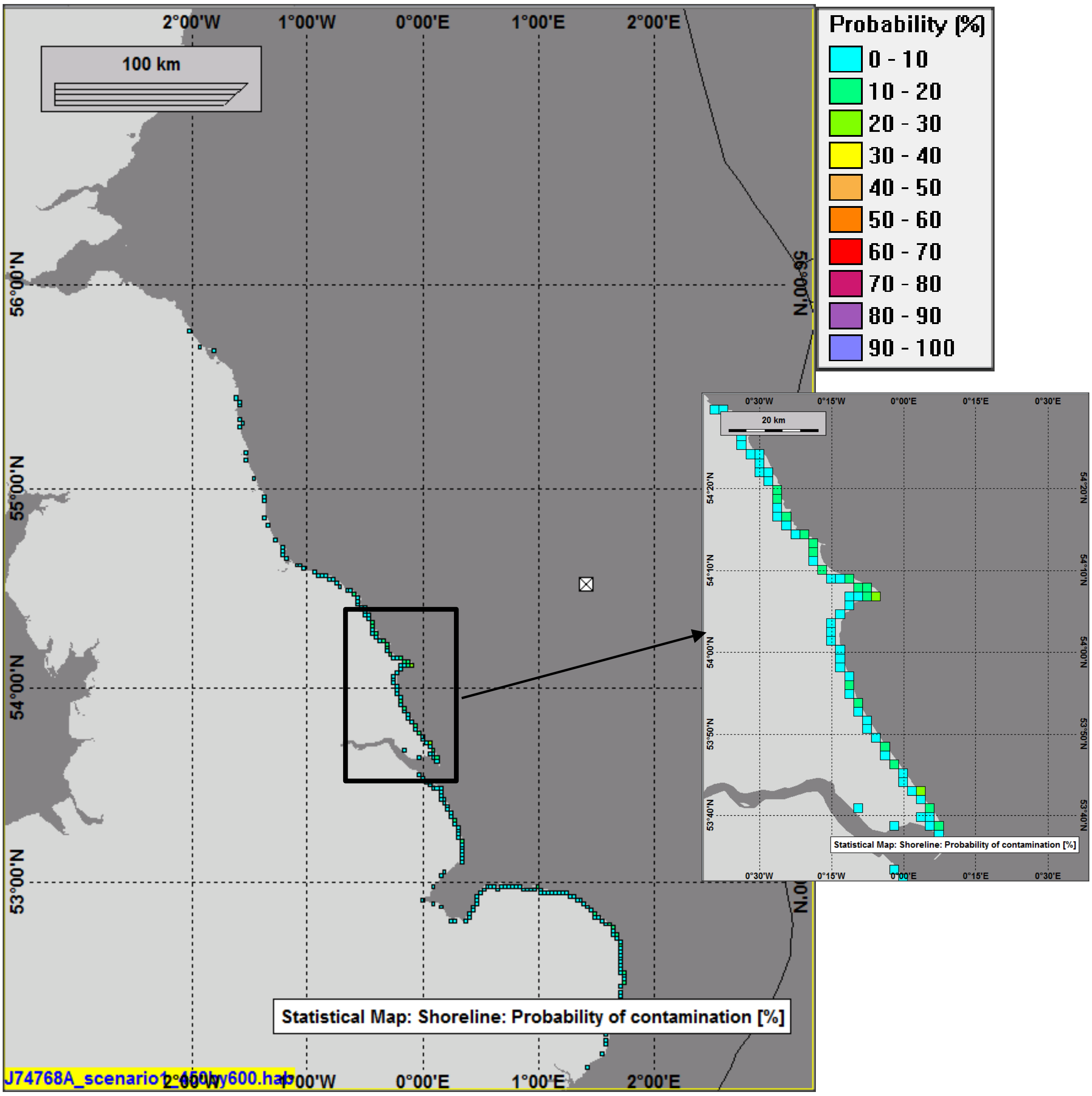


Figure C-5: Probability of oil beaching (no threshold, stochastic)

As noted in Section C2.4.3 no threshold has been applied to the shoreline oil density, therefore any mass of condensate, however small is shown in the model results.

Most of the cells where beaching is predicted contain less than 0.1 tonne of condensate per cell. Based on the model cell size (2 km by 2 km), this is equivalent to 0.1 tonne per 4 km^2 or 0.0245 g/m^2. The maximum predicted in any one cell is 0.258 tonnes, equivalent to 0.0645 g/m^2. The predicted values of mass of condensate reaching the shoreline are therefore well below the 100 g/m^2 threshold where potential impacts may occur.

It is also worth noting that almost half the stochastic runs (44 runs) did not result in any onshore oiling.

A single deterministic run (see Section C1.2) was conducted in order to investigate the worst case shoreline condensate concentrations. The blowout starting time for this deterministic scenario was selected to correspond to the individual stochastic simulation that resulted in the greatest mass of condensate arriving onshore (stochastic run 75, start time: 17/12/2011 at 09:00). The maximum condensate predicted to reach the shoreline is shown in Figure C-6. There are very isolated instances of condensate reaching the shoreline, at a maximum concentration of around 2 g/m^2 and generally at concentrations of less than 0.5 g/m^2, well below the 100 g/m^2 threshold where impacts are considered potentially significant.

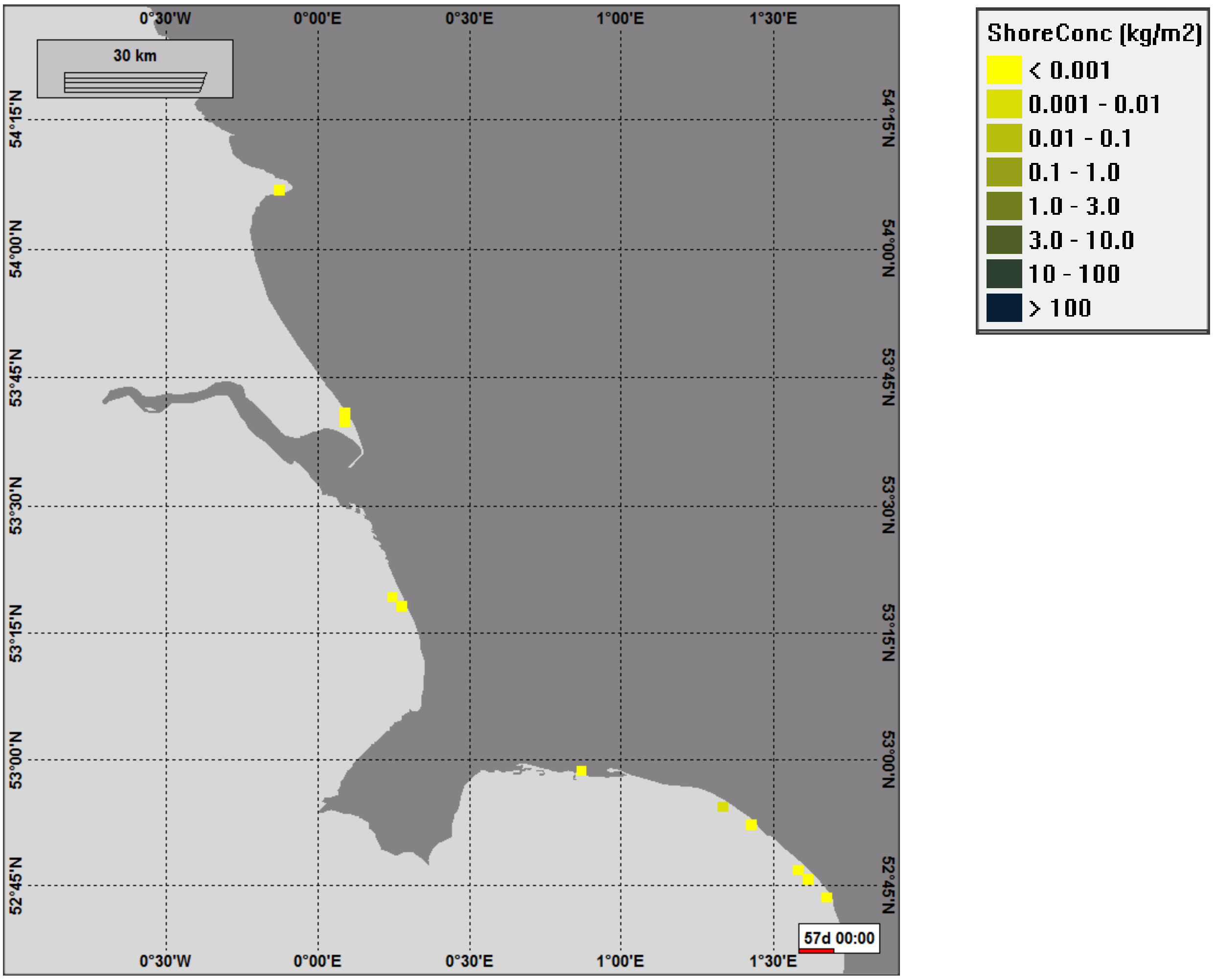


Figure C-6: Maximum shoreline concentrations (deterministic, snapshot at 57 days)

C.3.4 Water Column Concentrations

The probabilities of hydrocarbon concentrations ≥ 10 ppb (see Section D.2.4) in the water column are shown in Figure C-7. The modelling predicted that the area where there is a 90% to 100% probability of oil in the water column at a concentration greater than 10 ppb extends between 37 km and 47 km from the blowout location and extends to *c*. 40 m depth.

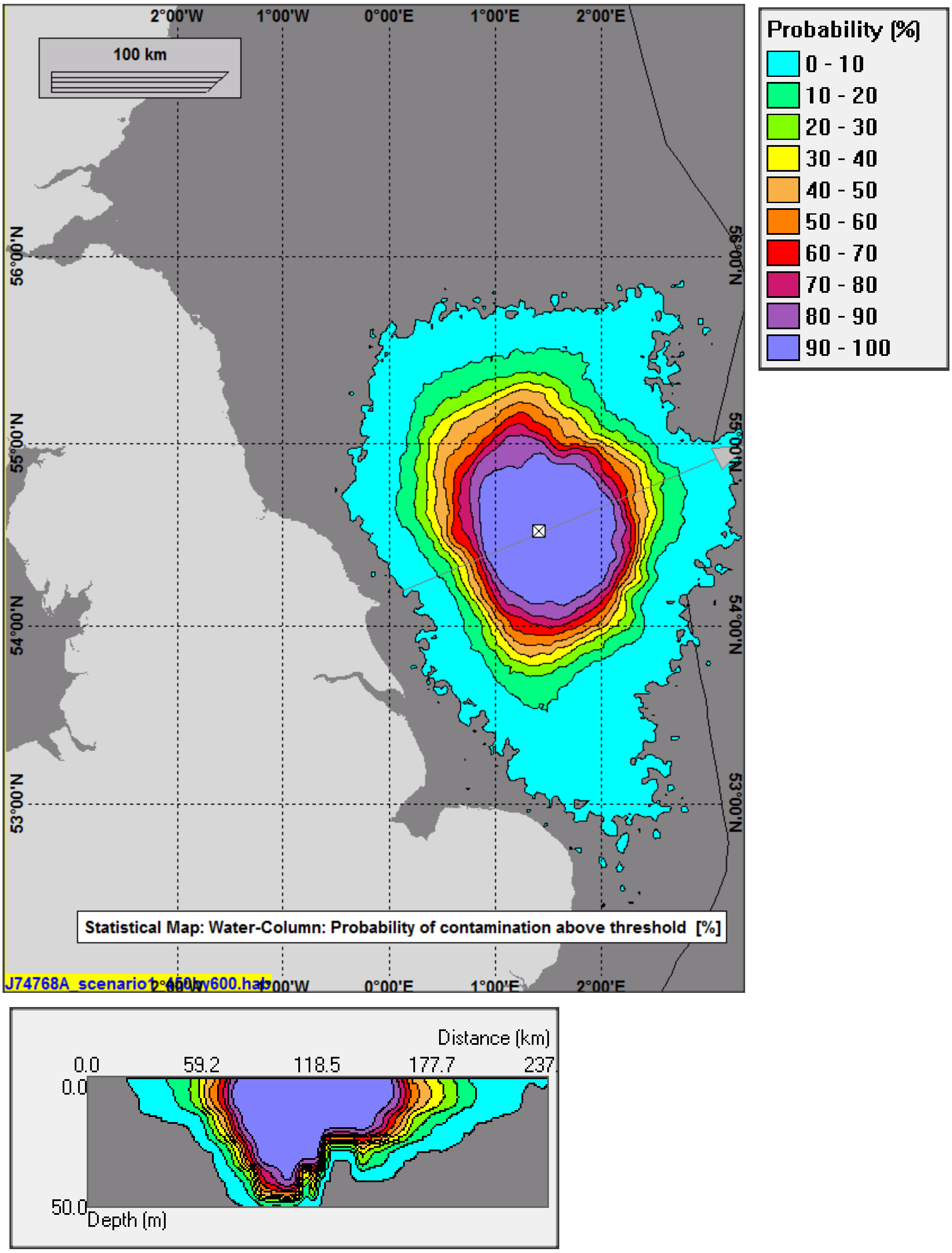


Figure C-7: Probability of water column impacts at concentrations ≥ 10 ppb (stochastic)

The results shown in C-7 were obtained from the stochastic modelling simulations and represent the aggregation of results from 100 different stochastic runs. A deterministic model was run in order to further assess the impact to the water column (based on stochastic run 75, worst case shoreline oiling). C-8 shows the maximum total water column concentrations that were observed through the water column for the deterministic run.

The deterministic modelling predicted that the total water column volume impacted by oil above a concentration of 10 ppb would be *c.* 383 km^3. No oil is predicted to cross the median line.

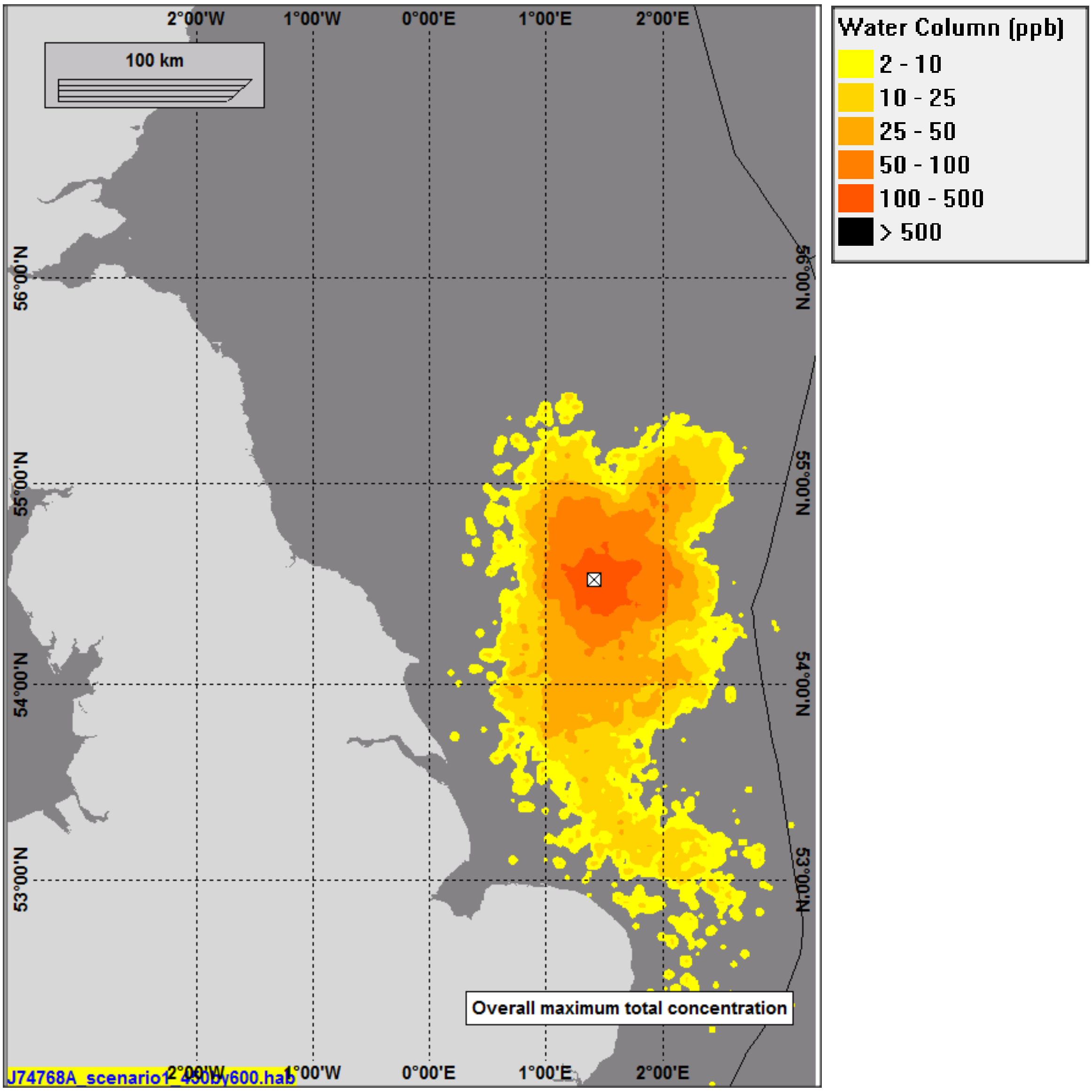


Figure C-8: Maximum oil concentration in water column (deterministic)

C.3.5 Deposition of Oil in Sediment

No threshold has been applied to sediment concentrations in the model. However, as noted in Section C2.4.4, in order to allow an assessment of impacts when reviewing model outputs, a mass of oil of 50 mg per 1 kg of sediment (50 mg/kg, equivalent to 5 g/m^2), has been taken as the level above which toxic effects on benthic fauna may begin to be discernible.

The model does not predict the level of oil in sediment for the stochastic runs therefore oil in sediment levels were determined from the deterministic run. The modelling predicted that the area of sediment within which the threshold of 5 g/m^2 (50 mg/kg) would be exceeded (see Figure C-9) is predicted to be extremely limited (56 km^2). No areas exceed 10 g/m^2 (equivalent to 100 mg/kg).

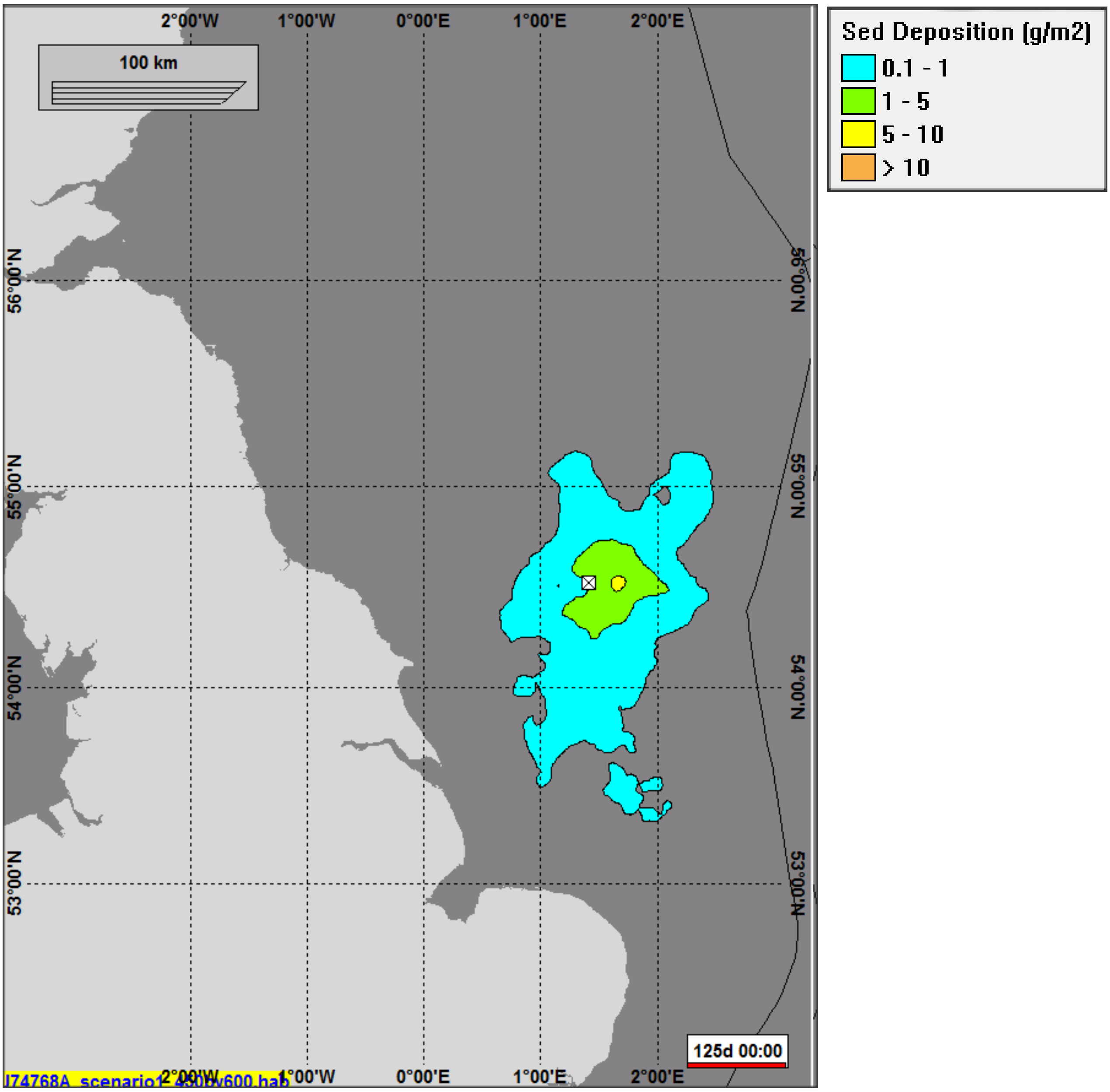


Figure C-9: Deposited oil in sediment (deterministic)

C.4 Uncertainties

There are uncertainties associated with modelling of oil spills and therefore conservative assumptions have been used to take account of these uncertainties. Results should be treated as indicative and used to draw conclusions at a high level.

C.4.1 Release Volumes

The scenario considered (uncontrolled blowout) is a very pessimistic outcome. Well blowouts are rare events, both during drilling and even more so during completions, that are often controlled within a matter of days using subsea intervention techniques or by the well “bridging” over and restricting the flow. The volume modelled assumes no intervention for 95 days (the time taken to drill a relief well) and no natural decrease in flow and therefore represents a worst case scenario.

C.4.2 Oil Characterisation

A specific oil weathering study has not been undertaken for this project. Oil weathering properties have been adopted from an analogue which is closest to the condensate sampled in the reservoir. The match is considered representative for the purposes of this assessment and an analogue was selected which would potentially give a slightly worse outcome given the lower pour point of the analogue (-6°C) (i.e. will flow at a lower temperature) compared to Pegasus condensate (6°C) (see Section C2.2). Given the viscosity of Pegasus condensate and Lavrans condensate are similar it is unusual for the pour points to differ significantly.

C.4.3 Long Term Predictions

It is normal to run scenarios for the entire duration of blowout or other release, and for sufficient time afterwards, to determine the behaviour and location of the oil, before taking a view on whether this poses a risk to receptors. Often some dispersed and surface oil remains at sea at the end of the scenarios. This is in very dispersed form and less likely to cause acute pollution than during or shortly after the releases. In reality, the longer-term surface predictions are conservative, as the oil droplets at sea will tend to combine with suspended solids and sink, a process which is not included in the model.

C.5 Conclusions

A surface blowout of condensate from the Pegasus West well was modelled over a period of 125 days (95 days blowout plus 30 days to allow time for oil dispersion).

A summary of the main modelling outputs is shown in Table C-6.

The model predicts a very low probability of condensate crossing any median lines and very limited quantities of condensate reaching the nearest coastline (England). All shoreline condensate is predicted to be well below the potential impact threshold of 100 g/m^2. The surface oil, oil in the water column and oil in seabed sediment thresholds are all exceeded over relatively small areas in the context of a major spill. This is as expected given the properties of the Pegasus condensate.

Environmental Fraction	%	Maximum extent	Threshold	Extent above threshold
Sea Surface	<0.1	76 km from well (0-10% probability)	0.3 µm	4,200 km^2
Shoreline oil	<0.1	0.258 tonnes, (0.0645 g/m^2) in single cell	100 g/m^2	0
Water column	0.8	200 km from well (0 to 10% probability)	10 ppb	383 km^3
Seabed Sediment	23	120 km from well (at concentrations ranging from 1 to 10 g/m^2, traces of oil extend further)	50 mg/kg (5 g/m^2)	56 km^2
Atmosphere	51	NA	NA	NA
Biodegraded	25	NA	NA	NA

Table C-6: Summary of modelling outputs